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Title:  Trends in ship-to-shore container cranes

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Subject: Trends in ship-to-shore container cranes

Introduction
For container transport, the link between the ships and the terminals are the container cranes. Many of these cranes have been delivered to terminals all over the world. For the department Marine and Transport Technology it is of great importance to know the latest developments in the field of ship-to-shore container cranes. This knowledge can be used to further improve lectures or for other research purposes.

Main research question
What are the trends in the ship-to-shore container crane market?

Sub questions
- What are the technical trends in the ship-to-shore container crane market?
- What is the size of the ship-to-shore container crane market?
- What can be found about the costs of ship-to-shore container cranes?
- What are the trends and developments for spreaders?
- What are the trends, developments and costs for quay walls and can the increase in size of ship-to-shore cranes lead to changes in the quay design?
- If ship-to-shore cranes were lighter and quay walls less heavy, would this reduce the total costs of the equipped quay (including the cranes)?

Boundary conditions
The following boundary conditions were used during this assignment:
- A ship-to-shore container crane is a crane that lifts containers from and to sea-going vessels. The smaller barge cranes are not taken into account in this research.
- Ship unloaders for bulk materials are not taken into account in this research.
Trends in ship-to-shore container cranes

F.F. Achterberg
Trends in ship-to-shore container cranes

LITERATURE ASSIGNMENT

F.F. Achterberg

September 23, 2012

Faculty of Mechanical, Maritime and Materials Engineering (3mE) · Delft University of Technology
Ship-to-Shore (STS) cranes are used for the transhipment of container between ship and shore. Cranes must grow to stay able to sever the ships.
For the department Marine & Transport Technology it is essential to know what the latest developments and trends are on all different field of transportation. Besides that, a good knowledge of the costs of STS cranes and quay walls could probably result in lower costs for both.
The main research question that will be answered is:

- What are the trends in the ship to shore container crane market?

To answer this question, the following sub questions are answered.

- What are the technical trends in the ship-to-shore container crane market?
- What is the size of the ship-to-shore container crane market?
- What can be found about the costs of ship-to-shore container cranes?
- What are the trends and developments for spreaders?
- What are the trends, developments and costs for quay walls and can the increase in size of ship-to-shore cranes lead to changes in the quay design?
- If ship-to-shore cranes were lighter and quay walls less heavy, would this reduce the total costs of the equipped quay (including the cranes)?

To answer the research questions, three ways are were used to get information. For the introduction to the different sub topics and the piece of quay walls, technical literature is used. For the information about the cranes over the years, many editions of World Cargo News is used. Finally, multiple visits to companies with relations to this subject were done. For the technical introduction of the STS cranes, the following sub topics are used.
The technical introduction of the quay walls contains

- Introduction to quay walls
- introduction to rails

World Cargo News publishes a annual list with an update of the orders from the different manufacturers. These different data is collected. The following six parameters are reviewed: outreach, lift height, safe work load, hoist speed loaded, hoist speed empty and trolley speed. From this six parameters an annual average is calculated. This averages makes it possible to ascertain trends. Besides that, this data is used to figure out market shares of the different manufacturers. This order numbers give a clear insight in the different types of cranes that are delivered. For this entire assignment, data from the period 2002 - 2012 is used.

The cost analysis of the STS cranes is done with the limited data from the World Cargo News.

The cost analysis of the quay walls is done with a Phd-Thesis that answers the questions of this assignment.

To make the founded data more concrete and to check it shortly, the assignment finishes with two cases. Both cases are two terminals (Rotterdam World Gateway (RWG) and Colombo International Container (CIC) terminals) that are currently built. For this terminals, it is calculated what the costs of the quay wall would be. Also it is calculated what the costs of the cranes would be. A comparison of these numbers will give insight if cranes or quay walls are more expensive.

This assignment shows that the average sizes of STS cranes increased. The averages hoist and trolley speeds increased, but were almost stable after 2004. Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC) is the main manufacturer of STS cranes. This company has a market share around 70% Due to mergers, acquisitions and bankruptcies, the market became from a fragmented market, a market with a few players left. The prices of cranes rise in the last ten year. The main reason for this is the growth of the cranes.

More spreaders have the ability to carry multiple containers with different dimensions. Besides that, the spreaders make a change to electrical controlled spreaders in stead of hydraulic control.

The costs for quay walls is for 2% related to the loads of STS cranes. Heavier cranes could require a new design for the quay walls. This also depends on local conditions.

The cases of the RWG and CIC terminals showed that the prices of the cranes are probably higher than the prices of the quay walls.
Container kranen worden gebruikt bij de overslag van containers tussen de kade en het schip. Om de schepen te kunnen blijven bedienen, moeten de kranen meegroeien met de schepen. Voor de afdeling Marine & Transport Technology is het essentieel om te weten wat de laatste ontwikkelingen en trends zijn op alle gebieden van transport. Daarnaast kan een goede kennis van de kosten van de container kranen en kade wanden er wellicht toe leiden dat de kosten van beide lager komen te liggen.

De hoofdvraag die wordt beantwoord in dit onderzoek is:

- Wat zijn de trends in container kranen?

Deze vraag wordt aan de hand van de volgende sub vragen beantwoord.

- Wat zijn de technische trends in de container kranen markt?
- Wat is de omvang van de container kranen markt?
- Wat kan er worden gevonden over de prijzen van container kranen?
- Wat zijn de trends, ontwikkelingen en kosten van kade wanden en kan een toenemende kraan grote leiden tot veranderingen in het ontwerp van kade wanden?
- Als container kranen lichter zouden zijn en kade wanden minder zwaar, zou dit dan de totale kosten van de uitgeruste kade (inclusief de kranen) reduceren?

Voor het beantwoorden van deze onderzoeksvragen is op drie manieren informatie gekregen. Voor de introductie tot de verschillende deel onderwerpen en het stuk over kade wanden is technische literatuur gebruikt. Voor de informatie over de kranen zijn verschillende jaren en edities van World Cargo News gebruikt. Tot slot zijn er meerdere bezoeken gebracht aan bedrijven die een relatie hebben met dit onderwerp.

Voor de technische introductie van de kranen zijn de volgende deel onderwerpen gebruikt.

- Introductie van container kranen
Introductie van aandrijf technieken
Transport en installatie van kranen
Spreaders

De technische introductie van de kade wanden bevat:

- Introductie van kade wanden
- Introductie van rails

World Cargo News publiceert jaarlijks een lijst met de stand van de orderboeken van de verschillende producenten. Deze verschillende data is vervolgens verzameld. Gekeken is naar de volgende zes parameters: reikwijdte, lift hoogte, veilige werk belasting, hijs snelheid beladen, hijs snelheid leeg en trolley snelheid. Van deze zes parameters is een jaarlijks gemiddelde uit gerekend. Met deze gemiddelde zijn trends te constateren. Daarnaast is met deze data gekeken naar de marktaandelen van de verschillende producenten. De order aantallen geven een duidelijk inzicht in de verschillende types kranen die worden geleverd. Voor deze hele opdracht is gekeken naar data uit de periode 2002 - 2012.

Voor de kosten analyse van de kranen is de gelimiteerde data gebruikt uit World Cargo News. Voor de kosten analyse van kade wanden is een promotie werk gevonden dat de vragen van deze opdracht beantwoord over dat onderwerp.

Om de gevonden gegevens concreet te maken en kort te checken besluit deze opdracht met twee cases. Beide cases betreffen twee terminals (RWG and CIC terminals) die momenteel worden gebouwd. Voor deze terminals wordt uitgerekend wat de kosten van de kadewand zouden zijn.

Tevens wordt berekend wat de kosten van de kranen zouden zijn. Een vergelijking van deze cijfers geeft inzicht of de kranen of de kade wanden duurder zijn. Deze opdracht laat zien dat de gemiddelde grootte en veilige werk belasting van container kranen is toegenomen en lijkt te stijgen. De gemiddelde hijsnemheden en de trolley snelheid zijn ook gestegen, maar zijn sinds 2004 redelijk stabiel. De grootste producent is ZPMC. Dit bedrijf heeft een marktaandeel van rond de 70%. Door overnames, fusies en faillissementen in de laatste tien jaar is de markt van een gefragmenteerde markt naar een markt gegaan met minder spelers. De prijs van kranen is gestegen in de laatste tien jaar. De belangrijkste reden hiervoor is de groei van de kranen zelf.

Spreaders hebben steeds meer de mogelijkheid om meerdere containers van verschillende afmetingen tegelijk te liften. Daarnaast is er een trend aan de gang om de besturing van de spreaders te laten veranderen van hydraulische besturing naar elektrische besturing. De kosten van de kadewanden zijn voor 2% gerelateerd aan de belasting door de container kranen. Zwaardere kranen zouden wellicht een ander ontwerp kade wanden vereisen. Dit hangt ook af van lokale condities.

De cases van de twee terminals laten zien dat de kosten voor de kranen waarschijnlijk hoger zijn dan de kosten van de kade wanden.
## Glossary

### List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>ASCE</td>
<td>American Society of Civil Engineers</td>
</tr>
<tr>
<td>CCCC</td>
<td>China Communication Construction Co., Ltd.</td>
</tr>
<tr>
<td>CIC</td>
<td>Colombo International Container</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DHT</td>
<td>Dual Hoist Trolley</td>
</tr>
<tr>
<td>ES</td>
<td>Engineering &amp; Shipbuilding</td>
</tr>
<tr>
<td>HI</td>
<td>Heavy Industries</td>
</tr>
<tr>
<td>HSE</td>
<td>Hoist speed empty</td>
</tr>
<tr>
<td>HSL</td>
<td>Hoist speed loaded</td>
</tr>
<tr>
<td>LS</td>
<td>Land side</td>
</tr>
<tr>
<td>OEM</td>
<td>Original Equipment Manufacturer</td>
</tr>
<tr>
<td>OLE</td>
<td>Operating Level Earthquake</td>
</tr>
<tr>
<td>MRI</td>
<td>Mean Return Interval</td>
</tr>
<tr>
<td>PV</td>
<td>Present Value</td>
</tr>
<tr>
<td>RMG</td>
<td>Rail Mounted Gantry</td>
</tr>
<tr>
<td>RTG</td>
<td>Rubber Tyred Gantry</td>
</tr>
<tr>
<td>RWG</td>
<td>Rotterdam World Gateway</td>
</tr>
<tr>
<td>SHT</td>
<td>Single Hoist Trolley</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<td>--------------</td>
<td>--------------------------------------------------</td>
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<tr>
<td><strong>SPMP</strong></td>
<td>Shanghai Port Machinery Plant</td>
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<tr>
<td><strong>SWL</strong></td>
<td>Safe Work Load</td>
</tr>
<tr>
<td><strong>WS</strong></td>
<td>Water side</td>
</tr>
<tr>
<td><strong>STS</strong></td>
<td>Ship-to-Shore</td>
</tr>
<tr>
<td><strong>TEU</strong></td>
<td>Twenty feet Equivalent Unit</td>
</tr>
<tr>
<td><strong>ZPMC</strong></td>
<td>Shanghai Zhenhua Heavy Industry Co., Ltd.</td>
</tr>
</tbody>
</table>
# Table of Contents

Glossary

List of Acronyms ............................... v

Preface

1 Introduction ................................. 1
  1-1 General introduction ..................... 1
  1-2 Assignment ............................... 1
  1-3 Structure of the report ................. 2

1 STS cranes ................................ 5

2 Introduction to STS cranes ................. 7
  2-1 History .................................. 7
  2-2 The components of a STS crane ....... 8
    2-2-1 Main boom and beam .......... 9
    2-2-2 Trolley .......................... 10
    2-2-3 Spreader ......................... 11
    2-2-4 Cabin ............................ 12
    2-2-5 Legs ............................... 12
    2-2-6 Cable reel and powersupply .... 13
    2-2-7 Machinery house ................. 14
    2-2-8 Boogie sets and wheels ........ 14
  2-3 Sizes .................................. 15
  2-4 Performance optimizers ............... 16
  2-5 Quay loads ............................. 16
  2-6 Earthquakes ........................... 17

Literature Assignment ........................ F.F. Achterberg
2-6-1 Standards ........................................ 18
2-6-2 Prevention ....................................... 19
2-7 Wind .................................................. 20
   2-7-1 Standards ..................................... 21
   2-7-2 Prevention .................................... 22
2-8 Stiffness ............................................ 23

3 Introduction to drive technology ........................ 27
   3-1 Motors ............................................. 27
   3-2 Manufacturers .................................... 28
       3-2-1 Siemens ...................................... 28
       3-2-2 ABB ........................................... 29
       3-2-3 Others ......................................... 29
   3-3 Automation and remote control ...................... 29

4 Manufacturers .......................................... 31
   4-1 ZPMC ............................................. 33
   4-2 Paceco ............................................ 35
       4-2-1 Mitsui Engineering & Shipbuilding (ES) Co., Ltd. 35
       4-2-2 Hyundai Heavy Industries (HI) ..................... 36
       4-2-3 Paceco Espana, S.A. .......................... 36
   4-3 Liebherr .......................................... 37
   4-4 Terex ............................................. 38
   4-5 Cargotec ......................................... 39
   4-6 Konecranes ....................................... 41
   4-7 Doosan HI&C ...................................... 42
   4-8 Mitsubishi HI ..................................... 43
   4-9 Others ............................................ 44

5 Transport and Installation ............................... 45
   5-1 Types of transport and installation .................. 45
       5-1-1 Parts transportation .......................... 45
       5-1-2 Fully erected transportation .................. 46
       5-1-3 Semi erected transportation ................... 47
   5-2 Shippers .......................................... 47
       5-2-1 Biglift ........................................ 47
       5-2-2 Jumbo ......................................... 48
       5-2-3 Sal ............................................. 48
       5-2-4 Dockwise ...................................... 48
# Table of Contents

## 6 Spreaders
6-1 Working principle .................................................. 51
6-2 Spreader types .......................................................... 52
6-3 Manufacturers .......................................................... 53
   6-3-1 Bromma ............................................................ 54
   6-3-2 Stinis ............................................................... 54
   6-3-3 RAM ................................................................. 54
6-4 Trends ................................................................. 54
   6-4-1 Hydraulic versus electric .................................. 54
   6-4-2 Tandem-lift and Triple 40 ................................. 55

## 7 Analysis STS cranes 2002 - 2012
7-1 Sale records .......................................................... 57
7-2 Dimensions ............................................................. 60
7-3 Safe Work Load (SWL) .............................................. 62
7-4 Hoisting speed ........................................................ 63
7-5 Trolley speed .......................................................... 65
7-6 Cranes by type ........................................................ 67
7-7 Order sizes ............................................................. 71
7-8 Comparison of trends and remarkable issues ............. 72

## 8 Purchase process and prices
8-1 Purchase process ..................................................... 75
8-2 Prices ................................................................. 77

## 9 Quay walls

### 11 Introduction to quay walls
9-1 History ........................................................................ 85
9-2 Basic parameters of a quay wall ................................ 85
9-3 Functions of quay walls .............................................. 87
   9-3-1 Retaining ............................................................... 87
   9-3-2 Bearing ................................................................. 87
   9-3-3 Mooring ................................................................. 87
   9-3-4 Protecting .............................................................. 87
9-4 Types of quay walls .................................................... 87
   9-4-1 Gravity walls ........................................................ 88
   9-4-2 Sheet pile walls ..................................................... 88
   9-4-3 Structures with relieving platform ....................... 89
   9-4-4 Open berth quays ................................................ 90
9-5 Materials ..................................................................... 91
9-6 Construction methods ............................................... 93
   9-6-1 Construction from the water side ......................... 93
   9-6-2 Construction in a dry building pit ...................... 93
9-7 Limitations on loads ................................................... 93

---

**Literature Assignment** F.F. Achterberg
## Table of Contents

### 10 Introduction to rails
- 10-1 Types of rails .......................................................... 95
- 10-2 Support ................................................................. 96

### 11 Prices of quay walls
- 11-1 Total costs .............................................................. 99
- 11-2 Factors of the price .................................................. 100
- 11-3 Costs per meter ....................................................... 100

### III Cases

#### 12 Maasvlakte 2, Rotterdam, The Netherlands
- 12-1 The RWG terminal .................................................... 107
- 12-2 Cranes ................................................................. 107
- 12-3 Quay walls ............................................................ 108
- 12-4 Conclusion ........................................................... 109

#### 13 Colombo, Sri Lanka
- 13-1 The CIC terminals .................................................... 111
- 13-2 Cranes ................................................................. 111
- 13-3 Quay Walls .......................................................... 111
- 13-4 Conclusion ........................................................... 112

### IV Conclusions and recommandations

#### 14 Conclusions and recommandations
- 14-1 Conclusions .......................................................... 115
- 14-2 Recommendations .................................................. 117

## Bibliography
List of Figures

2-1 First container crane in the port of Seattle (Port Seattle, 2012) .............. 7
2-2 Basic components and parameters of a STS crane ............................. 8
2-3 A STS crane with a box structured main boom (Konecranes, 2012) ........... 9
2-4 A STS crane with a lattice structured main boom (Liebherr, 2012) .......... 9
2-5 Basic hoisting mechanism of a STS crane (Verschoof, 2002) ................. 10
2-6 Direct driven trolley of Liebherr (Liebherr, 2012) ............................. 10
2-7 Headblock hanging on 12 wire rope falls (Verschoof, 2002) .................. 11
2-8 Wire rope support with two catenary trolleys (Verschoof, 2002) ............. 11
2-9 A picture of the patent of KoneCranes (Hakala, 2004) ....................... 11
2-10 A spreader lifting 2 Twenty feet Equivalent Unit (TEU) containers (ZPMC, 2012) 11
2-11 A cabin of Merford at the Euromax Terminal Rotterdam (Merford Cabins, 2012) 12
2-12 The position of the operator in his cabin (Merford Cabins, 2012) ............ 12
2-13 A STS crane with vertical legs (Liebherr, 2012) ............................. 13
2-14 A STS crane with an angle in Water side (WS) and Land side (LS) leg (Liebherr, 2012) 13
2-15 A high mounted reel with a "Pull and Store mechanism" (Cavotec, 2012) .... 14
2-16 A reel mounted close to the road (Cavotec, 2012) ............................ 14
2-17 The basic principle of the "Pull and Store mechanism" (Cavotec, 2012) ..... 15
2-18 The "Pantzerbelt System" that lifts the rubber slab (Cavotec, 2012) .......... 15
2-19 A boogie set of a crane with 10 wheels (Argonautics, 2012) ............... 15
2-20 Vertical forces on the quay by the crane (Liang, 2011) ...................... 17
2-21 Horizontal forces, normal to the crane rail by the crane (Liang, 2011) ....... 17
2-22 Horizontal forces, parallel to the crane rail by the crane (Liang, 2011) .... 17
2-23 Total collapsed crane in Kobe, Japan ......................................... 18
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-24</td>
<td>Heavy damaged crane in Kobe, Japan (Soderberg, Hsieh and Dix, 2009)</td>
<td>18</td>
</tr>
<tr>
<td>2-25</td>
<td>A system to isolate the displacement (Soderberg et al., 2009)</td>
<td>20</td>
</tr>
<tr>
<td>2-26</td>
<td>Added diagonal pipe braces to let the crane tip (Soderberg et al., 2009)</td>
<td>21</td>
</tr>
<tr>
<td>2-27</td>
<td>Added external stiffeners to get ductility (Soderberg et al., 2009)</td>
<td>21</td>
</tr>
<tr>
<td>2-28</td>
<td>Wind loads on cranes in the Dutch standarization (Nederlands Normalisatie instituut, 1983)</td>
<td>22</td>
</tr>
<tr>
<td>2-29</td>
<td>The movement of the crane perpendicular to the rails (McCarthy, Soderberg and Dix, 2009)</td>
<td>23</td>
</tr>
<tr>
<td>2-30</td>
<td>The position of the brakes when the crane is lifted (McCarthy et al., 2009)</td>
<td>23</td>
</tr>
<tr>
<td>3-1</td>
<td>Basic components and parameters of a STS crane (Siemens, 2012)</td>
<td>28</td>
</tr>
<tr>
<td>4-1</td>
<td>Orders of ZPMC and SPMP</td>
<td>33</td>
</tr>
<tr>
<td>4-2</td>
<td>Orders of Paceco and Paceco Licensees</td>
<td>35</td>
</tr>
<tr>
<td>4-3</td>
<td>Orders of Liebherr</td>
<td>37</td>
</tr>
<tr>
<td>4-4</td>
<td>Orders of Terex (former Fantuzzi, Noell and Regianne)</td>
<td>38</td>
</tr>
<tr>
<td>4-5</td>
<td>Orders of Cargotec/Kalmar</td>
<td>39</td>
</tr>
<tr>
<td>4-6</td>
<td>The history of Cargotec (Cargotec, 2012)</td>
<td>40</td>
</tr>
<tr>
<td>4-7</td>
<td>Orders of Konecranes</td>
<td>41</td>
</tr>
<tr>
<td>4-8</td>
<td>Orders of Doosan HI&amp;C</td>
<td>42</td>
</tr>
<tr>
<td>4-9</td>
<td>Orders of Mitsubishi Heavy Industry</td>
<td>43</td>
</tr>
<tr>
<td>5-1</td>
<td>A welded structure between the legs to increase stiffness of the crane</td>
<td>46</td>
</tr>
<tr>
<td>5-2</td>
<td>A welded structure to mount the crane to the ship</td>
<td>46</td>
</tr>
<tr>
<td>5-3</td>
<td>Semi erected transport of two Cargotec cranes</td>
<td>47</td>
</tr>
<tr>
<td>5-4</td>
<td>A crane delivery with the forklift principle</td>
<td>47</td>
</tr>
<tr>
<td>6-1</td>
<td>The head block of a spreader</td>
<td>52</td>
</tr>
<tr>
<td>6-2</td>
<td>Design of an electric twin lift spreader</td>
<td>52</td>
</tr>
<tr>
<td>6-3</td>
<td>Bromma T45 spreader with the different load possibilities.</td>
<td>53</td>
</tr>
<tr>
<td>7-1</td>
<td>Total crane sales in the period 2002 - 2012 with ZPMC and total</td>
<td>58</td>
</tr>
<tr>
<td>7-2</td>
<td>Crane sales in the period 2002 - 2012 without ZPMC</td>
<td>59</td>
</tr>
<tr>
<td>7-3</td>
<td>The outreach of the ordered cranes in the period 2002 - 2012</td>
<td>60</td>
</tr>
<tr>
<td>7-4</td>
<td>The lift height of the ordered cranes in the period 2002 - 2012</td>
<td>61</td>
</tr>
<tr>
<td>7-5</td>
<td>The SWL of the ordered cranes in the period 2002 - 2012</td>
<td>62</td>
</tr>
<tr>
<td>7-6</td>
<td>The average Hoist speed loaded (HSL) of the ordered cranes in the period 2002 - 2012.</td>
<td>63</td>
</tr>
<tr>
<td>7-7</td>
<td>The average Hoist speed empty (HSE) of the ordered cranes in the period 2002 - 2012.</td>
<td>64</td>
</tr>
<tr>
<td>7-8</td>
<td>The average trolley speed of the ordered cranes in the period 2002 - 2012</td>
<td>65</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>7-9</td>
<td>Number of cranes ordered per type</td>
<td></td>
</tr>
<tr>
<td>7-10</td>
<td>Number of heavy cranes ordered per type</td>
<td></td>
</tr>
<tr>
<td>7-11</td>
<td>Distribution of cranes ordered per type</td>
<td></td>
</tr>
<tr>
<td>7-12</td>
<td>Distribution of heavy cranes ordered per type</td>
<td></td>
</tr>
<tr>
<td>7-13</td>
<td>The size of the orders with the average order size</td>
<td></td>
</tr>
<tr>
<td>7-14</td>
<td>Average outreach, lift height and SWL.</td>
<td></td>
</tr>
<tr>
<td>7-15</td>
<td>Average HSE, HSL and trolley speed.</td>
<td></td>
</tr>
<tr>
<td>8-1</td>
<td>The growth of cranes over the last 10 years.</td>
<td></td>
</tr>
<tr>
<td>8-2</td>
<td>The prices per crane (€) found in the period 2002 - 2012 including trend lines.</td>
<td></td>
</tr>
<tr>
<td>8-3</td>
<td>The prices per crane ($) found in the period 2002 - 2012 including trend lines.</td>
<td></td>
</tr>
<tr>
<td>9-1</td>
<td>The construction of a mole. (de Gijt, 2010)</td>
<td></td>
</tr>
<tr>
<td>9-2</td>
<td>Basic components and parameters of quay wall</td>
<td></td>
</tr>
<tr>
<td>9-3</td>
<td>A block wall. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-4</td>
<td>A caisson wall. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-5</td>
<td>A sheet pile wall without an anchor (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-6</td>
<td>A sheet pile wall with an anchor wall. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-7</td>
<td>A sheet pile wall with a grout anchor. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-8</td>
<td>A quay wall with a deep relieving platform. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-9</td>
<td>A quay wall with a high relieving platform. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-10</td>
<td>An open berth quay. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-11</td>
<td>An open berth quay with retaining wall. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-12</td>
<td>Different cross-sections of single walls (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-13</td>
<td>Different cross-sections of combined walls (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>9-14</td>
<td>The construction of a diaphragm wall (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)</td>
<td></td>
</tr>
<tr>
<td>10-1</td>
<td>A high rail type (Bemo Rail, 2012)</td>
<td></td>
</tr>
<tr>
<td>10-2</td>
<td>A low rail type (Bemo Rail, 2012)</td>
<td></td>
</tr>
<tr>
<td>10-3</td>
<td>A continue supported rail (Bemo Rail, 2012)</td>
<td></td>
</tr>
<tr>
<td>10-4</td>
<td>A discontinue supported rail (Bemo Rail, 2012)</td>
<td></td>
</tr>
</tbody>
</table>
11-1 The total costs of quay walls. (de Gijt, 2010) .............................................. 99
11-2 Driving factors of the costs for quay walls. (de Gijt, 2010) .................................. 100
11-3 Historical data about the price of quay walls in the world. (de Gijt, 2010) ............. 101
11-4 Historical data about the price of quay walls in The Netherlands. (de Gijt, 2010) .. 102
11-5 Historical data about the price of quay walls in Rotterdam. (de Gijt, 2010) ........... 103
12-1 The red area is the location of the RWG terminal ................................................. 108
13-1 An artist impression of the CIC terminal (Sri Lanka Ports Authority, 2012) ............ 112
List of Tables

2-1 Parameters of a STS crane (Liebherr, 2012) ........................................... 8
2-2 Components of a STS crane ................................................................. 9
2-3 Standardized dimensions for STS cranes (Liebherr, 2012) (Konecranes, 2012) ... 16
2-4 Typical quay loads for STS cranes (Liebherr, 2012) (Konecranes, 2012) ....... 17
2-5 Vertical stiffness of some cranes .......................................................... 24
2-6 Horizontal stiffness of some cranes ....................................................... 24
2-7 Stiffness in trolley traveling direction due to test load 100kN acting on bridge girder 25

4-2 Cranes sold by ZPMC (Inclusive Shanghai Port Machinery Plant (SPMP)) ....... 34

6-1 Parts of a spreader ................................................................. 51

8-2 Currency from € to $ per year (Dollarkoers.nl, 2012) (Valuata.nl, 2012) ........ 79
8-3 Assumed prices Rubber Tyred Gantry (RTG) ........................................ 79
8-4 Calculated price per crane ................................................................. 80

9-1 Parameters of a quay wall (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002) ................................................................. 86
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-2</td>
<td>Components of a quay wall</td>
<td>87</td>
</tr>
<tr>
<td>10-1</td>
<td>Dimensions of different rail types (Bemo Rail, 2012)</td>
<td>95</td>
</tr>
<tr>
<td>12-1</td>
<td>Calculated costs of quay walls at RWG (Scenario 1)</td>
<td>109</td>
</tr>
<tr>
<td>12-2</td>
<td>Calculated costs of quay walls at RWG (Scenario 2)</td>
<td>109</td>
</tr>
<tr>
<td>13-1</td>
<td>Calculated costs of quay walls at CIC</td>
<td>112</td>
</tr>
</tbody>
</table>
Preface

For this assignment is was looking for a field of study where high performance requirements and huge steel structures were combined. Since this has interested me for quite some time, it will make the assignment more enjoyable. The STS crane market is such a field.

The idea began with the following idea

’What if we can make quay walls less heavy, and therefor less expensive, and make cranes lighter and therefor more expensive, would this be financial attractive?’.

Besides the question above, the following question rose as well:

’What are the trends in STS container cranes?’

This concept requires knowledge about STS cranes as well as quay walls. That’s what will be considered in this assignment.

I would like to thank my supervisor Ir. W. van de Bos for his assistance during the writing of this assignment and pushing me in the right direction now and then.

I would also like to thank Prof. Ir. J.C. Rijsenbrij for the inspiring conversations we had about his vision on cranes and the history of cranes and harbours.

Finally, I would like to thank all people from the industry who were willing to help me. It is noticeable how helpful and friendly the conversations I had were.
Chapter 1

Introduction

1-1 General introduction

Ship-to-Shore (STS) cranes are used to lift containers between ships and shore. Due to growing ships, the cranes seem to grow as well.

For the department Marine & Transport Technology it is essential to stay up to date about the trends in STS cranes. This assignment is an analyses of the last 10 year (2002 - 2012) of STS cranes. The cranes are not the only things that grow, other equipment that is used by the cranes are also increasing in size, therefor this will be considered as well.

More questions rose about the cost relation between quay walls and STS cranes. This will be analyzed in this assignment. This requires a short introduction to quay walls and crane rails.

1-2 Assignment

Main research question

- What are the trends in the ship-to-shore container crane market?

Sub questions

- What are the technical trends in the ship-to-shore container crane market?
- What is the size of the ship-to-shore container crane market?
• What can be found about the costs of ship-to-shore container cranes?
• What are the trends and developments for spreaders?
• What are the trends, developments and costs for quay walls and can the increase in size of ship-to-shore cranes lead to changes in the quay design?
• If ship-to-shore cranes were lighter and quay walls less heavy, would this reduce the total costs of the equipped quay (including the cranes)?

**Boundary conditions**
The following boundary conditions were used during this assignment:

• A ship-to-shore container crane is a crane that lifts containers from and to sea-going vessels. The smaller barge cranes are not taken into account in this research.
• Ship unloaders for bulk materials are not taken into account in this research.

### 1-3 Structure of the report

This report is split into four parts. The distribution in parts is used to split the different subjects.

#### STS cranes

This part will give an introduction to STS crane and their parts. Also an analysis of the trends in STS cranes is provided. This part will also contain an analysis of the manufacturers, the prices and the transport of cranes.

#### Quay walls

This part will provide a short introduction to quay walls and crane rails. This part will also show the costs of quay walls.

#### Cases

To understand and to test the data found in the other parts, two cases are done. These cases are about the construction of the Rotterdam World Gateway (RWG) and Colombo International Container (CIC) terminals.
Conclusions and recommendations

This part will give the answers to the research questions. The conclusions are focused on all the earlier parts. Also recommendations are given to further improve this research.
Part I

STS cranes
Chapter 2

Introduction to Ship-to-Shore (STS) cranes

2-1 History

With the introduction of the standardized intermodal container by Sealand, it became necessary to load and unload these containers from the ships. The first container cranes were gantry cranes mounted on the ships. After several years the cranes were not fixed on the ships anymore, but were placed on the quays. Sealand introduced their first A-framed STS crane around 1966 in the port of Seattle. A drawing of this crane can be found in figure 2-1. Nowadays cranes are developed from the same concept. The development has continued and therefor the following chapter will give an introduction to STS cranes of today.

Figure 2-1: First container crane in the port of Seattle (Port Seattle, 2012)
2-2 The components of a STS crane

Figure 2-2 gives a typical representation of a STS crane. Although almost all cranes worldwide differ in technical description, there are still similarities. Table 2-1 will provide the names that are used in the industry for the different parameters of the crane matching with the letters in figure 2-2. Table 2-2 can be used to see typical components that can be distinguished in a STS crane. Further on in this chapter a more specified description about these components will follow.

Table 2-1: Parameters of a STS crane (Liebherr, 2012)

<table>
<thead>
<tr>
<th>Ref. in fig. 2-2</th>
<th>Parameter name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Gantry span</td>
</tr>
<tr>
<td>B</td>
<td>Outreach</td>
</tr>
<tr>
<td>C</td>
<td>Backreach</td>
</tr>
<tr>
<td>D</td>
<td>Lift height</td>
</tr>
<tr>
<td>E</td>
<td>Clearance under sill beam</td>
</tr>
<tr>
<td>F</td>
<td>Travel wheel gauge</td>
</tr>
<tr>
<td>G</td>
<td>Buffer to buffer</td>
</tr>
</tbody>
</table>

Figure 2-2: Basic components and parameters of a STS crane

(Liebherr, 2012) edited by F.F. Achterberg
Table 2-2: Components of a STS crane

<table>
<thead>
<tr>
<th>Ref. in fig. 2-2</th>
<th>Component name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main boom</td>
</tr>
<tr>
<td>2</td>
<td>Trolley</td>
</tr>
<tr>
<td>3</td>
<td>Spreader</td>
</tr>
<tr>
<td>4</td>
<td>Cabin</td>
</tr>
<tr>
<td>5</td>
<td>Water side (WS) leg</td>
</tr>
<tr>
<td>6</td>
<td>Land side (LS) leg</td>
</tr>
<tr>
<td>7</td>
<td>Cable reel</td>
</tr>
<tr>
<td>8</td>
<td>Topping line</td>
</tr>
<tr>
<td>9</td>
<td>Machinery house</td>
</tr>
<tr>
<td>10</td>
<td>Beam</td>
</tr>
<tr>
<td>11</td>
<td>Boogie set</td>
</tr>
<tr>
<td>12</td>
<td>Wheels</td>
</tr>
</tbody>
</table>

2-2-1 Main boom and beam

The main boom is the part that is hanging over the ship. For a high stability of the spreader, it is essential that the main boom is as close to the maximum stacking height of the ship, although this makes it more difficult for the ship to berth. Therefore, the main boom has a hinge point just above the tip of the quay. The main boom can be lifted so the ship has no limitation of the crane. The lift of the main boom can result in a real high tip of the boom. This may conflict with local aviation rules or will result in view obstructions of the environment.

Manufacturers sell different types of main booms. It depends on the requirements of the ports or the design ideas of the manufacturer which boom will be delivered. The main difference in cranes is a box structured main boom and lattice structured main boom. Figures 2-3 and 2-4 respectively show a box and a lattice structured main boom.

Some cranes have different structures in one crane. For instance a main boom with a box...
structure and a beam with a lattice structure. The beam is the part of the crane that leans over the land and the quay.

2-2-2 Trolley

The trolley is the part of the crane that is driving over the mean boom. The trolley is the supporting structure for the spreader and the cabin. Trolleys have to support the hoisting mechanism and the mechanism that enables the trolley to ride over the main boom. Figure 2-5 shows the basic hoisting mechanism. Every corner of the headblock (or spreader) has a pulley with a separate cable. This makes the spreader more stable, which increases the handling speed of the trolley. Besides stability, the different cables work as a safety mechanism if one of the cables break.

For trolley driving and hoisting, many mechanisms are used. Figures 2-7 and 2-8 illustrate two ways of driving and hoisting. Figure 2-7 shows the headblock hanging on 12 ropes. Both the hoisting and the driving mechanism of the trolley are done by the ropes. The next figure, shows the way in which the trolley driving is separated from the headblock. Here, the trolley driving is only in the main boom. Two catenary trolleys help the driving of the main trolley.

As mentioned before, there is no industrial standard for trolley riding. Manufacturers try new ways of trolley driving all the time. Liebherr, for instance, promote their cranes with the "Direct driven trolley". According to Liebherr, this will result in better positioning of the trolley and increase the lifetime of the wheels.

Still, the wired trolley riding is used by other manufacturers. KoneCranes has patented their own way of trolley riding. This is represented in figure 2-9. This mechanism has a lot of similarities with the mechanism from figure 2-7.
2-2 The components of a STS crane

2-2-3 Spreader

The spreader is the device that picks up the containers. Spreaders are mounted on the trolley with cables. Since spreaders are technical high-end devices and a lot has changed in the spreader market recently, chapter 6 will go deeper into this subject.
2-2-4  Cabin

The cabin is the place where the crane is controlled. This can be done by one person. The operator can access the cabin via stairways on the side of the crane or, if available, with an elevator in that place. For accessing, the trolley needs to be close to the stairways platform. The cabin is fixed to the trolley, so the operator is always above his spreader. This is necessary to enable the operator to look deep in the vessels that need to be served. Therefore, the floor of the cabin is transparent. The position of the operator is quite unnatural. This can been seen in figure 2-12.

![Figure 2-11: A cabin of Merford at the Euromax Terminal Rotterdam (Merford Cabins, 2012)](image1)

![Figure 2-12: The position of the operator in his cabin (Merford Cabins, 2012)](image2)

Cabins are most of the time not built by the crane manufacturer themselves. A cabin producer is Merford. They build cabins for companies like Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC), Kranbau and Kockskrane. Recently, Merford fitted 16 cabins to STS cranes in the port of Rotterdam at the Euromax Terminal. These cranes were made by ZPMC.

2-2-5  Legs

The legs of the crane generate the height. The height of the cranes has been increasing over the last years due to the increase of height of the container ships. In general, the WS leg is thicker than the LS leg. This is because the WS leg has to support more moment forces. Figure 2-13 shows a crane with vertical legs and a thicker WS leg.

Legs can be vertical, but some of the WS legs have a slight angle in the LS direction. When loading ships, it can occur that, due to off balance of the ship, the ship will roll a little. This could result in a collision between the ship and the crane. Figure 2-14 shows a crane with a...
slight angle in the WS leg.

Some cranes have LS legs with a angle as well. This can be the result of a small requested gantry span by the costumer of the crane.

2-2-6 Cable reel and powersupply

For full flexibility during loading and unloading of the ships, it is necessary for the cranes to move along the quay. Most STS cranes are electrically powered and therefor need to have a connection to the grid. This connection is realized by huge cables that are lying in gutters over the quay. When the crane needs to move, the cable has to roll on or off by the motorized reel.

A producer of the cables reels and supporting systems is the company Cavotec. This company has several systems that are used for cranes from different manufacturers. Figures 2-15 and 2-16 show two different reels; one mounted high and one mounted on street level. Another cable reel company is Tratos Cavi. They claim to have several Original Equipment Manufacturer (OEM) s to their costumers.(Tratos Cavi, 2012)

The ratio between a full and an empty rolled reel can be hugh. This ratio is important for the rolling speed of the reel. A reel that is rolling to fast for the cable will result in unnecessary tension in the cable. Cavotec developed the "Pull and Store mechanism". Figure 2-17 shows the principle of this mechanism and figure 2-15 shows the implementation of the technique in real life. The use of this system overcomes the need for a sophisticated torque controlled system (Cavotec, 2012).

The gutter in the quay need to give as little as possible nuisance for the other users of the quay. Therefor the gutter is covered with a rubber slab. This requires a supporting system
to get the cable under that slab. Figure 2-18 shows the 'Pantzerbelt System' that lifts the rubber slab locally so the cable can go under it. The red rolls in the figure are the guidance for the cable.

![Figure 2-15: A high mounted reel with a "Pull and Store mechanism" (Cavotec, 2012)](image1)

![Figure 2-16: A reel mounted close to the road (Cavotec, 2012)](image2)

2-2-7 Machinery house

The machinery house contains all the machinery of the crane. This can be the drums with the hoisting cables. If the trolley is driven by ropes, this requires more drums. The drums are most frequently driven by electrical motors, which are in the house as well. Some cranes cannot be connected to the local power grid and therefore need a power generator in the machinery house.

The machinery house is always on top of the crane. Chapter 3 will give more information about the different drives and their manufacturers.

2-2-8 Boogie sets and wheels

The forces of the crane on the quay are transferred by the boogie sets and the wheels of the crane. The boogie set is the part of the crane that is under the leg of each corner. A crane therefore has 4 boogie sets. Typically, a crane has 8 wheels per corner. The total loads of one corner need to go through the 8 wheels. If the quay is insufficiently strong, cranes with more wheels per corner can be made. This can be seen in figure 2-19 where a crane with 10 wheels per corner is offloaded from a heavy lifting vessel.
Since the crane has to ride over the rails, the wheels need to be powered. The drives for the wheels are mounted in the boogie sets. This can be seen in figure 2-19 as well. The vertical mounted cylinders are the electrical drives.

2-3 Sizes

In the crane industry, the sizes of STS cranes are mostly referred to the size of the Panama channel. The largest ships that can pass that channel are called the Panamax size, which have a beam around 32 meter.
Table 2-3: Standardized dimensions for STS cranes (Liebherr, 2012) (Konecranes, 2012)

<table>
<thead>
<tr>
<th>Name</th>
<th>Outreach [meter]</th>
<th>Outreach [containers]</th>
<th>Lifting height [meter]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panamax</td>
<td>30 - 40</td>
<td>up to 13 rows</td>
<td>28 - 32</td>
</tr>
<tr>
<td>Post Panamax</td>
<td>40 - 46</td>
<td>up to 18 rows</td>
<td>32 - 36</td>
</tr>
<tr>
<td>Super Post Panamax</td>
<td>46 - 69</td>
<td>up to 22 - 24 rows</td>
<td>36 - 40</td>
</tr>
</tbody>
</table>

Table 2-3 gives a representation of the different dimensions of the standardized cranes. Still, most dimensions can be chosen by the customer and will depend on characteristics of the quay where the crane will operate and the ships that are expected. More about the drivers of crane dimensions can be found in chapter 8.

2-4 Performance optimizers

Ports try to optimize their throughput constantly. Therefore, the handling speed of cranes need to improve as well. Trends in the increasing trolley and hoisting speed will be considered in chapter 3, but other techniques are implemented as well to improve the handling speed. For instance, cranes can be equipped with a second lower trolley. The main trolley unloads the container from a ship to a platform. From this platform, the second trolley picks up the container and puts the container on the truck on the quay.

2-5 Quay loads

The size of STS cranes results in major loads for the quay. Although the wide diversity of cranes, some data was found about this issue. Some manufacturers provide information about the loads of their cranes.

The industry uses three different units to compare the loads. The first one is "load on corner-point". This is the load of the crane on the four different corners. The second unit is "load per wheel". As the name suggest, this is the load per wheel of the boogie. The last unit is the "load per meter". This last load is mostly used for the selection of the most suitable track for the crane.

Table 2-4 shows the information provide by some manufacturers about the loads of their cranes.

When new quays are build, this quay has to be suitable for cranes for the next decades. Therefore, builded quays are much heavier than the maximum loads represented in table 2-4. Besides that, it is not sure if the manufacturer has calculated this when the crane is in operation. The lifted cargo and wind for example can influence the load on the quay wall. The maximum allowable loads for the quay walls that are used by the municipality of Rotterdam.
Table 2-4: Typical quay loads for STS cranes (Liebherr, 2012) (Konecranes, 2012)

<table>
<thead>
<tr>
<th>Crane type</th>
<th>Loads by Konecranes</th>
<th>Loads by Konecranes</th>
<th>Loads by Liebherr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panamax</td>
<td>35-45 tons/wheel*</td>
<td>30-40 tons/m*</td>
<td>30-45 tons/m**</td>
</tr>
<tr>
<td>Post Panamax</td>
<td>45-70 tons/wheel*</td>
<td>35-55 tons/m*</td>
<td>40-55 tons/m**</td>
</tr>
<tr>
<td>Super Post Panamax</td>
<td>46-90 tons/wheel*</td>
<td>45-65 tons/m*</td>
<td>60-80 tons/m**</td>
</tr>
</tbody>
</table>

* Wheel loads are calculated case-by-case, according to the crane dimensions and the local conditions.

** Based on 8 Wheels per Corner at 1.00m Spacing

are represented in figure 2-20, 2-21 and 2-22

Figure 2-20: Vertical forces on the quay by the crane (Liang, 2011)

Figure 2-21: Horizontal forces, normal to the crane rail by the crane (Liang, 2011)

Figure 2-22: Horizontal forces, parallel to the crane rail by the crane (Liang, 2011)

2-6 Earthquakes

The first STS cranes were relatively small compared to the cranes built nowadays. These early seismic criteria do not suit for modern cranes. The increase of gantry span, higher clearances and increasing weight make todays cranes unable to withstand earthquake as well as early
Cranes have withstood earthquakes very well. No significant damage was reported, some cranes were lifted from the rails. This could be fixed easily. However, the earthquake in Kobe, Japan (1995) resulted in major damage to some cranes. This was the result of failing foundations of the quay.

2-6-1 Standards

Liftech, an American lift consultant, did research on the resistance of STS cranes to earthquakes. To compare earthquakes, the Operating Level Earthquake (OLE) in years of Mean Return Interval (MRI) is used. This number indicates what could be the return period of an earthquake from the same impact. An earthquake with a 475 year MRI is much heavier than an earthquake with 72 year MRI.
The US design standards up until 2006 would result in significant damage and local plate buckling with a 72 year MRI earthquake. The same standards with a 475 year MRI earthquake would result in significant damage and possible crane collapse. The industry has noticed the imperfection in the standards and therefore adapted new regulation. This new regulation is adapted by the American Society of Civil Engineers (ASCE) in 2010 and should prevent cranes from collapsing when the largest design earthquake occurs.

2-6-2 Prevention

When an earthquake occurs, the crane can tip. Now, the entire weight of the crane is supported by one side of the gantry. Because of the increasing crane weight over the years, this reaction force has grown significantly. Combine this with the growing gantry span and growing clearance under the sill beam and it is clear that these forces have grown enormously. The main loads due to the tip movement occur in the corner points between the legs and the horizontal beam between the legs. Figure 2-24 shows that the crane indeed is deformed in that point.

To prevent cranes from total collapse or heavy damage, the first thing that needs to be done is to make that corners stiffer or more flexible. The main target is to let the stress that can occur, be below the maximal allowable stress in the points or ensure that no stresses can occur.

New design

Designing new cranes according to the new standards require some changes in the design.

- Design to tip
  In this design, the crane is assumed to tip in case of an earthquake. Therefore, the connection legs to horizontal beam need to be stronger, so no plastic deformation will occur. To strengthen this point, more steel is needed. The implementation costs are around $150,000 - $180,000 in the year 2008. The added weight was around 5%. These projects were on cranes with a gantry span of 30.48 meter. For cranes with larger gantry spans, other prevention methods are recommended.

- Design for ductile yielding
  This way of earthquake prevention has not yet been used in this industry. This may be because this way of designing requires more research. Liftech expects this design to become very successful.

- Design for isolation
  In this design type, the crane has a certain flexibility so no peak stresses will occur. A Japanese manufacturer has implemented a mechanism in the boogie sets so the wheels are more free to move. Liftech designed their own way to isolate the vibrations, figure 2-25 shows this way. This mechanism has not yet been used in cranes. Liftech also developed dampers for other corner points in the cranes. Four new cranes
that will be delivered to the APL terminals in the Port of Los Angeles will be equipped with these dampers.

![Figure 2-25: A system to isolate the displacement (Soderberg et al., 2009)](image)

**Retrofit to existing cranes**

When existing cranes have insufficient strength in the case of an earthquake, these cranes can be modified. The same design targets as for new cranes can be used.

- **Design to tip**
  Figure 2-26 shows a retrofit to a existing crane. These additional pipes cost around $300,000. The main disadvantage is the reduction of clearance under the horizontal beam. This method can not be used on ports with Rubber Tyred Gantry (RTG)s or straddle carriers.

- **Design for ductile yielding**
  If the clearance is required, it is possible to mount external stiffeners on the corner point. This will cost about $500,000 and around two months to install. This method will result in ductility in the steal.

- **Design for isolation**
  The implementation of isolation parts will be the most expensive operation. If a crane raise modification is done, this could be done as well, because this will reduce the costs.

### 2-7 Wind

For high structures like STS cranes, wind can be a threat. Although most damage can be repaired, cranes can still collapse due to wind. Cranes have never collapsed due to failing
structures under hurricane load. The main cause is failing tie-downs. Another reason for crane collapse are winds during operation.

Tie-downs are the connections that are used to fasten the crane to the quay when heavy winds are expected. When heavy winds or hurricanes occur, it is possible that lifting winds appear. The tie-downs prevent the crane from getting lifted off the rails. The tie-downs keep the crane on its place when uplifting forces occur. Corners are tied-down with one or more tie-downs. When one of the tie-downs break, loads are abruptly changed in other tie-downs.

The main reason for crane collapse due to wind in operating situations is failing brakes. When high wind procedures are not followed correctly this may result in running cranes. This is a phenomena when cranes can not brake anymore when they are riding on the rails. The breaking failures can be caused by lifted cranes where the wheels do not have sufficient grip. It is also possible that the wind adds so much additional force on the crane that the brakes become insufficient.

2-7-1 Standards

The Dutch standards for cranes contain a part about the wind loads on cranes. The wind pressures that are used can be found in figure 2-28. STS cranes will be type B cranes and therefor have to withstand winds higher than hurricane speeds. The wind pressure for hurricanes is > 662 N/m$^2$ according to the International Beaufort scales.

For the USA, the ASCE-7 standards are used. These are the same standards that are used for high buildings. The wind speeds in the standard have not been adjusted for the last 50 years. Questions rise if this is correct. Global warming could result in heavier hurricanes.

Literature Assignment

F.F. Achterberg
2-7-2 Prevention

So the main cause of collapsing cranes by hurricanes is failing tie-downs. The first problem with tie-downs is that the crane has freedom to move when the tie-downs are installed. The rails and the wheels do not perfectly match and therefore the crane can move perpendicular to the rails. Figure 2-29 shows this. This movement may result in unequal distribution of the loads in the tie-downs.

To prevent collapsing cranes due to failing tie-downs, other tie-downs were developed. These tie-downs contain a part that when it is loaded, the shape changes due to ductility. Instead of breaking due to overload, the tie-down now gets enlarged until it has the same load as the tie-down on the other side of the corner. It is recommended to mount one set of tie-downs to each corner.

Prevention of running cranes in operation wind is solvable with two solutions. The first one is to well inform the crane operator about the wind conditions. An anemometer in the highest point of the crane can be a good tool to inform the operator. The second solution is the design of the brakes. When the brake system is designed, the designer should consider the possibility of the combination of a lifting wind force and a wind force in the driving direction.
Currently, there are no standards for stiffness requirements for STS cranes. Manufacturers design their cranes on experience or with requirements from the costumer. Some terminals give requirements of the stiffness in their tender. This requirements could, for instance, contain the maximal allowable deflection of the boom in all directions. Besides that, a maximum allowable natural period can be prescribed.

For considering the stiffness of cranes, tables 2-5 and 2-6 can be used. These data are from existing cranes from a manufacturer. The stiffness is always related to the outreach. To compare the stiffness of different cranes, the last columns can be used. The higher the value in the last column, the stiffer the crane. Preferable, cranes that are designed have higher relative deflection values than order number 5.

For the natural frequencies of existing cranes, 2-7 can be checked. For this stiffness indicator, there are, again, no standards. The higher the value in the last column, the stiffer the crane.
### Table 2-5: Vertical stiffness of some cranes

<table>
<thead>
<tr>
<th>Order #</th>
<th>Hoistload</th>
<th>Outreach</th>
<th>Deflection (mm)</th>
<th>Deflection relative to outreach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82</td>
<td>37</td>
<td>140</td>
<td>264</td>
</tr>
<tr>
<td>2</td>
<td>53</td>
<td>45</td>
<td>125</td>
<td>360</td>
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<tr>
<td>3</td>
<td>53</td>
<td>38</td>
<td>129</td>
<td>295</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>56</td>
<td>126</td>
<td>444</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>40</td>
<td>132</td>
<td>303</td>
</tr>
<tr>
<td>6</td>
<td>78</td>
<td>43</td>
<td>139</td>
<td>309</td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>59</td>
<td>108</td>
<td>546</td>
</tr>
<tr>
<td>8</td>
<td>82</td>
<td>52</td>
<td>173</td>
<td>301</td>
</tr>
<tr>
<td>9</td>
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<td>343</td>
</tr>
<tr>
<td>10</td>
<td>82</td>
<td>61</td>
<td>147</td>
<td>415</td>
</tr>
<tr>
<td>11</td>
<td>82</td>
<td>61</td>
<td>143</td>
<td>427</td>
</tr>
<tr>
<td>12</td>
<td>84</td>
<td>63</td>
<td>142</td>
<td>444</td>
</tr>
<tr>
<td>13</td>
<td>105</td>
<td>70.5</td>
<td>173</td>
<td>408</td>
</tr>
</tbody>
</table>

### Table 2-6: Horizontal stiffness of some cranes

<table>
<thead>
<tr>
<th>Order #</th>
<th>Trolley mass</th>
<th>Trolley + load</th>
<th>Deflection (mm)</th>
<th>Deflection relative to outreach</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>39</td>
<td>121</td>
<td>69</td>
<td>536</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>84</td>
<td>90</td>
<td>500</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>80</td>
<td>59</td>
<td>644</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>111</td>
<td>91</td>
<td>615</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>96</td>
<td>80</td>
<td>500</td>
</tr>
<tr>
<td>6</td>
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<td>11</td>
<td>33</td>
<td>115</td>
<td>119</td>
<td>513</td>
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<td>12</td>
<td>38</td>
<td>122</td>
<td>112</td>
<td>563</td>
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<tr>
<td>13</td>
<td>30</td>
<td>145</td>
<td>125</td>
<td>564</td>
</tr>
</tbody>
</table>
### Table 2-7: Stiffness in trolley traveling direction due to test load 100kN acting on bridge girder

<table>
<thead>
<tr>
<th>Order #</th>
<th>Displaced mass</th>
<th>Deflection cm/1000kN</th>
<th>Nat. Freq (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450</td>
<td>0.745</td>
<td>0.83</td>
</tr>
<tr>
<td>2</td>
<td>430</td>
<td>0.901</td>
<td>0.78</td>
</tr>
<tr>
<td>3</td>
<td>365</td>
<td>0.980</td>
<td>0.81</td>
</tr>
<tr>
<td>4</td>
<td>765</td>
<td>0.523</td>
<td>0.78</td>
</tr>
<tr>
<td>5</td>
<td>410</td>
<td>1.005</td>
<td>0.76</td>
</tr>
<tr>
<td>6</td>
<td>575</td>
<td>0.506</td>
<td>0.91</td>
</tr>
<tr>
<td>7</td>
<td>861</td>
<td>0.479</td>
<td>0.77</td>
</tr>
<tr>
<td>8</td>
<td>630</td>
<td>0.445</td>
<td>0.92</td>
</tr>
<tr>
<td>9</td>
<td>530</td>
<td>0.506</td>
<td>0.94</td>
</tr>
<tr>
<td>10</td>
<td>615</td>
<td>0.607</td>
<td>0.79</td>
</tr>
<tr>
<td>11</td>
<td>775</td>
<td>0.472</td>
<td>0.81</td>
</tr>
<tr>
<td>12</td>
<td>890</td>
<td>0.369</td>
<td>0.86</td>
</tr>
<tr>
<td>13</td>
<td>1300</td>
<td>0.332</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Chapter 3

Introduction to drive technology

3-1 Motors

In the early days of the Ship-to-Shore (STS) cranes, Direct Current (DC) drives were used. These drives can be well controlled which results in a good hoist behaviour. The disadvantage of DC motors is the amount of wear inside the motor. This results in high maintenance costs. Besides that, the energy consumption of the DC motors is high.

The first crane with an Alternating Current (AC) motor was produced in 1995 by Siemens. Siemens found a way to control AC motors in such a way that they would respond like DC motors. AC motors are much cheaper than DC motors, because maintenance become a less expensive cost factor. Besides that, the power consumption of an AC motor is lower.

It took a while until all manufacturers decided to build cranes with AC drives. Liebherr for instance delivered their first AC equipped crane in 2005. The cranes that are currently working with DC drives are built before the wide introduction of the AC motors. Some terminals transformed their DC cranes into AC cranes for the reasons mentioned above. Almost all cranes that are delivered these days are equipped with an AC power systems.

The current configuration of the power supply installed in cranes by Siemens is represented in figure 3-1. The crane is connected to a AC power grid. The power is transformed to a handleable voltage between 480-500 Volt. Using computers and controllers, the power is distributed over the different motors. The entire configuration of power elements of the crane will be chosen by the costumer (mostly the terminal) and designed by the supplier of the electrical parts.

Literature Assignment

F.F. Achterberg
3-2 Manufacturers

Some manufacturers of cranes build their own installations, Liebherr and Konecranes build their own installations. This can give them a competitive advantage, because they can offer lower prices. Most of the cranes are built with external suppliers of these elements. The manufacturers of these electrical components are called 'E-suppliers' in the industry. The two major manufacturers in the annual survey of World Cargo News are pointed out bellow.

3-2-1 Siemens

Siemens is a German based company with a large amount of working fields. The company has 360,000 employees and has an annual turnover of €73,5 billion. Siemens has been one of the main E-suppliers for cranes of Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC). Currently, ZPMC is not providing information anymore about their E-suppliers. Siemens
built their first AC driven crane in 1995 in the port of Rotterdam. The crane technology of Siemens is called SIMOCRANE (Siemens, 2012).

### 3-2-2 ABB

ABB is a Swiss based company with main focus on energy and automation. ABB has 133,600 employees with an annual turnover of €38,0 billion. ABB is about to install the electrical components for the cranes at the RWGW terminal of the Maasvlakte II. These cranes will be completely remote controlled.

### 3-2-3 Others

Siemens and ABB are not the only E-suppliers. Others will follow down here:

- General Electrics
- Fuji
- Yaskawa
- Alstom

### 3-3 Automation and remote control

The STS crane development has not stopped. To overcome problems and to further improve the capacity of the crane, still innovations are continuously implemented. Examples of innovation in the control of the crane are to automated the crane or to make it remote controlled.

The first problem to overcome is the ergonomics of the operator. The crane driver has to sit and look between his legs. Meanwhile he has to bend over. Combine this with constant acceleration and braking, this will result in serious back issues for operator. To solve this problem, ABB is developing remote controlled cranes for the Rotterdam World Gateway (RWG) Terminal located at the Maasvlakte II. These cranes will be controlled from a desk in an office. For other terminals this technology is still in testing phase. The challenge is that an operator of a crane currently uses his basic motor skills such as his eyes, ears and touch. There has to be a way in which all these signals can reach the operator behind the desk.

Automation of the cranes have already begun. Although a crane is not capable of fully loading and unloading containers automatically, it is capable of calculating the most efficient trajectory of the container, to tell the trucks where to stop, to automatically damp sway etc. Fully automation of container cranes will be an option in the near future, however this will only be
safe if no other humans are near the loading and unloading operation. For now, there is still a person necessary on deck of the ship to lash the containers.

Cranes will continuously become smarter, but total automation require more changes in the entire container industry.
Chapter 4

Manufacturers

This chapter will give an overview of the history of the manufacturers of Ship-to-Shore (STS) cranes worldwide. A short introduction to the company, combined with some facts will be pointed out. The order numbers for the period 2002-2012 are in the figure of the section of the manufacturer. The manufacturers are ranked based on the amount of cranes ordered in the period 2002-2012 according to the annual survey of World Cargo News.

For the annual survey, the World Cargo News asked the crane manufacturers to send them their current order book. So the indication of the specific year does not match with the amount of cranes delivered in that year, but with the status of the order book.

This survey does not claim to show a complete overview of the entire market, but it can be assumed that all major players on the STS crane market are mentioned. Manufacturers can choose how much information they would like to provide to the survey. Some manufacturers only publish the amount of cranes delivered, while others publish the technical specifications as well. It seems that, under the current economic situation, manufacturers are more anxious to publish their records.

Table 4-1 indicates the market shares of the different manufacturers over the period 2002-2012. The top eight manufactures are responsible for 95% of the market. These manufacturers will be pointed out in this chapter.

The STS crane market seems to have changed over the last period. The annual survey of 2002 shows a fragmented market with a few big players and several small players. Due to mergers and acquisitions the amount of manufacturers has been decreased. This might be the response of the European manufacturers to the upcoming players like Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC). However, ZPMC did the same themselves by acquiring Shanghai Port Machinery Plant (SPMP)

Literature Assignment F.F. Achterberg
An interesting movement for the industry is the opening of new production facilities in India for Original Equipment Manufacturer (OEM)s (World Cargo News July, 2008b). In December 2011, Mitsubishi Heavy Industries (HI) announced setting up a joint venture with Anupam Industries Ltd. This venture will start in 2012 with producing mixed aggregates and plans to build their first STS crane in 2015. The joint venture plans to make Mitsui Engineering & Shipbuilding (ES)/Paceco container cranes. The reason for opening the facility is because the companies expect a growing demand for their products in that region.


<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Market share</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZPMC/SPMP</td>
<td>69,1%</td>
</tr>
<tr>
<td>Paceco licensees</td>
<td>7,0%</td>
</tr>
<tr>
<td>Liebherr</td>
<td>6,0%</td>
</tr>
<tr>
<td>Fantuzzi/Noell/Regianne/Terex</td>
<td>3,6%</td>
</tr>
<tr>
<td>Cargotec/Kalmar</td>
<td>2,9%</td>
</tr>
<tr>
<td>Konecranes</td>
<td>2,5%</td>
</tr>
<tr>
<td>Doosan</td>
<td>2,4%</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>1,6%</td>
</tr>
<tr>
<td>Others</td>
<td>4,9%</td>
</tr>
<tr>
<td>Totaal</td>
<td>100,0%</td>
</tr>
</tbody>
</table>
ZPMC is the world’s largest manufacturer of STS cranes. The headquarter of ZPMC is located in Shanghai. The company owns 8 production facilities in China which cover a total area of 6670 hectares and 10 kilometers coastline. The major stakeholder is China Communication Construction Co., Ltd. (CCCC) (ZPMC, 2012). ZPMC was been formed out of a joint venture between SPMP and partners from Hong Kong in 1992 (World Cargo News May, 2008). In 2008 ZPMC acquired SPMP. ZPMC itself claims to manufacture 75% of the STS crane market.

In 1995 ZPMC converted a panamax tanker so the ZHEN HUA 2 was able to transport fully erect STS cranes. In 2006, over 2000 fully erected cranes made by ZPMC where transported (World Cargo News July, 2008c). Still, all cranes of the company are transported fully erected to the costumer. ZPMC owns 26 transportation ships. ZPMC made big investments in the STS crane industry. The company is now targeting other markets as well. In 2006 ZPMC bags the order for supplying steel structures for American Bridge (World Cargo News July, 2006a).

In the beginning of the company, the main costumers where located in the domestic market. The domestic market has always been very important for ZPMC, but the rest of the world has noticed ZPMC as well. Table 4-2 gives a good indication of the enormous growth of ZPMC over the last two decades.
### Table 4-2: Cranes sold by ZPMC (Inclusive SPMP)

<table>
<thead>
<tr>
<th>Year</th>
<th>China*</th>
<th>Export</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>6</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>1994</td>
<td>6</td>
<td>1</td>
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<td>1996</td>
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<td>120</td>
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<td>2013**</td>
<td>20</td>
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</tr>
<tr>
<td>2014**</td>
<td>-</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>

*Includes Hong Kong, but not Taiwan

**As of 19 July 2012 (World Cargo News July, 2012)
4-2 Paceco

Paceco is the name of an engineering company that designed the "Portainer" crane. Paceco stands for PAcific Coast Engineering COmpany. Paceco developed their first container crane in 1958. This crane can be seen in figure 2-1. This crane was the starting point for all container cranes worldwide (Paceco, 2012).

Now, the design of the "Portainer" crane is licensed to several production companies and has been produced by Paceco Espana, the production facility of Paceco Corp. The combined annual orders of the "Portainer" are showed in figure 4-2.

![Figure 4-2: Orders of Paceco and Paceco Licensees](image)

4-2-1 Mitsui ES Co., Ltd.

Mitsui ES is a Japanese shipbuilder that has a technical licensing agreement for the "Portainer" trademark. The first crane of Mitsui ES was delivered in 1967. Since then, over 200 cranes have been made (Mitsui ES, 2012).
4-2-2  Hyundai HI

Hyundai HI is a Korean manufacturer of ships, engines, construction machines and offshore equipment. The company was founded in 1972 (Hyundai HI, 2012).

4-2-3  Paceco Espana, S.A.

Paceco Espana is the Spanish crane production facility that is part of the Paceco Group (Paceco, 2012). The head office is located in Madrid.
4-3 Liebherr

Liebherr is a manufacturer of machines for the construction industry. The company was founded in 1949 by mister Liebherr with the idea to build cheap tower cranes. Currently, the company has around 23,000 employees and has facilities all around the world.

The container cranes are produced in Killarney (Ireland). This production site was started in 1958 and nowadays around 580 people are working there.

Liebherr provides a clear overview of their available cranes on their company website where they promote their "Self Powered Trolley" and their unique boom-beam hinge point. Besides that, they promote assembly of the crane on site. Most of the cranes made by Liebherr are delivered in parts and assembled at the destination of the crane. According to Liebherr this would "Reduces Unnecessary Risks Associated with Fully Erect Sea Transport" (Liebherr, 2012).

Figure 4-3: Orders of Liebherr
Terex Corporation is founded in America. The company is listed at the New York Stock Exchange. This producer of heavy industry equipment undergone many acquisitions in their history.

The history of the crane building division runs way back. It began in Italy with Luciano Fantuzzi who started the company Fantuzzi to develop agricultural equipment around 1960. In 1973 the company made their first container handling equipment. This grew out to be one of the main activities of the company. In 1993 Fantuzzi acquired Regianne, a heavy industry engineer. The brand Regianne was used to build several STS cranes.

In 2000 Fantuzzi acquired the German Noell Crane Systems. Until 2008 both companies made several container cranes and published their records in World Cargo News. In 2008, the Fantuzzi Group was acquired by the Terex Corporation. From that moment on, no more crane building records where published. The market share represented in table 4-1 is therefore not the best representation of their actual market share. Recently, Terex acquired Demag/-Gottwald to strengthen their position in the international mobile harbor crane market.
Cargotec is a company that acquired several other companies over the last 25 years. The acquisitions related to the container crane industry started in 1997 when Partek acquired Kalmar industries. In 2001 Kalmar acquired the Dutch company Nelcon B.V. In 2002 the name Kone Cargotec came from a merger between Kone and Partek. Finally, in 2005 Kone splitted from Cargotec. Cargotec now is a company with Kalmar (and so the former Nelcon B.V.) as a daughter enterprise. Figure 4-6 visualize the history of Cargotec.

Cargotec is a company that develops all kind of port equipment. With all their daughter enterprises, just like Kalmar, Cargotec can sell forklifts, port trucks and other port equipment. The headquarter of Cargotec is located in Helsinki, Finland. Cargotec employs 10.500 people all over the world. (Cargotec, 2012)
Figure 4-6: The history of Cargotec (Cargotec, 2012)
4-6 Konecranes

KONE was founded in 1910 when the first electrical winches were made. After several acquisitions in the following decades, the brand Konecranes was split from the original company KONE. KONE has a focus on escalators, elevators and automated doors. Konecranes makes several types of cranes for all kinds of purposes.

The headquarter of Konecranes is located near to Helsinki, Finland. The company is listed at the Helsinki stock exchange. In the first quarter of 2012, Konecranes employs around 11,000 people worldwide. In 2011 Konecranes acquired an Indian crane builder WMI Cranes Ltd. to strengthen their position in the Indian market.

![Figure 4-7: Orders of Konecranes](image)

Figure 4-7: Orders of Konecranes
4-7  Doosan HI&C

Doosan HI&C is a Korean manufacturer of power supplies, construction machines, green energy solutions and material handling. The company was founded in 1962 and the headquarters are located in Seoul. Doosan HI&C is part of the much bigger Doosan group. This group contains several other departments like real estate, finance and consultancy.

Doosan has a representation of 121 STS cranes worldwide. Besides that they made 521 Rubber Tyred Gantry (RTG) and Rail Mounted Gantry (RMG) cranes, of which they made 246 for the port of Singapore and 144 for Korea (Doosan HI&C, 2012).

Figure 4-8: Orders of Doosan HI&C
Mitsubishi HI is originally a Japanese shipbuilder. The shipbuilding activities started back in 1884. Over the decades that followed, the company was split up and combined again several times. In 1970 the car production department was split from the other activities.

Nowadays, Mitsubishi HI has a wide range of departments. The company still makes ships, but infrastructure, energy, aircraft and space belong to their expertise as well (Mitsubishi HI, 2012).

Figure 4-9: Orders of Mitsubishi Heavy Industry
4-9 Others

The following manufacturers made such a small amount of cranes in the last period or stopped making cranes that they will not be pointed out in this research.

- OMG
  OMG MGM does not make enough cranes for a reasonable market share.

- JFE Engineering
  JFE Engineering is still making cranes. The company promotes their aseismic container crane. Although they make cranes, the amount is too small for a reasonable market share.

- Kocks Krane
  Kocks Krane seems not to have stopped with making container cranes. The website provides clear information about their cranes. The company probably doesn’t share production records.

- C Rokas
  This Russian company does not provide information about their current production records.

- Impsa
  Impsa stopped the production of STS cranes. The company has not published information since 2005.

- Baltkran
  Baltkran has a very outdated website and has not published their production records since 2007.

- Golf Port Cranes
  Golf Port Cranes have produced a too small amount of cranes.

- K. Eberswalde
  K. Eberswalde has merged with Kocks Krane and primarily focus on smaller cranes.

- Dalian
  No information found about this company.

- Sumitomo
  Sumitomo has a focus on other types of cranes.

- IHI
  IHI does not make STS cranes anymore.
5-1 Types of transport and installation

The transport of built cranes is a challenging operation. Due to the enormous dimensions and weight of the structure it is hard to transport the cranes. The transportation and installation of Ship-to-Shore (STS) cranes can be distinguished into three types. These types will be discussed in the following sections.

Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC) is the only manufacturer who owns transportation ships and is therefore always responsible for the transport of their own cranes. The costumer of the transport is frequently the terminal. Sometimes the manufacturer is responsible for the transport.

5-1-1 Parts transportation

The first type of transport is transportation in parts. The parts of the crane are made at the production plant of the manufacturer but are not assembled into one big piece. The pieces of the crane can be transported with general cargo ships. This results in lower transport costs. No giant cranes are needed to lift the pieces off the crane.

When the crane arrives at the terminal of destination, it has to be assembled. This assembly takes some time. Besides that, there has to be enough space for the assembly cranes to move around the crane parts. This results in an area that cannot be used for normal terminal activities.

Liebherr promotes the transportation in parts for their cranes, because this would be less risky.
5-1-2 Fully erected transportation

The second way of transportation is when the crane is completely assembled at the production plant of the manufacturer. Transporting such a high structure requires a lot of stiffness of the structure. Therefore, the crane has diagonal welded beams between the legs. Figure 5-1 shows the rusted beams that are welded between the leg for more stiffness.

On the ship, the shipper mount the same rails as at the quay. The crane is rolled on deck or lifted by cranes on the ship. When the crane is onto the ship, it is mounted to the deck with the same welded beam connections as the diagonal welded beams. Figure 5-2 shows a welded structure under the crane that fixes the crane to the ship. Cables would not be sufficient to mount the crane, because cables have a lot of yield.

Dockwise used to deliver STS cranes with a forklift principle. Some of their ships were equipped with overhanging bars at the rear of the ship. Cranes could slide over this bars until they were above the quay. Then the ship would suck up water through the ballast tanks and the ship would sink a bit so the crane is close to the quay. An example of this type of delivery can be seen in figure 5-4 However, Dockwise has sold these ships.

The speed of the transport depends on the weather conditions. Although fully erected transportation is a risky operation that needs a lot of calculations beforehand, it has major advantages. The quay is only closed for a limited period. This is desirable for busy terminals. An other advantages is that the crane can be assembled on a production facility with lower labor costs.

ZPMC has several transportation ships for their products. For terminals it is an attractive offer if the manufacturer delivers the crane and it can operate quickly.
5-1-3 Semi erected transportation

The last type of transportation is semi erected transport. In this type of transportation the crane is assembled only partly. Figure 5-3 shows two cranes that are lifted on a heavy lifting vessel. The top part is separated from the legs and the gantry.

The increasing sizes of the STS cranes makes fully erected transport more difficult. Wide ships are required and the weather conditions become a crucial factor with increasing weights and dimensions of the load. If the gantry is wider than the deck of the ship, the rails of the crane can not be mounted. Semi-erected transport reduces the assembly time on the terminal compared to transportation in parts, This makes it an attractive way of transportation.

5-2 Shippers

5-2-1 Biglift

Biglift is a Dutch shipper that is located in Amsterdam. The company was founded in 1973 as Mammoet Shipping. In 2001 the shipping part of Mammoet was sold to the Spliethoff group. This group is the current owner and was forced to change the name into the current name.

Biglift has 13 ships with giant cranes onboard. The capacity of the ships are from 550mt up to 1400mt. Biglift has also ordered two ships both with a capacity 1800mt.
Biglift transported many STS cranes, but the increasing gantry span makes it impossible to put the cranes on the deck. Therefore, Biglift will be a good party for cranes with smaller gantry span and for cranes that are transported in parts or semi-erected state. (Biglift Shipping, 2012)

5-2-2 Jumbo

Jumbo is also a Dutch shipper. This shipper is located in Rotterdam. The company was founded in 1968 with the idea that not everything could fit into containers.

Jumbo has 12 heavy lifting vessels. The capacity of the ships are from 500mt up to 1800mt. Jumbo has ordered one ship with a capacity of 3000mt.

For Jumbo, the same applies as for Biglift. The increasing gantry spans of the cranes makes it more difficult to transport fully erected cranes. Other transportation methods are possible. (Jumbo Shipping, 2012)

5-2-3 Sal

Sal shipping is a German based shipper. The company was founded in 1850, but the current business model was introduced in 1980. in 2007 the company started a joint venture with 'K'line. In 2011 'K'line became the total owner of Sal.

Sal has a fleet of 16 heavy lifting vessels. The capacity of the vessels are up to 2000mt. (Sal Shipping, 2012)

5-2-4 Dockwise

The last shipper mentioned is Dockwise. Dockwise is a shipper that uses semi-submersible
ships. These ships are mostly used in the offshore business. The reason why Dockwise is mentioned here is that Dockwise has transported several cranes in the past using their fork-lift method. The DOCK EXPRESS 10 was a ship that uses that method to deliver cranes. Currently, other types of delivery of fully erected cranes are used.

Dockwise was founded in 1992 as a joint venture between several offshore companies. The company is listed at the Oslo stock exchange. (Dockwise, 2012)
Chapter 6

Spreaders

As promised in section 2-2-3, this chapter will give an overview of spreaders; the part of the crane that picks up the container.

6-1 Working principle

The connection between the container and the container crane is the head block and the spreader. Figure 6-2 shows a spreader with some essential parts that every spreader has and figure 6-1 shows a head block.

The head block is the part that is connected with the trolley by hoisting cables. Connected to the head block, with twist locks, is the spreader. The spreader comes in many sizes and options.

<table>
<thead>
<tr>
<th>Ref. in fig. 6-2</th>
<th>Part name</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Control system</td>
</tr>
<tr>
<td>B</td>
<td>Flipper</td>
</tr>
<tr>
<td>C</td>
<td>Twist lock</td>
</tr>
</tbody>
</table>

Every container is equipped with the same corner points. With a twist lock mechanism, it is possible to connect the container to the ship deck or to other containers. This corner point is also used to lift the container. Spreaders have a twist lock system so they can 'grab' the container.

The operator of the Ship-to-Shore (STS) crane is most of the time high above the container level. To help the operator with picking up a container, the spreader is equipped with a

Literature Assignment F.F. Achterberg
guidance assistance to perfectly aim for the container. These guiders are called ‘flippers’. The operator can use which flipper he wants to use to help him.

When the operator has aligned the spread to the best of his knowledge, the control system of the spreader uses light signals on the spreader to inform the operator if the container is attached properly to the spreader. When the system is ready, the hoist process can begin.

6-2 Spreader types

Although the intention of the container was mainly focussed on standardizing, a wide variation of containers is nowadays used. Containers can be 20ft., 30ft., 40ft. or 45ft. This variation in containers requires more flexibility of the spreaders. Together with a continues demand for increasing productivity and decreasing downtime for the crane, this results in a variation of spreaders on the market. A few spreader setups will be mentioned.

Starting with the most simple spreader. This is a spreader just for one container size. These spreaders are rarely mounted in STS cranes.

The second spreader are spreaders with the possibility to adjust the distance between the twist locks. These spreaders can hoist, for instance, 40ft. and 45 ft. containers.

20ft. containers are mostly stored in a 40ft. frame. The twin-lift principle is when two 20ft. container together are lifted. Many spreaders have the possibility to lift a 40ft., 45ft, or two
20ft, container. The spreader in figure 6-2 is such a spreader. When the spreader does a twin-lift, the containers in the ship are mostly close together, which is difficult if the containers need to be offloaded to separated trucks. Therefore, the spreader can pull the containers from each other.

The last spreader setup that is mentioned is the tandem-lift. When two containers next to each other are lifted, this is called a tandem lift. This setup can increase the productivity of the crane, since twice the amount of containers can be lifted. A disadvantage of this spreader is that the containers need to be on the same level of the ship. Therefore it is not possible to lift two containers all of the time. This type of lifting is called Single Hoist Trolley (SHT), which means that for a tandem spreader, there is just one trolley.

One of the spreaders that can do everything mentioned above is the T45 from Bromma. Figure 6-3 shows a drawing of this spreader, together with all the possible loads it can handle.

![Figure 6-3: Bromma T45 spreader with the different load possibilities. (Bromma, 2012)](image)

### 6-3 Manufacturers

From all cranes made by manufacturers, except the Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC) cranes, most of them are equipped with Bromma spreaders. Some Original Equipment Manufacturer (OEM)s build their own spreaders, but the number of OEMs is decreasing. Spreaders account for most of the downtime, so a lot of R&D is required. Crane builders like to leave the design of the spreader to a specialist. Other spreader builders other than Bromma are Stinis and RAM spreaders (World Cargo News September, 2010)
6-3-1 Bromma

Bromma is the main spreader manufacturer in the world. This company was founded in 1960. Now, over 5000 spreaders are in operation around the world. Bromma claims to have 97 of the top 100 ports worldwide to their costumers (Bromma, 2012).

6-3-2 Stinis

Stinis is a dutch producer of spreaders. Their main office is located in Krimpen aan de Lek. The company started as a black smith company by mister Stinis. Now the company focus on container handling equipment (Stinis, 2012).

6-3-3 RAM

RAM spreaders was founded in the UK in 1972. The company claims to have 3500 active installations over the world. 60% of the world’s major container port would like to work with RAM spreaders. The annual crane survey does not show big sells for RAM (RAM, 2012).

6-4 Trends

6-4-1 Hydraulic versus electric

The power supply has historically been done with hydraulic cylinders in the spreader. The cylinders powered the twist lock mechanisms and the translation of the spreader for the different load possibilities. An upcoming trend is the replacement of the hydraulic systems by
electric drives. These replacements makes spreaders much lighter, which is feasible for the energy consumption of the crane. Another improvement is the reduction of oil spills on the containers.

Initially, the flippers were connected with electric drives as well. The drives and the clutches of the flippers where not powerful enough and it was impossible for the operator of the crane to aim the spreader with the flippers. The drives and clutches of the flippers where replaced and the spreader industry continues moving towards electrical spreaders. (World Cargo News September, 2010)

The most recent order records of Bromma show not a single sell of an electric spreader. Despite all the advantages, the industry seems not to adopt to this innovation. It is possible that Bromma forgot to mention the type of drives of the spreaders. If an electrical spreader is the current industrial standard, it can be that Bromma does not mention the type of drive anymore.

6-4-2  Tandem-lift and Triple 40

The SHT spreaders have already been mentioned. However, what if the tandem spreader is fixed at two trolleys? The spreader is now in the Dual Hoist Trolley (DHT) configuration. This configuration allows the operator to easily convert to a single lift operation. Besides that, the drive can handle unequal height stacks.

The disadvantages of the DHT system are additional maintenance due to two hoist systems and additional weight. This results in additional cost of the crane (Lind, Jordan and Hsieh, 2008). The systems seems not to work out fine when the crane is equipped with two trolleys. Therefore this technique is decreasing in popularity.

ZPMC build a prototype for a Triple 40 spreader. This was actually a single spreader and a tandem spreader fixed on a DHT system. Currently, this has not been widely used in the industry.

The first option mentioned above seems out to to have the most advantage for the terminals. The order records of Bromma shows that for the new APM Terminals project at Maasvlakte II 22 single spreaders, but also 9 Tandem-spreaders have been ordered. The same records show that the other orders are only single spreaders. So, terminals believe in the tandem-lift, but only for the trolley above the crane. For a second trolley above the trucks, single spreaders are used.
Chapter 7

Analysis Ship-to-Shore (STS) cranes 2002 - 2012

The annual survey of World Cargo News (World Cargo News July, 2002) (World Cargo News July, 2010c) (World Cargo News July, 2010a) (World Cargo News July, 2005) (World Cargo News July, 2006b) (World Cargo News July, 2007) (World Cargo News July, 2008a) (World Cargo News July, 2009) (World Cargo News July, 2010b) (World Cargo News July, 2011) (World Cargo News July, 2012) shows the amount of STS cranes ordered in that specific year. These surveys can be used to find trends in the container crane market. Beside the amount of cranes and the destination terminal, the survey also provide technical information. In this chapter, the data from the annual surveys from 2002 to 2012 will be used. The trends that are found can be used to predict the future of the STS cranes.

The writers of the survey mentioned that it is possible that these data is not complete. Some manufactures see competitive disadvantages in data sharing. However, the main manufactures provide their data so it will give a good overview of the changes in the market.

7-1 Sale records

The sales of the different manufactures are mentioned earlier. However, to understand trends in following figures, it is good to have an overview of the total market in the period 2002 - 2012. Figure 7-1 shows, for example, that 2008 was an extremely good years with over 350 sales, but 2010 was less than the half of that success year. The following technology trends seems to be related to the total market.

Figure 7-1 shows the major marketshare of ZPMC. Their orders are the main driver for the total market. Figure 7-2 shows that the other manufacturers don’t have remarkable changes
Figure 7-1: Total crane sales in the period 2002 - 2012 with ZPMC and total.

in their marketshare.
Figure 7-2: Crane sales in the period 2002 - 2012 without ZPMC.
7-2 Dimensions

For the following figures (7-3, 7-4, 7-5, 7-6, 7-7 and 7-8) the black points are unweighted orders (large orders have a similar point as small orders). The red lines in the figures are the weighted averages. So, here the size of the order is taken into account.

The speed of different parts in a crane are expressed in meter/minute. This m/min unit is widely used in the industry.

![Outreach Graph](image)

**Figure 7-3:** The outreach of the ordered cranes in the period 2002 - 2012.

Over the last ten years, trends in the height and the outreach of the cranes seem to be similar. Starting in 2002 an increasing line suggests a growing demand for bigger and heavier cranes. This trend seems to stop in 2007. In this year, both the average outreach and the average height reach a maximum. However, after decreasing lines until 2010, the averages go up again.
and end higher than 2007.

Over the reviewed period, the average lift height increased with almost 18%. The average outreach went up with over 11%.

**Figure 7-4**: The lift height of the ordered cranes in the period 2002 - 2012.
7-3 Safe Work Load (SWL)

The average SWL of the cranes show a different figure than the two figures of the dimensions. Although there is a slight peak, this peak is in 2006 instead of 2007. 2010 shows a expected sink. The line towards 2012 is not increasing very fast. This might suggest that there has been reached an equilibrium.

Remarkable is the order for cranes with a SWL of 115mt. This has never been done before and is much higher than the former heaviest cranes.
7-4 Hoisting speed

Figures 7-7 and 7-6 respectively show the Hoist speed loaded (HSL) and the Hoist speed empty (HSE).

The two figures of the HSL and HSE have exactly the same profile. This was expected, because almost all cranes are equipped with Alternating Current (AC) drives. For AC drives, the HSE is twice the HSL.

It is remarkable that, although the average speed has been about the same in the period 2004 - 2009, 2010 shows a lower speed. So the cranes that were ordered in 2010 also had slower drives.
Figure 7-7: The average HSE of the ordered cranes in the period 2002 - 2012.
7-5  Trolley speed

Nowadays, a typical trolley speed is 240m/min for big cranes. The average however is just above 225m/min. Although the increasing average in the period 2002 - 2004 might suggest a trend in trolley speed, the years that followed make this an invalid prediction. There seems to be no trend in the trolley speed over the last ten years.

![Trolley Speed Graph](image)

*Figure 7-8: The average trolley speed of the ordered cranes in the period 2002 - 2012.*

The averages mentioned above seems to be not in a lift anymore. The industry might have figured out that with these working speeds, a good output rate can be achieved. Besides that, the accelerating time of the trolley and the hoisting devices are not measured. These are important as well to compare different speeds. For E-suppliers like Siemens, the speeds...
can go up if costumers really want this. However, higher speeds and accelerations means higher wear in cables and all types of other parts which results in higher costs. Therefor, the current maximum speeds are not expected to change that much in the near future.
7-6 Cranes by type

Section 7-2 shows an inexplicable dip in average dimensions in 2010. To investigate this, the cranes were ranked on their average outreach. Figure 7-9 shows how many cranes were sold from the different types.

![Figure 7-9: Number of cranes ordered per type](image)

It is clear that Super Post Panamax is responsible for the most cranes. Since so many cranes are ranked as Super Post Panamax, this might suggest that this ranking is not sufficient anymore. Therefore, a new ranking is introduced to analyze the heavy cranes. The outreach...
dimensions are chosen arbitrary. The purpose of this ranking is to get a better overview if a type of crane is less popular in times of crisis.

The first type still is Super Post Panamax. Now, cranes with an outreach until 60m are ranked as Super Post Panamax. The second type is Super cranes. These are the cranes with an outreach from 60m to 65m. The last rank is Super Super cranes. This are the crane with an outreach over 65m. The result of this ranking is represented in figure 7-10.

![Figure 7-10: Number of heavy cranes ordered per type](image)

To compare the different years, both figures are converted to figures were the numbers are changed to percentages of the total amount of cranes. The result are figures 7-11 and 7-12.

With this four figures, it became clear that in 2010 more Post Panamax crane were ordered.
Figure 7-11: Distribution of cranes ordered per type

This is absolutely as well as relatively. No direct reason for this was found.
Figure 7-12: Distribution of heavy cranes ordered per type
7-7 Order sizes

The order sizes in the analyzed period are represented in figure 7-13. This figure shows no direct trends in the average order sizes. 2010 was the worst year, as is seen before. Besides that, in 2010 there was just one order above 4 (6 cranes). This differ from other years.

Figure 7-13: The size of the orders with the average order size
7-8 Comparison of trends and remarkable issues

The averages of the outreach, the lift height and the SWL are combined to one picture, the result is picture 7-14. All the lines show a similar path. This implies that the average crane is growing.

![Diagram of Dimensions and SWL](image)

**Figure 7-14:** Average outreach, lift height and SWL.

The different speeds that are published about cranes are three almost similar lines. These lines show that for these specifications the averages have nearly not changed over the last 10 years, except in 2010 when all the lines show the depression.

The year 2010 was the worst year for the container industry in the period 2002 - 2012. Still some cranes where ordered, but only smaller cranes with lower speeds. Big cranes are more capital intensive, it might be that terminals don’t want to do big investments in uncertain periods. Smaller cranes would not fit in their port setup, so it might be that the crane ordered in 2010 are only ordered by small terminals or replacement orders.

in 2012, just two years later, less small cranes were ordered. A difference can be seen between
the crane with the lowest lift height in 2010 and 2012. The same trend can be seen in the figures of the speeds. The scatter of the points has been reduced over the measured period. There seems to be no direct relation with the overall demand for STS cranes. The sales for cranes never been that good as in 2008. However, the industry ordered cranes with less heavy specifications.

Figure 7-15: Average HSE, HSL and trolley speed.
Chapter 8

Purchase process and prices

8-1 Purchase process

The purchase of Ship-to-Shore (STS) cranes is a typical process. First it is important to understand "who is the costumer"? The costumers of the cranes are the terminals. They buy the cranes to be used on their quays.

The cranes that are ordered have to increase the capacity of the terminal or have the make the terminal suitable for bigger ships. This last point is the driver for the size of the cranes. The shipping companies are increasing the sizes of their ships. For instance Maersk announced their Tripple E vessel, which will become the largest container ship in the world. When the companies announce new dimensions for vessels, this directly influences the terminal since they will need to be able to match the sizes of the cranes to the sizes of the shipping vessels.

To compare the growth of the vessels figure 8-1 can be used. This shows the largest vessel expected in 2012 (the Maersk Tripple E). The same figure shows the maximum and averages outreach and lift height from the cranes in 2002 and 2012.

As seen before, there is a high diversity between cranes in the world. The continuous changes in dimensions of the new ships require different crane dimensions. An other issue for the diversity in cranes are the local conditions. The design of a crane is strongly dependent on whether the crane is in an earthquake or storm area. The use of the power system in the crane depends on the local stability of the power grid and the frequency. Some area’s have their own standards that the crane has to meet. The last factor that results in diversity of cranes are the requirements of the terminals.

For the purchase process, the terminals make their requirements and publish them. Now, the crane manufacturers can come with their bid for the order.

Literature Assignment
Figure 8-1: The growth of cranes over the last 10 years.

The requirements of the terminals can be a huge document. The document contains for instance the technical requirements, the standards that should be met and several other things. Besides the main document with requirements, the terminal can decide to send a list of wishes as well. This enables the manufacturer to get extra points which helps to win the bid.

For terminals, the requirements can be based on a vision, or on the requirements that are used on other locations of the terminal. It is an attractive proposition for a terminal to have the possibility to exchange cranes between different locations without doing major, expensive, conversions.
8-2 Prices

The prices of cranes is a topic that many people are interested in. However, it seems to be one of the best kept secrets of the business. Figure 8-1 shows the limited information that is available. This information is found in the annual surveys of World Cargo News. Some of the prices are confirmed by terminals or other parties. Others are estimations. Therefore, the quality of the data needs to be doubted. Also it is not known what type of cranes are mentioned in the deals represented in figure 8-1. Therefore it is hard and slightly unfounded to draw hard conclusions out of it.

Figure 8-1 shows the orders, the composition of the orders, the price, the currency and the reference that are found. Some of the orders are package deals with Rubber Tyred Gantry (RTG).

Figure 8-1 shows a variety of orders and currencies. To compare the different prices, the first thing to do is to convert all prices to the same currency. To convert the dollar orders into euro orders, the currencies of that specific years are used. Figure 8-2 shows the currencies found.

To compare the crane prices in 8-1 the second thing one needs to do is to compare the sizes of the order and to make sure that the price of the RTG are not included the crane price anymore.

So, the price of the RTG should be known. 2002 shows two orders with RTGs. Assuming that these are the same RTGs and the same cranes, than the price of the RTGs and STS cranes can be found. The price that was found is 1.3M€ in 2002. Combine this with the currencies mentioned earlier, the prices of RTGs for the different years are showed in figure 8-3. An annual mark up of 1.5% is chosen.

Now the currency is taken into account and all RTGs are extracted from the orders. This results in figure 8-4. This figure shows the price per crane.

This data does provides a rough estimation of the prices of cranes. In the table, it can be seen that the prices are increasing over the period. Several factors can result in increasing prices.

The price of order 2 is the highest price found (15.5M€). It is possible that this data however is not correct.

The first thing that was found earlier, is that the average crane is growing in outreach, length and Safe Work Load (SWL). Growing cranes means more steel and other materials are needed. This automatically result in higher prices. This could be a key drive of the increasing prices.

A second thing that could have been the factor is inflation and rising steel prices. This would mean that the same crane would become more expensive without changes of the design. Someone from the industry (Anonymous, 2012) "The price of cranes per mass has been
increasing with 1% to 2% per year. This quote says that the inflation and changes in the price of steel results in an annual 1% to 2% mark-up.

So the major price rise seems to be the result of the growing dimensions of the cranes. Changes in the price of steel or inflation result in an annual mark-up.

If the calculated prices of the cranes are put in a graph, this results in figure 8-3. Two trend lines were added to see the expected trend. The first line is the line with all the data, so including order 2. This line shows a slight increase of the prices. However, if order 2 is not

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<table>
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<th>Order #</th>
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<tbody>
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<td>1 STS</td>
<td>5.5</td>
<td>€</td>
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<td>(2002)</td>
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<tr>
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<td>3</td>
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<td>$</td>
<td>-</td>
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<td>$</td>
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<td>(2010a)</td>
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<td>$</td>
<td>-</td>
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<td>$</td>
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<td>(2005)</td>
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<td>$</td>
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<td>(2005)</td>
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<td>$</td>
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<td>$</td>
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<td>$</td>
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<td>(2007)</td>
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<tr>
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<td>$</td>
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<td>$</td>
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</tr>
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<td>$</td>
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<td>$</td>
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</tr>
<tr>
<td>19</td>
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<td>€</td>
<td>Konecranes</td>
<td>(2008a)</td>
</tr>
<tr>
<td>20</td>
<td>27 STS &amp; 60 RTG</td>
<td>343</td>
<td>$</td>
<td>ZPMC</td>
<td>(2009)</td>
</tr>
<tr>
<td>21</td>
<td>8 STS</td>
<td>100</td>
<td>$</td>
<td>ZPMC</td>
<td>(2009)</td>
</tr>
<tr>
<td>22</td>
<td>8 STS</td>
<td>50</td>
<td>$</td>
<td>-</td>
<td>(2009)</td>
</tr>
<tr>
<td>23</td>
<td>2 STS</td>
<td>27</td>
<td>$</td>
<td>Doosan</td>
<td>(2009)</td>
</tr>
<tr>
<td>24</td>
<td>3 STS</td>
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<td>$</td>
<td>Doosan</td>
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<td>€</td>
<td>Liebherr</td>
<td>(2012)</td>
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<tr>
<td>29</td>
<td>12 STS &amp; 40 RTG</td>
<td>175</td>
<td>$</td>
<td>ZPMC</td>
<td>(2012)</td>
</tr>
<tr>
<td>30</td>
<td>14 STS</td>
<td>109</td>
<td>€</td>
<td>ZPMC</td>
<td>(2012)</td>
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</table>
Table 8-2: Currency from € to $ per year (Dollarkoers.nl, 2012) (Valuata.nl, 2012)

<table>
<thead>
<tr>
<th>Year</th>
<th>€</th>
<th>$</th>
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<tr>
<td>2002</td>
<td>1.0013</td>
<td>0.9913</td>
</tr>
<tr>
<td>2003</td>
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<td>1.1543</td>
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<tr>
<td>2004</td>
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<td>1.2168</td>
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<td>1.3588</td>
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<td>1.5175</td>
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<td>1.4096</td>
</tr>
<tr>
<td>2010</td>
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<td>1.4495</td>
</tr>
<tr>
<td>2012</td>
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<td>1.267</td>
</tr>
</tbody>
</table>

Note: The currencies are taken on July 1 of that year.

Table 8-3: Assumed prices RTG

<table>
<thead>
<tr>
<th>Year</th>
<th>Price (M€)</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>2003</td>
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<td>1.38</td>
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<td>2007</td>
<td>1.40</td>
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<tr>
<td>2008</td>
<td>1.42</td>
</tr>
<tr>
<td>2009</td>
<td>1.44</td>
</tr>
<tr>
<td>2010</td>
<td>1.46</td>
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<tr>
<td>2011</td>
<td>1.49</td>
</tr>
<tr>
<td>2012</td>
<td>1.51</td>
</tr>
</tbody>
</table>

Calculated with annual 1.5% mark-up and assumed from orders from 2002.

taken into account, the linear trend line is much steeper and seems to be more realistic.
Table 8-4: Calculated price per crane

<table>
<thead>
<tr>
<th>Order number</th>
<th>Calculated price/crane (M€)</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.50</td>
<td>2002</td>
</tr>
<tr>
<td>2</td>
<td>15.50</td>
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</tr>
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<tr>
<td>30</td>
<td>7.79</td>
<td>2012</td>
</tr>
</tbody>
</table>
Figure 8-2: The prices per crane (€) found in the period 2002 - 2012 including trend lines.
Figure 8-3: The prices per crane ($) found in the period 2002 - 2012 including trend lines.
Part II

Quay walls
Chapter 9

Introduction to quay walls

9-1 History

The first water transport dates back to 6000 BC. From then to now the ships has changed majorly. The ships are the driver of the dimensions of the quay walls. The information about quay walls from the past are based on information from the Romans and archaeological findings. Figure 9-1 shows the construction of a mole in 1000 BC. The development of quay walls has continued over the years. This assignment will further focus on the early history and current design of quay walls. For more information, (de Gijt, 2010) is an interesting book about the history of quay walls (de Gijt, 2010).

![Figure 9-1: The construction of a mole. (de Gijt, 2010)](image)

9-2 Basic parameters of a quay wall

This section will give an introduction to the basic terminology of quay walls. The design in figure 9-2 shows a typical quay wall. The parameters are represented in table 9-1 and table
9-2 shows the different parts of the quay wall.

An important parameter is the retaining height. This is the height of the quay wall from the quay floor to the construction depth. This height is used to compare different quay walls. The NAP is the average water level. In the design of the quay wall, the tidal influences needs to be considered.

This figure does not show rails for the Ship-to-Shore (STS) cranes. The Water side (WS) rail is mostly mounted right above the hinge support. The Land side (LS) rail is mostly not taken into account for the design of the quay wall.

Figure 9-2: Basic components and parameters of quay wall
(Civieltechnisch Centrum Uitvoering Research en Regelgeving , 2002) edited by F.F. Achterberg

<table>
<thead>
<tr>
<th>Ref. in fig. 9-2</th>
<th>Parameter name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Retaining height</td>
</tr>
<tr>
<td>B</td>
<td>Construction depth</td>
</tr>
<tr>
<td>C</td>
<td>Contract depth</td>
</tr>
</tbody>
</table>

Table 9-1: Parameters of a quay wall(Civieltechnisch Centrum Uitvoering Research en Regelgeving , 2002)
9-3 Functions of quay walls

Quay walls have four basic functions. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002) (de Gijt, 2010)

9-3-1 Retaining

The quay wall must be able to retain the soil from the area behind the quay. When designing a quay wall, it should be considered that the soil can’t flow under the walls.

9-3-2 Bearing

The quay wall must be able to carry the loads of the cranes and the other transshipment facilities.

9-3-3 Mooring

The initial function of quay walls has always been to moor the ships. This is still an important function.

9-3-4 Protecting

The quay walls must ensure that the ships can moor without damage. The wall also protects the cranes from incoming ships.

9-4 Types of quay walls

Quay walls are build all over the world. The different ports have all kinds of different soil characteristics. Besides requirements of the port, the type of quay wall depends on the soil
Although the wide variety in quay walls, there are four basic types. These types will be introduced shortly now. The walls are ranked according to the Handbook Quay Walls. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)

### 9-4-1 Gravity walls

Gravity walls are walls that have such a high self-weight that is has a sufficient resistance to shearing is generated in the soil and it cannot tilt or slide.

Gravity walls are mainly used:

- when the subsoil is not suitable for sheet pile wall because it consist of rock or very firm sand.
- when the subsoil has sufficient bearing capacity.

Figures 9-3 and 9-4 show different types of gravity walls. Gravity walls are often constructed with prefabricated elements. This can reduce the costs.

![Figure 9-3: A block wall](image)

![Figure 9-4: A caisson wall](image)

### 9-4-2 Sheet pile walls

Sheet pile wall structures derive their soil retaining function and stability from the fixation capacity of the soil, possibly in combination with anchors. These wall structures are used in places where the subsoil has poor bearing capacity and is easily penetrable. The walls may also be anchored. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)
Over the years, there has been a development of all types of walls. The walls can be made from steel sheet piles in all kinds of configurations or can be made from concrete diaphragm walls. The choice will depend on local conditions and required retaining height. The anchorages are also widely developed, leading to a large variety.

Figure 9-5: A sheet pile wall without an anchor (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)

Figure 9-6: A sheet pile wall with an anchor wall. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)

Figure 9-7: A sheet pile wall with a grout anchor. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)

Figure 9-5 shows a sheet pile wall without anchors. If more strength is needed, anchors can be added. Figures 9-6 and 9-7 are two examples of that.

9-4-3 Structures with relieving platform

When high horizontal loads may occur, a relieving platform can reduce these loads. For this technique, besides a sheet pilling structure being built also a platform is put on it. This
platform is anchored with piles.

The relieving platforms will be used in the following cases:

- High retaining heights
- Heavy loads on the site
- High demands in relation to allowable deformations, a fixed crane track
- Without a relieving platform it would not be possible to construct the sheet piling with the available equipment or it is no longer economically interesting

Figures 9-8 and 9-9 show two types of relieving platform quay walls. The difference in the figures is the depth of the platform.

![Figure 9-8: A quay wall with a deep relieving platform. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)](image1)

![Figure 9-9: A quay wall with a high relieving platform. (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)](image2)

### 9-4-4 Open berth quays

For this structure, the height difference is not covered by a horizontal wall but with a slope. This structure has a horizontal deck founded on piles.

This structure is mainly used when:

- Construction takes place above water
- There is sufficient space in the river
- There is relatively poor subsoil
- There are existing protected slopes

It should be considered that the underside of the deck is hard to access for maintenance.
This section will only focus on different wall types. For the construction of quay walls, a large variety of anchorages is applicable, but these will not be considered.

The first wall type that will be considered are the single walls. Figure 9-12 shows cross sections of different types of single walls. The materials that are used here are steel, wood and concrete. The figure also shows the different types of cross section.

To increase the strength of the walls, combined walls can be used. These walls are made of different types of piles. Figure 9-13 shows these types of walls.

An upcoming technology is quay walls made of diaphragm walls. These walls are excavated panels that are filled with concrete. One side of the built wall will be cleared by dredging when the panels are finished. The construction method can be seen in figure 9-14.
Figure 9-13: Different cross-sections of combined walls (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)

Figure 9-14: The construction of a diaphragm wall (Civieltechnisch Centrum Uitvoering Research en Regelgeving, 2002)
9-6 Construction methods

The way to construct quay walls can be split into two types. Both types will be discussed shortly.

9-6-1 Construction from the water side

The choose of construction method depends on specific local conditions. If the construction level of the foundation is above the water, mostly this method is chosen. Floating equipment is used to construct the quay walls. Things like water level, wave heights and water current can be a risk for this construction method. This have to be considered before using this method.

9-6-2 Construction in a dry building pit

For this construction method, on both sides of the future quay wall there is soil. After constructing the wall, one side of the wall is dredged free. If the construction level of the wall (for instance the relieving platform) is under the water level, then this method is required. The ground water level should be investigated on beforehand and should be monitored during the construction. (Civieltechnisch Centrum Uitvoering Research en Regelgeving , 2002)

9-7 Limitations on loads

For this assignment, it would be useful to know what the maximum allowable loads on the quay walls are. With these data it would be possible to calculate how much the allowable weight of a crane may be.

However, the design of quay walls is based on the demands of the terminal. A terminal provide the requirements for the quay wall to several contractors. The contractors can do a bid for the job. With this bid they promise that they build a wall according to the requirements.

If a terminal considers to increase the loads on the quay wall above the requirements, they have to hire an external advisor to recalculate the quay walls. The walls may be overdeveloped, although this is not very likely. This would mean that the contractor did his work above the necessary standards.

Would there be a realistic limit to the load on quay walls? According to (van Kaam, 2012) from Delta Marine Consultants: "Currently, there seems not to be direct realistic limitations on the loads on new quay walls. If terminals come up with higher crane loads, this needs a new design. It is very likely we can make that design. Higher loads require sometimes deeper walls, so more material, so a higher price"
Chapter 10

Introduction to rails

Rails are the connection between the cranes and the quay wall. The crane loads need to be guided to the quay wall via the rails. Therefore, the rails have to deal with high loads. This chapter will give information about different types of rails that are commonly used for Ship-to-Shore (STS) cranes. Countries may have their own standards and regulations for rail tracks.

10-1 Types of rails

Although there is a wide variety in rail types, there are two types that are mostly used. This is the high profile (A-profile) and low profile (for instance the MRS-profile). Figures

<table>
<thead>
<tr>
<th>Rail type</th>
<th>Ref. fig.</th>
<th>H (mm)</th>
<th>B (mm)</th>
<th>K (mm)</th>
<th>W (mm)</th>
<th>e (mm)</th>
<th>Wheel load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 75</td>
<td>10-2</td>
<td>85.00</td>
<td>200.00</td>
<td>75.00</td>
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<td>200.00</td>
<td>100.00</td>
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</tr>
<tr>
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<td>77.30</td>
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<td>10-1</td>
<td>180.00</td>
<td>180.00</td>
<td>120.00</td>
<td>40.00</td>
<td>91.40</td>
<td>725</td>
</tr>
</tbody>
</table>

This data shows a maximum wheel load of 1050 kN. This would mean that the newest cranes would require at least 11 wheels. However, the quality of the rail steel can increase the maximum allowable load on the rails. If this was still not enough sufficient, other profile types can be used. This profiles are used in other industries already.

The Euromax terminal and the APM Terminal in Rotterdam uses A150 rail profile on their quays. The crane track in Port Said, Egypt uses MRS125 profile.

Literature Assignment

F.F. Achterberg
10-2 Support

For crane tracks, the support of the rails van split in two types; continue and discontinue.

In case of continue supported track, the rail is mounted on a steel plate along the entire length. This system is very suitable for high dynamic loads. Figure 10-3 shows a continue supported track. This system can also be used in a gutter if the rail track has to be crossed by other vehicles.

Discontinue supported track is shown in figure 10-4 when the loads on the track are far under the allowable loads, this way can be used. This type of support is less expensive.
Figure 10-3: A continue supported rail (Bemo Rail, 2012)

Figure 10-4: A discontinue supported rail (Bemo Rail, 2012)
This chapter will give more insight in the costs of quay walls. Since quay walls are no mass products, there is no standard price per quay wall. The costs and prices represented here are based on data from quay walls all over the world. (de Gijt, 2010)

11-1 Total costs

Building quay walls is an expensive business. The prices will follow furtheron, but this section will be to compare the total cost as a function of the initial construction costs.

The costs of quay walls can be expended, besides the initial investments \( (I_0) \), with maintenance costs \( (M_1, M_2, M_i) \) and the demolition costs. Figure 11-1 gives an graphical display of this. With historical data the total costs can be calculated.

If this value is combined with the annual interest and the lifetime of the quay walls, the result is the Present Value \( (PV) \). For this calculations of the PV the annual interest rate of 4% and

Figure 11-1: The total costs of quay walls. (de Gijt, 2010)
Prices of quay walls

11-2  Factors of the price

Since the price of quay walls is mostly unique, what are the factors that influence the prices? Figure 11-2 shows this different factors and their contribution to the costs.

![Figure 11-2: Driving factors of the costs for quay walls.](image)

The retaining height is the key driver for the costs. The retaining height is for 75% responsible for the costs. More height requires more material to build the walls so therefore the price will be higher. The crane loads are only responsible for 2% of the costs. (de Gijt, 2010)

11-3  Costs per meter

For future projects it could be helpful to predict the costs of the quay walls. Historical data is used to find the costs per meter for quay walls. As seen in section 11-2 the main driver for the costs is the retaining height. So the costs of the quay walls are represented as a function of the retaining height. Figure 11-3 shows the historical data with the trend line.

This data is for ports all over the world. The data is indexed to prices in 2008. Over the world, the costs of quay walls vary 20%. Scale advantages for building quay walls can be achieved when the retaining height is over 20 meter and the length is more than 1000 meter. The costs advantages can go up to 30% by improving the logistics and the process of the
11-3 Costs per meter project. (de Gijt, 2010)

11-4 and 11-5 shows the costs of the quay walls of The Netherlands respectively Rotterdam.

![Figure 11-3: Historical data about the price of quay walls in the world.(de Gijt, 2010)](image)

*Figure 11-3: Historical data about the price of quay walls in the world.(de Gijt, 2010)*
Figure 11-4: Historical data about the price of quay walls in The Netherlands. (de Gijt, 2010)
Figure 11-5: Historical data about the price of quay walls in Rotterdam. (de Gijt, 2010)
Part III

Cases
In this chapter, rough estimations about the cost of the Rotterdam World Gateway (RWG) terminal at Maasvlakte 2, Rotterdam are done. If the costs are known, it become more clear where cuts can be made.

12-1 The RWG terminal

In 2008, the Dutch started with reclaiming land for the Maasvlakte 2. This harbor would be build to increase the capacity of the Port of Rotterdam. The reclaimed land will be used for different types of industry. Some of the land has been rent by RWG terminal. This terminal, a joint venture between several terminals, will build a total of 1,700 meters quay wall with, for now, 14 cranes. Figure 12-1 shows the location of the RWG on the Maasvlakte 2.

12-2 Cranes

RWG will start to operate with 14 cranes. This cranes will be delivered by Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC). The price of the total order seems to be €109M. This order contains 3 barge cranes and 11 Ship-to-Shore (STS) cranes.

The estimated costs of the quay walls that will come in the next section, are based on prices in 2008. This means that the prices of the cranes should be calculated as prices in 2008. Assuming an annual price increase of 1,5%, the prices of the same order in 2008 would be 6,1% (1,5% to the power of 4) lower, this is 102,7M
12-3 Quay walls

There is no price found for this project. However, with the data provided by (de Gijt, 2010) it is possible to calculate the price roughly.

The first thing is the length of the quay walls. RWG has ordered 1,700 meters quay wall. However, this is the combined length of 2 types. The first type is quay wall for large vessels. This wall has a length of 1,150 meters. The second wall is specially for barges and has a length of 550 meters.

For the calculations of the price, the retaining height is needed. The depth of the ports are 20 meters. Let’s assume there are 3 meters quay wall above water level. This makes a total of 23 meters.

The contract depth is not known. Therefor this has to be assumed. An arbitrary value of 7 meters is chosen. This makes the retaining height total 30 meters with a safety margin.
Table 12-1: Calculated costs of quay walls at RWG (Scenario 1)

<table>
<thead>
<tr>
<th>Quay length (m)</th>
<th>Retaining height (m)</th>
<th>Price per meter (€)</th>
<th>costs (M€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,150</td>
<td>30</td>
<td>50,000</td>
<td>57,5</td>
</tr>
<tr>
<td>550</td>
<td>30</td>
<td>50,000</td>
<td>27,5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>85,0</strong></td>
</tr>
</tbody>
</table>

Table 12-2: Calculated costs of quay walls at RWG (Scenario 2)

<table>
<thead>
<tr>
<th>Quay length (m)</th>
<th>Retaining height (m)</th>
<th>Price per meter (€)</th>
<th>costs (M€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,150</td>
<td>30</td>
<td>50,000</td>
<td>57,5</td>
</tr>
<tr>
<td>550</td>
<td>15</td>
<td>22,000</td>
<td>12,1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>69,6</strong></td>
</tr>
</tbody>
</table>

There are 2 scenario’s.

1. All the walls have the same retaining height. This is possible, because the big ships have to go along this wall (see figure 12-1). They don’t berth here, but they will pass.

2. The wall for barges has less retaining height. It is unnecessarily to build heavy and deep walls when they are not used.

For both scenarios in this case figure 11-5 is used.

If the first scenario is considered the table 12-1 illustrates the costs.

The second scenario results in table 12-2. For this scenario an other retaining height is used for the berth quay walls. The depth of a barge can go to 5 meters. Adding the same 3 meters of height above the water level and again 7 meter for the contract height. This results in a retaining height of 15 meters.

Figure 11-2 has already shown that the costs for quay walls are only for 2% of the total costs by crane loads. This would mean that for scenario 1, ideally, the quay walls could be 1,7M cheaper of more expensive. For scenario 2, this is only 1,4M.

If we would like to have the same total costs for crane and quay walls, the percentage can be calculated that the crane price may change. For scenario this is 1,6% and for scenario 2 this is only 1,3%.

12-4 Conclusion

Even in the worst case scenario, with a safety margin, the quay walls are cheaper then the cranes.
This case is an example that shows that lighter, more expensive cranes can only be between 1.3% and 1.6% more expensive if quay walls are 2% cheaper due to decreasing crane loads. If the weight reduction costs more, than the total project price will rise.
This chapter will give another cost estimation. The Colombo International Container (CIC) Terminals at Colombo, Sri Lanka is taken. If the costs are known, it became more clear where cuts can be made.

13-1 The CIC terminals

In 2011, private investors and the Sri Lanka Port Authority signed an agreement to build a container terminal at the port of Colombo. The participants are China Merchants Holdings (International) Co., Ltd. (CMHI), Aitken Spence PLC and the Sri Lanka Ports Authority (SLPA). The terminal will have a quay length of 1,200 meters. 12 Ship-to-Shore (STS) cranes are ordered at Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC). Figure 13-1 shows the planned terminal.

13-2 Cranes

The CIC Terminals ordered 12 STS cranes and 40 Rubber Tyred Gantry (RTG) cranes from ZPMC. The total price of this order was $175M. Table 8-4 has shown that for this order, the price per crane in € in 2012 would be €6,48M. This would mean that the total prices for all 12 cranes would be €77,8M. Again, this price need to be converted to a price of 2008 with an annual mark up of 1,5% the price in 2008 would have been €73,3M.

13-3 Quay Walls

The total costs for the civil project is $500M. This includes reclaiming of the land. For the price of the quay walls, the data provided by (de Gijt, 2010) is used.
The terminal will have 1,200 meters quay wall. The depth of the ports is 18 meter, but has an option to be dredged to 20 meters if necessary. Therefore, the same quay wall parameters are used as in the chapter about the Rotterdam World Gateway (RWG) terminals. The total retaining height is 30 meter with a safety margin.

The estimated price of the quay wall is presented in figure 13-1.

### Table 13-1: Calculated costs of quay walls at CIC

<table>
<thead>
<tr>
<th>Quay length (m)</th>
<th>Retaining height (m)</th>
<th>Price met meter (€)</th>
<th>costs (M€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,200</td>
<td>30</td>
<td>50.000</td>
<td>60.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>60.0</strong></td>
</tr>
</tbody>
</table>

### 13-4 Conclusion

Again, the quay walls are more expensive then the cranes. The difference between both is smaller then in the other case. This can have several reasons. For instance the distance between ZPMC and the harbor is much smaller then in the other case.
Part IV

Conclusions and recommandations
14-1 Conclusions

Main research question

- What are the trends in the ship-to-shore container crane market?

The average sizes of Ship-to-Shore (STS) cranes increased. The averages hoist and trolley speeds increased, but were almost stable after 2004. Shanghai Zhenhua Heavy Industry Co., Ltd. (ZPMC) is the main manufacturer of STS cranes. Due to mergers, acquisitions and bankruptcies, the market became from a fragmented market, a market with a few players left. The prices of cranes rise. The main reason for this is the growth of the cranes.

More spreaders have the ability to carry multiple containers. Besides that, the spreaders make a change to electrical controlled spreaders in stead of hydraulic control.

The costs for quay walls is for 2% related to the loads of STS cranes. Heavier cranes could require a new design for the quay walls. This also depends on local conditions.

The cases of the Rotterdam World Gateway (RWG) and Colombo International Container (CIC) terminals showed that the prices of the cranes are probably higher than the prices of the quay walls.

Sub questions

- What are the technical trends in the ship-to-shore container crane market?
To answer this question, 6 parameters of STS cranes are analyzed (Safe Work Load (SWL), outreach, lift height, Hoist speed empty (HSE) Hoist speed loaded (HSL) and trolley speed). The dimension related parameters (i.e. outreach, lift height and SWL) show an increasing line. The parameters related to speed (i.e. HSE, HSL and trolley speed) are increasing in the period 2002-2004, but it seems that this parameters has reached their maximum.

In the year 2010, all parameters showed an depression in their values. This year, the lowest amount of cranes from the researched period was ordered.

- **What is the size of the ship-to-shore container crane market?**

  The main manufacturer of STS cranes is ZPMC. This company has a market share from around 70%. Paceco Licensees and Liebherr are the second en third biggest manufacturers with a market share of 7% and 6%. In 2002, the STS crane market was a quite fragmented market with several small manufacturers. From 2002 to 2012, the amount of manufacturers decreased due to several acquisitions, mergers and bankruptcies.

  In 2002, the amount of cranes ordered was around 200. This increases to nearly 400 in 2008. After that year, the market collapsed with a major depression in 2010. After 2010, the market seems to grow slightly just above the amounts of 2002.

  The most (over 70%) cranes that were ordered between 2002 and 2012 are Super Post Panamax size.

- **What can be found about the costs of ship-to-shore container cranes?**

  Data about the price of STS cranes are very rare. The data that were found show a increase of the price. The price of the cranes per mass unit increases only between 1% and 2% a year. The growth the cranes will be the main cause of the price increase.

  Based on the limited amount of data, a single crane in 2012 would cost around 7M€.

- **What are the trends and developments for spreaders?**

  The spreaders that ordered recently show an increasing demand for spreaders that can be used to lift different size containers. Also there is a growing demand for spreaders that can lift multiple containers in the same lift.

  The control of spreaders has always been done with hydraulics. Manufacturers develop spreaders that are controlled with electrical components. This would reduce leakage caused by the hydraulics and it would reduce the weight of the spreader. The weight reduction will result in a power reduction for the terminals.
What are the trends, developments and costs for quay walls and can the increase in size of ship-to-shore cranes lead to changes in the quay design?

Almost every new order for quay walls requires a new design. This design depends on local conditions. The retaining height of the quay walls are the main driver for the costs of the quay wall. The load by the crane causes only for 2% of the costs.

Due to the increasing size of the container ships, the size of the cranes increases as well. The ships require deeper ports, this results in other more expensive quay walls. So, the price and the design of the quay increases not due to other cranes but due to larger ships.

If the loads by STS cranes would increase enormously, this would probably require an other design of the walls, however, this is not specified.

If ship-to-shore cranes were lighter and quay walls less heavy, would this reduce the total costs of the equipped quay (including the cranes)?

This will only have a small effect. Since the influence of the crane load on the quay wall price is only 2%, the price of the crane can increase with less than 2%. This is probably not possible because the weight reduction have to be significant. This would probably require other materials in the cranes.

14-2 Recommandations

To further improve the results from this assignment, some recommendations are done.

The quality of the data may improve the results. In this assignment, all data of the cranes was found in several World Cargo News editions. It is recommended to check this data at the manufacturers or ask other journals for their records.

The part about spreaders can be a assignment on its own. The spreader market is market were a lot of developments are done. The development discussed in this assignment could be expanded with more sophisticate research on spreaders. The same can be said about the transport. A good introduction is provided, but the transport of cranes is another research on its own.

For quay walls, it can be interesting to look for other references about the issue of the cost of the quay walls related to the crane load. The main conclusions about this subject are based on little diverse references.

The two cases are built on several assumptions. To improve the quality of the cases, the assumptions must be checked at the different parties. The outcome of the cases can be checked as well, this would make the conclusions about that subject more founded.
Anonymous (2012), Interview.


van Kaam, M. (2012), Interview.


World Cargo News July (2010c), ‘Crane market on the way up again’, *World Cargo News* pp. 16 – 18.