Port Congestion

Container Handling

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Management summary

The Maritime symposium of the Rotterdam Mainport University focusses on improvements and innovations that can benefit existing problems experienced in the international sea trading. Of the many possible topics, the topic ‘Port Congestion’ was chosen. It is up to the project group to orientate on the topic, specify the problem and come up with a solution.

The topic of port congestion caused by container handling covers the interaction of the ship with the port that eventually leads to congestion on the sea side of the port, with a focus on the port of Rotterdam. Ports will have to be ready for future developments with cargo volumes, container carrier sizes and customer demand are all increasing in size. This leads to the definition of the problem:

*The port of Rotterdam does not have the means to handle container carriers fast and flexibly to keep up with demand. This causes a bottleneck in the cargo handling chain that will lead to port congestion because the container carriers are still fully dependent on port facilities.*

Which leads to the main question of this research:

*How can the port congestion, caused by container handling, be solved through a technical solution?*

And the following sub questions:

1: *What is the container handling process and were lies the congestion problem?*
2: *What are the general requirements of a new system?*
3: *How can short sea and inland shipping be implemented in a new system?*
4: *In what way can techniques from offshore installations improve the cargo handling in the transport chain?*
5: *In what way can the redesign of the ship improve the cargo handling in the transport chain?*
6: *In what way can container bundling improve the cargo handling in the transport chain?*
7: *What are the advantages and disadvantages of these techniques?*
8: *What is the best new container handling system?*

This research focusses on breaking down the ‘bulk factor’ of the container loads prior to entry of the port. Doing so the container carriers and deep water terminals are not directly dependent on each other in respect to on-time arrival of the carrier and available quay space.

To do so, this research aims at creating a new system, based on other innovative techniques in the maritime sector. Four sectors stand out the most: offshore technologies, special carrier designs, the cargo unit and short-sea shipping.

The best system to tackle port congestion in the ship-shore limit is a redesigned vessel, based on old lash-type vessels. This vessel would use boxes of bundled containers which are placed directly in a short-sea ship by an on board gantry crane.

Some technology, essential for this system, does not exist yet and some topics still require further research but the system suggested would work if the recommendations at the end of this report are followed. The system would then not only offer a solution to port congestion but also offer a platform that is able to gradually grow in conjunction with cargo volumes, container carrier sizes and customer demand all steadily increasing in size.
Preface

The topic turned out to be what we thought it would be: challenging but very interesting. From the beginning to the end, this project pushed us to think just that little further ahead.

In the early stages of data gathering and brainstorming about possible ways to solve port congestion it was hard for us to stay realistic about feasible systems. It was remarkable that in the process of specifically defining how the system would work and what technological innovations could be used, it was exactly the other way around. New ideas would sometimes be rejected just a little too soon. This was when we had to say: “what we have might not be the perfect solution, but it is definitely a step forward and if we work it out correctly, maybe it could be feasible in the near future”. Moments like that, teach that there is always a middle way between being over enthusiastic and nearly having tunnel vision and just continuously looking at the negative side and wanting to condemn every idea.

We were privileged to have an interview with Mr. Orgers who, with his expertise, answered nearly all our questions and helped us getting an idea about the processes on container terminals by taking us to the APM Terminal. This, in combination with help from teachers, our project principal and our project manager ensured that we looked at the problem from the right angle.

Keeping an eye on what exactly was the problem was sometimes quite challenging. This was shown when the biggest part of a chapter of research about a possible solution was eventually rejected as “just moving the problem”. For helping us with this, and delivering a constant flow of feedback, we want to thank our project managers Mrs van der Drift and Mr van Kluijven and our principal Mr Weeke.

We are proud of the results and the conclusion the research led us to and we hope you will find reading this report just as interesting as it was making it.

Rotterdam, March 30th 2015

Project group 7

Denise Caron  Jop Vermeer
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1. Introduction

Background information

The Maritime symposium of the Rotterdam Mainport University will be held again this year. This symposium focusses on developments in improvement and innovations that can benefit existing problems experienced in the international sea trading. Of the many possible topics we have chosen the topic ‘Port Congestion’. This topic covers the interaction of the ship with the port that eventually leads to the congestion of the port. It is up to the project group to orientate on the topic, specify the problem and come up with a solution.

Project name: Port Congestion
Client: Mr van Kluijven, Mrs van der Drift and Mr Weeke
Contractor: Denise Caron, Jop Vermeer, Guillaume Nijssen and Remi van Doorn
The Stakeholders: The Port of Rotterdam, container terminals, consignees and ship owners.

Problem description

Rotterdam, Europe’s biggest container port (Port of Rotterdam, 2013), will have to be ready for future developments to stay the most attractive port to container carriers. This means the port has to face the problems that will arise with cargo volumes, container carrier sizes and customer demand all increasing in size.

In spite of its modern container handling on the terminal, the port will face some big problems in the future with the loading and unloading of the container carriers. The usage of the container as a cargo unit has been on the rise since 1970 leading to a total of 11.6 million handled TEU containers in 2013 (Port of Rotterdam, z.d.). The sheer number of handled containers underline the importance of having a streamlined container handling process.

Port congestion has played, and is going to play a major role in the Port of Rotterdam (Portstrategy, 2014). Seeing that the port of Hamburg can also handle container carriers up to 18,000 TEU, and the ports of Antwerp and Felixstowe are also on the rise (Markus, N., 2013), big container carriers now have attractive alternatives instead of waiting in queue at the port of Rotterdam. Container carriers waiting in queue or in the port will cost the ship owner a great amount of money without moving any cargo.

Container ports are complex pieces of infrastructure hosting a broad number of activities besides container loading and unloading, e.g., mending, pilotage, tugging, etc. With container cargo being a major part of today’s transport means and container carriers still increasing in size, one delayed ship can now disrupt the entire port schedule and thus congesting it due to the inflexibility of the port (Wackett, M., 2014). This inflexibility is the effect of container terminals only being able to handle a couple of big carriers at a time and the time schedules being made months in advance.

Expanding the port (Maasvlakte 1,2,(3)) will only be a temporary solution because transportation of various goods through containers is still on the rise and container carriers are still dependent on the ports for loading and unloading their cargo. The container carriers increasing in size will also be a
A problem for the cranes (Joc.com, z.d.), they will not be able to keep up with the growth of the carriers due to their limited height and capability.

The port of Rotterdam has to come up with solutions to the port congestion to stay the most important and flexible European container port. Possible solutions, beside logistical solutions inside the port, can be found in two categories: complete redesign of the carrier or the usage of techniques derived from other sectors, for example: offshore installations such as a Spud-system, floating docks or ship-ship container handling.

**Problem definition**

The port of Rotterdam does not have the means to handle container carriers fast and flexible to keep up with demand. This causes a bottleneck in the cargo handling chain that will lead to port congestion because the container carriers are still fully depended on the port.

**Definition of end objective**

Solving port congestion caused by container handling through a technical solution.

**Main question**

How can the port congestion, caused by container handling, be solved through a technical solution?

**Sub Questions**

**Sub question 1:** What is the container handling process and were lies the congestion problem?

**Sub question 2:** What are the general requirements of a new system?

**Sub question 3:** How can short sea and inland shipping be implemented in a new system?

**Sub question 4:** In what way can techniques from offshore installations improve the cargo handling in the transport chain?

**Sub question 5:** In what way can the redesign of the ship improve the cargo handling in the transport chain?

**Sub question 6:** In what way can container bundling improve the cargo handling in the transport chain?

**Sub question 7:** What are the advantages and disadvantages of these techniques?

**Sub question 8:** What is the best new container handling system?

Research methods per sub question are described in appendix II.
**Project Borders**

Project start date: Tuesday September 2, 2014  
Project end date: Week 5, 2015

From research done in the Orientation Phase the project group has learned that container handling, from ship to shore and from shore to ship, causes the biggest congestion problem. Within the topic of Port Congestion the project group will only research the problem of the container handling process. Possible solutions have to be found within the ship-shore, shore-ship, ship-ship or ship-platform limits or in a new carrier design. This means the project group will not look at logistical solutions within the port.

The port of Rotterdam is only taken as an example. This is done because the Rotterdam Mainport University, that facilitates this research, is located within the port of Rotterdam. This ensures accessible and accurate information because the port of Rotterdam is a familiar environment for the project members. Port congestion will play a major role in the global trade. This means that not only the Port of Rotterdam will be affected by this problem, but all the ports worldwide will be affected.

The solution lies in innovative technical systems. The project group will not completely design these systems in detail. Sketches and ideas will be explained and structural limits will be calculated. The members of the project group are not marine builders. The project members will make sure they understand these systems and can explain the working of them.

Furthermore, this project was time bound. The project has to be finished before: week 5, 2015. This does not leave room for detours from the specified topic; Port Congestion caused by problems with container handling. The goal is to answer the main question and all the sub questions. These measures will be taken to stay within the given time for this project.

**Structure**

The current process and the congestion problem is described in chapter 2. Investigating the current situation showed were improvements could be made. These possible points of improvement were translated in general requirements for a new system as shown in chapter 3. The research to sectors that could aid to meeting these requirements is presented in the chapters 4, 5, 6 and seven with the respective subjects of estuary shipping, offshore systems, redesigned carrier systems and the cargo unit. All the advantages and disadvantages of these techniques are listed in chapter 8. This, in combination with the data-matrix in appendix III, led to the new system explained in chapter 9 and the conclusion and recommendations in chapter 10.
2. Container handling process and the congestion problem

What is the container handling process and were lies the congestion problem?
This question will be answered by desk research and an interview with Mr Orgers which can be found in appendix I. More details on the research methods can be found in appendix II.

The history of the container handling, the container handling process from ship to shore and shore to ship, equipment used in this process and facts and figures will be discussed in this chapter. To give an idea of the enormous increase in the worldwide container business, some important facts and dates will be mentioned in a brief history of the container as a cargo unit.

History

In 1966 container transport was a hot topic around the world. But the history of the container handling begins in Canada around 1952. The Canadian National Railway, Traffic Services and companies like Montréal and White Pass & Yukon, began transporting their cargo in containers.

In 1955 White Pass & Yukon introduced the world’s first container vessel: the MV Clifford J. Rogers. The vessel was built in Montréal. In 1963 CN Express used the 20 feet container system. The first of three container vessels, that could carry up to 500 20 feet containers, began as a service line between Manchester and Montréal, Manchester liners, in 1968. The first container vessel that arrived in Rotterdam in 1966 discharged 35 feet containers.

Container transport was a big development. It was such a success because the container could travel by rail, road and sea and break-bulk could be transported in one standardized cargo unit.

A development also took place in the size of the containers. The original containers were different than the standardized 20 feet and 40 feet equivalent units today. The container dimension were modest in the early days. The containers used in Canadian services by CN in 1953 began as 3’x 2’6” containers. In 1953 White & Yukon also introduced a 8’x 8’x 7’ container.

In 1958 CN had a container of 10’x 6’4”x 8’ and with a big jump in size, White & Yukon had container of 25’x 8’x 8’. But these containers were not suitable for international trade because of their variable dimensions. International trade required a “standardized” container.

The Committee for standardization of freight Containers, later known as the ICS, decided for the dimensions most commonly used today. (Hunter, P., 1993)

20 ft container: 20’x 8’x 8’6” (6,1 x 2,4 x 2,6 m) (= 1 TUE)
40 ft container: 40’x 8’x 8’6” (12,2 x 2,4 x 2,6 m) (= 1 FUE) (Stella Containers Logistics, 2014) (ECT, z.d.)

Ship-shore, shore-ship process

Nowadays the port of Rotterdam is the 4th biggest container port of the world. Because the port of Rotterdam is so big, a lot of different vessels arrive each day. The large amount of vessels that enter the port of Rotterdam every day require a good overall organisation and planning. This is most notable in container transport.

The container transport chain is a very streamlined transport chain. This is what makes it so attractive for businesses around the world. To make this chain so streamlined it requires an even more detailed approach to planning. The smallest problem can disrupt the entire schedule.
The problem here is that this container transport chain is reliable on the carriers that transport the containers oversea. And this is a part of the chain where a lot of variables come in to play that can disrupt the entire container transport chain.

The current process of unloading containers

- Vessel approaches the port
- The vessel is waiting for the pilotage
- The pilot will guide the ship into the port
- The vessel arrives at the shore
- The vessel needs to be moored
- The cranes are placed over the vessel
- The containers will be unloaded.
- *The container will be placed on a straddle carrier or an AGV (automatic guided vehicle)*
- *The container will be brought to his holding place*
- *The container will be picked up and will be brought to the next transporter.*

The last three points are written in italics because these process actions are outside the project borders. And of course, entering a port to load and unload some containers comes with the mandatory paperwork and security hazards.

Every year approximately 30,000 (Port of Rotterdam, w.-d.) vessels arrive in the port of Rotterdam. From these 30,000 vessels a large percentage will be delayed due to multiple factors in the last port of call or underway.

These factors include:

- Delays in the loading of cargo
- Pilotage unavailable at port of loading
- Emergency situations underway
- Rerouting to evade active piracy
- Adverse weather underway
- Technical problems underway
- Pilotage unavailable of destination

These variable delay factors will lead to an arrival outside the marges of the agreed estimated time of arrival. For example; Maersk Line is currently leading with 85% of her carriers arriving on the scheduled time, according to the interview with Gerrit Orgers from APM Terminals, which can be found in appendix I. This brings the biggest problem at light; unavailable berthing place.

Due to the ever increasing size of the container carriers, they are already limited to a couple of deep water terminals. In Rotterdam there are only 3 deepwater terminals that can handle the current 18,000+ size container carriers. According to the interview with Mr. Orgers from APM Terminals, which can be found in appendix I, the different terminals in Rotterdam are already working together to facilitate all the container carriers as good as possible. These are the APM, Euromax and ECT terminals. This means the available berthing place is already limited and the terminal also has to work with constantly delayed carriers.
Gantry cranes

As the container carriers become bigger and bigger, they have the capability to carry much more cargo than before. Naturally, it also takes longer to load and unload such a vessel. Most of the ports are using gantry cranes as seen in figure 1. These cranes can be made in a single lift and a twin lift version. These cranes are limited by height (wind), reach (current carriers are 60 meters wide) and handling capacity.

![Gantry cranes](image)

As an example: the time it takes for an 18,000+ TEU class carrier to load from empty to fully laden: The Maersk Mc-Kinney Møller has a load capacity of 18,270 TUE. This number is made up of TEU, FEU and otherwise dimensioned containers. For this calculation it will be assumed that there are 9135 containers of 40 foot. According to the interview with Mr. Orgers from APM Terminals, which can be found in appendix I, the capacity of a Single Lift gantry crane is about 29 containers per hour. This will mean a total load time of 53 hours. This situation rarely happens but when looking at partial loads, for example 5000 moves, it will still cost 28 hours when 6 cranes are used to handle one ship.

This is the time it takes to unload a vessel without taking into account the time for mooring, administration, port regulations and security situations and using an ideal load situation. This means the whole process of handling a carrier at a land based terminal will take a lot of time, too much time. (Kocks, z.d.) (McCarthy, P.W. & Jordan, M.A., z.d.)

Delayed carriers

The duration of the process is a problem for the terminal itself but even more so for the vessel and its ship operator. If one ship is severely delayed, it is possible that its berthing place at the terminal will be granted to another carrier that is ready to be handled.

A container carrier is designed to move cargo around the world for the vessel to be profitable for the shipowner. If the carrier has to wait at the port until its berthing place is free it will cost the shipowner a great amount of money without moving any cargo. The ideal situation for the shipowner would be that the carrier would not be bound to go into a port and berth alongside a quay, to load and unload its cargo. This would also relieve the big deepwater terminals.

If the shortage of berthing spaces could be resolved in cooperation with the terminal everyone involved in the transportation chain, from consignor to consignee, would benefit. The most obvious approach would be to tackle the delays a carrier could face underway. This however falls outside the borders of the project. That is why the different parties involved in the shipping have to come up with a fitting solution to the problem, described in the problem description, that faces the situation as described above.

The main goal of a new system must break down the bulk factor of the container load into smaller groups prior to entry of the port. Doing this, the containers can be handled by a larger number of terminals, thus relieving the terminals and providing more quay space for ship-shore cargo handling.
This approach has numerous advantages:

- The terminals does not have to facilitate the enormous container carriers
  This means more cargo can be fitted in the space that was previously claimed by the vessel carrying the cargo.

- The cargo can be spread among a larger number of (smaller) terminals
  Doing so, a very busy terminal that has no room for the incoming cargo will be able to redirect the handling process to other terminals. The container carriers themselves will not have to rely on one terminal that has a berthing place planned for it because its cargo can be handled by numerous terminals.

- The terminal only has to make room for cargo that will be handled by Rotterdam
  Previously the Port had to facilitate not only the cargo that would be handled by Rotterdam, but also for other ports. If an 18,000+ TEU vessel berths in the port, maybe only 3000 containers will be handled by Rotterdam. The rest will only take up quay space.

- The container carriers do not have to enter the port itself

The objective is not to design a system that takes the current deep water terminals out of the process. The current terminals are state of the art and can handle container carriers relatively fast but have some important flaws. It would be preferable, and likely unavoidable, to integrate the existing terminal system into the new system.

To implement such a system, the terminals should cooperate with short sea and inland shipping (estuary shipping) to make the Port of Rotterdam partially a ‘hub’ for transferring cargo from big carriers to smaller carriers.
3. General requirements of a new system

What are the general requirements of a new system? This question will be answered by desk research. More details on the research methods can be found in appendix II.

From the research conducted for the problem description and for sub question 1; What is the container handling process and were lies the congestion problem?

The following was concluded:

The big container carriers can currently only be handled by the largest and deepest terminals in Rotterdam, for example the APM, ECT and Euromax terminals. If one of these carriers is late, the entire planning of this terminal is ruined as stated earlier.

This means a solution should realise the following:

- To relief the port and to save time for the carrier, the loading and unloading process of the carrier has to be taken outside of the port.

- To relief the biggest container terminals, a new system should be able to break down the bulk factor of the container load in to smaller groups prior to entry of the port. Doing this, the containers can be handled by a larger number of terminals.

- A new system should be able to react to delayed container carriers.

- To realise a realistic implementation process, a new system should be able to work in cooperation with the current process.

With all of the above in mind, the use of two separate innovative systems seemed the best solution, this unless further research proved otherwise; an offshore system and a redesigned container carrier.

The two systems

- A new carrier design that will realise a new, more flexible and fast cargo handling process.

- A new offshore system that will act as a backup system for the port to react to delayed carriers.

To come up with a new carrier design and a new offshore system three sectors that are relevant to the issue of taking the container handling process outside the port will be looked at.

- Estuary shipping
  A system that takes the cargo handling process outside the port will rely on short sea or inland (estuary) shipping to further distribute the containers.

- Offshore
  Very innovative and problem solving techniques are already being used in the offshore sector. These new and innovative solutions used in the offshore sector are used to find inspiration for a new system.
• Redesign of the ship
  For the new design of the carrier the focus will be special vessels that are being used today or where used in the past decennia to handle cargo, it is expected that inspiration for a new vessel will be found in abundance.

With the all the research done for the problem description and for sub question 1, the conclusion was that it would also be wise to look at the cargo unit itself. This adds one more sector that is relevant to the issue:

• Cargo unit
  Improvements to the cargo handling process could be made by improving the cargo unit itself.

The research of, or orientation on, the different sectors are described in the order as listed above.
4. Estuary shipping

How can short sea and inland shipping be implemented in a new system?
This question will be answered by desk research. More details on the research methods can be found in appendix II.

The direct implementation of short sea ships or barges into the system will be needed to load and unload a ship outside of the port to:

- Supply the offshore system or carrier with cargo to be loaded on the carrier
- Transport the cargo unloaded from the container carrier by the offshore system or by the carrier itself.

These short sea ships or barges are able to transport the cargo to other terminals than those which are specifically designed for post-panama container carriers. Seeing there are a lot more of these smaller terminals, the handling of the cargo will not be a problem.

A vessel which can sail in plain seas as well as in inland waterways must possess a certificate of registry and a certificate of soundness. The certificate of soundness is intended to sea-going vessels, when in possession of this certificate it is allowed to sail the totality of the EEG areas, those so called EEG areas are allowed to be used by the Dutch government in for economic purposes. The certificate of soundness is handed out after the inspection of the vessel in question, this certificate confirms that the vessel can sail safely in EEG areas.

The vessels which hold a certificate of soundness are pilot compulsory unless mentioned otherwise. The above mentioned legislation is compulsory for vessels of Dutch origin and vessels sailing through Dutch territorial waters. (Bergsma, H. & Reem, R. van., 2013) (FOD, 2013)

Figure 2 Estuary shipping

The Dutch law makes a separation between sea going vessels and inland vessels according to the Dutch codes for Shipping:

“In Articles 2 and 3 of Book 8, a distinction is made between seagoing vessels, fishermen boats and barges.

Sea going vessels: ships and ship to be known in the public registers referred to in Section 2 of Title 1 of Book 3, and the ships not recorded in the registers and, according to their construction solely or primarily intended for floating in sea.

Inland vessels: ships and barges to be known in the public registers referred to in Section 2 of Title 1 of Book 3, and the ships not recorded in the registers and, according to their construction neither exclusively nor chiefly for floating in sea intended.” (Overheid, 2014)
The operating of vessels in the area that is the transition between inland waters and plain sea is called ‘Estuary shipping’. This is possible with strengthened vessel that comply with certain demands. Such a vessel is seen in figure 2. So it is possible for vessels to pick up container cargo just outside of the port to return to a terminal within the port as long as certain demands are met.

Implementation of this form of shipping in the new system is explained in chapter 9.
5. Offshore sector

In what way can techniques from offshore installations improve the cargo handling in the transport chain? This question will be answered by desk research and the offshore fare. More details on the research methods can be found in appendix II.

The inflexibility of the port causes most of the Port Congestion. In this chapter the techniques in the offshore sector that could benefit from a new system that will act as a backup system for the port to react to delayed carriers will be looked at. This will make the availability of cargo handling equipment much more flexible.

By using, and maybe combining, some of the techniques being used in the offshore industry the number of options on how to handle a container carrier greatly improves. Most of the techniques in the offshore sector focus on one specific problem to provide the best possible system for that job. Combining some of these techniques will most likely lead to a new offshore system.

The techniques that are being used in the offshore sector that relate to the topic of this project, and could possibly aid a new offshore system, where categorized in 4 categories:

- Spud legs
- Motion stabilizers
- Floating docks
- Offshore platforms

An exploratory desk research was conducted to each separate category. The possibilities and requirements of a new system are listed afterwards.
Spud legs

Description
Spud leg systems are used on board of specialized floating units such as crane barges, pontoons, self-elevating offshore units, platform supply vessels, diving support vessels and other specialized crafts. A spud system consist of one or more ‘legs’ mounted on the vessel (DLS, 2014) as seen in figure 3. When the vessel is in the desired position it lowers the spud legs onto or into the ground to fixate the vessel in that position.

If only one spud leg is being used the vessel will still heave and yaw due to weather and sea. But it will not make other movements. 
If two spud legs are being used the vessel will still heave due to weather and sea but it will not yaw or make other movements. 
To make a completely stable offshore platform the vessel has to be equipped with an elevating system combined with the spud legs. This systems places the bottom of the spud legs on the seabed and jacks the vessel out of the water. This way the vessel rises above the waves and is fixated in the ground.

![Figure 3 Spud leg system](image)

Implementation
When the handling of cargo will take place outside of the port it is important that the system handling this cargo is stable enough to make it possible to operate cranes and move heavy cargo units. The Spud leg technique is very usable to make such a stable platform. 
This system however is only suitable for shallow waters. If the implementation of this technique in a new system is planned, research to the working water depths has to be done.
Motion stabilizers

Description
Weather influence is a major factor when loading and discharging outside the port, a standard floating crane encounters difficulty with waves cresting at 30 centimetres (Bosch Rexroth, 2013). Safe crane operation cannot be guaranteed beyond this point. Therefore, when loading and discharging is taking place in plain sea, the motion of the vessel needs to be compensated.

The motions that need to be compensated are:

- Swaying
- Yawning
- Rolling
- Pitching
- Heaving
- Surging

The motion compensating platform relies on sensors which deliver motion data to a central system. This system calculates the platform movement needed in order to compensate for the motion of the vessel caused by the waves. Three degrees of freedom (heave, roll and pitch) are compensated by three hydraulic cylinders, which connect the platform and hull of the ship (Bosch Rexroth, 2013).

Implementation
The system seen above in figure 4, (a motion compensating platform designed by Barge Master and Bosch Rexroth) has a broad number of applications. It is able to carry cranes with a weight up to approximately 400 tons (Bosch Rexroth, 2013) and compensates 95% (MarineLink.com, 2012) of the vessel’s movement. With the aid of this system the application window in which floating cranes can be operated safely is extended. Because of the broad number of applications this system is highly flexible; it can not only be used in combination with a container crane but also with bulk cargo cranes.

Figure 4 Motion stabilizer
**Floating berthing place**

**Description**
A floating dry dock is used for dry docking ships as seen in figure 5. For doing so it relies on a ballast system to rise and lower the dock. When the deck is submerged a ship can be moved in. To make it a ‘dry’ dock the dock rises again to lift the ship out of the water.

The dock normally has a U – shaped cross section whereby the wall gives the dock stability and strength when the deck is below the surface of the water.

A typical floating dry dock involves multiple rectangular sections. These sections can be combined to handle ships of various lengths, and the sections themselves can come in different dimensions. The largest floating dry dock nowadays is 350m in length. The addition of a bow section can facilitate the towing of the dry dock once assembled. Under keel clearance will be of great importance with this technique.

**Implementation**
It is not the aim of the project to raise the container carrier out of the water in any way. This means the ballast system has no value to this project but a floating dock that does not have the capability of raising a vessel out of the water will provide a reliable platform that:

- Protects the vessel from wind an sea conditions to a certain level
- Offers room for the installation of cranes and other equipment to handle containers

A floating dock also provides flexibility, because it is made up of multiple sections which can be combined to facilitate a ship of nearly any dimension.
This means a floating dock will provide a reliable platform for any cargo handling system as long as a technique to keep the dock in one position is used such as the techniques described in the chapter ‘Position fixation’.

![Figure 3 Floating dock](construction_photography.png)
Offshore platforms

Description
An offshore platform is any platform that is fixed to the seabed by a rigid connection or some form of anchoring as seen in figure 6. It can be used for numerous application such as a platform for oil drilling installations and research operations.

Implementation
An offshore platform as described above offers the most stable platform and the most opportunities for installing cranes, berthing equipment and other systems. The disadvantage of this system is that it lacks any type of flexibility in its positioning, installation is very expensive and placing an offshore platform in front of the port will obstruct marine traffic.

Flexibility is a big factor in a solution for port congestion. This is why an inflexible installation like an offshore platform is not likely to be very usable. If implemented, and positioned, correctly it could provide a fast way of handling cargo in combination with the TEU boxes.
6. Redesign of the container carrier

In what way can the redesign of the ship improve the cargo handling in the transport chain? This question will be answered by desk research and an interview with Mr Orgers. More details on the research methods can be found in appendix II.

There are a lot of ways to improve the vessel's design to realise a more flexible cargo handling process. For example by changing the shape of a vessel, the way a vessel will be loaded or unloaded but also the shapes of the holds.

To start the research for the redesign of a carrier, the focus will lie with special vessel designs used for variable purposes in the past decennia, that could be beneficial to improve the container handling process and aid in meeting the general requirements.

The type of vessels described in this chapter are:

- LASH vessels
- BACAT vessels
- Rail - ship combinations
- Semi submergible vessels
LASH type loading/unloading

Description

LASH-vessels or Lighter Aboard Ship vessels are single-decked vessels with large hatches and a clear access to the stern as seen in figure 7. This is necessary to load and unload the barges. Barges are watertight boxes which are loaded with cargo. These barges cannot operate on their own. The barges used for LASH vessel had a carrying capacity of 340 MTON and had a draft of 2.4m shown in figure 8. The loading and unloading of the barges was done using the crane installed on the vessel. The barges were then transported to their intended position or to other cargo vessels waiting for their cargo load. A LASH-vessels can load or unload three to four barges in one hour. (global security, 2000-2014)

The LASH-vessels were introduced around 1960 to keep up with the requirements of container transport. The usage of containerised cargo was blossoming at that point of time. The first LASH vessel was built in 1969 for Central Gulf Lines. The design was problematic in rough weather and the workers were unfamiliar with the technologies. The cost of building these vessels was higher than the cost of a traditional container carrier. This caused the container carriers to dominate the LASH-vessels in the rapidly expanding container cargo industry (Blume, K.J., 2012). Container shipping is constantly improving and thus the lash-vessel quickly became obsolete. (Talleur, K.C., 2013)

Implementation

It will be possible to breathe new life into the LASH-vessel concept if a few conditions are met:

- LASH-vessels need to be built/improved;
- Barges need to be built/improved;
- Container carriers need to be able to jettison their cargo;
- Crew needs special training to use the technologies on board;
- It is totally dependent on short sea shipping for transporting the cargo from and to the vessel.

Further research is needed to be able to determine if LASH-vessels are a more efficient alternative for container handling. It could be considered as a backup system or as a ‘revolution’ in container shipping.
Barge aboard catamaran

Description
A barge aboard catamaran (BACAT) vessel is primarily a catamaran structure with two hulls (unknown author, z.d.) as seen in figure 9. The cargo, consisting of floating standardized barges is carried between the 2 hulls. A vessel of this type has been in use between 1977 and 1983 by the Mackinnon, Mackenzie & Company (Private) Ltd (P&O Heritage, 2010). This system used small lash type barges, loaded between the hulls and on top of the weather deck (TRB, 2014).

This vessel has a fixed, streamlined bow and the space between the hulls can only be reached from the stern side. The BACAT principle has never been implemented on a large scale because it was a ‘niche’ vessel and there was not enough interest in the system at the time (BIMCO, 2013). It was never build in great numbers. Nowadays the demands in the transport chain are so high that interest for new, or renewed, ideas has grown again to tackle current and future port congestion problems.

The barges itself need to hold a large amount of TEU to minimize the amount of handlings taking place when unloading the vessel and to provide stability to the ship and the barges itself.

Implementation
If implemented again in a new form, this system should be able to keep the big container carriers out of the port. This means that barges should be loaded with containers bundled for an specific port or region. Doing this you only bring the cargo that needs to be handled by Rotterdam to the port itself. This reliefs the port because only the barges will ‘berth’ at the terminals and not the oversized current day container carriers. This means a reduced need of berthing place because only the cargo destined for a specific port or region will be handled. This saved berthing space could be used as a backup space for carriers running late.

The carrier itself will eventually profit the most of this system. It does not have to berth in a port. This saves money on:

- Towage service (only the barge has to be towed)
- Pilot service
- Other port costs

And the most important advantage for the carrier itself is that it can load and unload without the need to berth in a port. It could use a anchor, a dynamic positioning system with azipods or a spud system to keep the vessel in one position. This saves a lot of time as it will be able to load and unload a number of barges and then immediately sail on.
The barges will be berthed alongside the gantry cranes like a normal carrier and the cranes will unload and load the barge. This barge will then wait in a special holding area for the next BACAT vessel.

Due to the 2 hulls and barges between the hull, the vessel will have a lot of water resistance. This will lead to a high fuel consumption. To make this system cost effective, the capacity of the ship has to be large. The vessel could also use a moveable bow section to give room for cargo handling and provide a streamlined stem when moving. The barges itself also need to hold a large amount of TEU to minimize the amount of handlings taking place and to provide stability to the ship.

These barges will be so large that a normal locking system will not stand. For this problem the vessel will be equipped with a lot of ballast volume. By using this ballast system the carrier can be lowered onto the barges so they will be held in place by the floatation force directed upwards and the weight of the carrier.

**Rail-ship combination**

**Description**

In the port a lot of time will be lost in the loading and unloading of a vessel. As said before, a container carrier in berth costs money without moving cargo. Nowadays a lot of actions need to be done before the container has been transported from the vessel onto the shore and onto next carrier. This costs too much time. By taking out some actions it is possible to speed up this process and make the cargo handling shorter.

**History**

In the year of 1820 the first plans were made up for using a railway for the transport of cargo. These systems were very important for the industrial revolution and the connections across the world. The railroad transportation increased to high levels. In the beginning in 1830 the total length of the railroads in the USA was 40 miles. In 1916 the total length of the railroads was already 254,000 miles. The transport by railroad is still growing and it is a good way of transporting cargo, now and in the future.

**Implementation**

A good system to improve the cargo handling process is to combine the use of trains and ships as seen in figure 10. The expectations for the next 10 years are that rail freight transport will increase with 2.4% globally each (Arntz, A.K., 2014). The Dutch government intends to invest €4.5 billion euro’s in the railway system. (De nationale transportgids, 2014)

The idea is to design a Ro-Ro ship where trains, including the cargo, can be parked in the vessel. This could speed up the loading and unloading process significantly. When the vessel has arrived in the port two ramps will be attached at the new vessel, one at the front and one at the back. The vessel can be equipped with big doors to open the main hold. In the vessel, but also on the ramps, tracks will be attached so a locomotive with a train of containers is able to ride into the vessel and leave the cargo behind. The cargo will be transported on the coach, in the ship.
Semi-Sub vessels

Description

Semi-submersible vessels are vessels which, as the name indicates, are able to submerge themselves partly to load and unload their cargoes as seen in figure 11. The vessel submerges by filling up the ballast tanks, cargo is than towed onto the submerged deck. The vessel empties it’s ballast tanks to float again. The semi-sub ship is used to carry large and heavy equipment (oil drilling rigs, other vessels etc.).

The big disadvantage of these so called semi-subs is that they cannot operate in bad weather conditions because of the precision required to load or unload the cargo. The seize of the cargo that is to be transported also has a role in the operating window of the vessel.

Implementation

The idea is to implement the semi-submersible concept to container shipping. Instead of loading containers onto the ship with the traditional crane, the ship will submerge and a barge loaded with container will be towed/pushed onto the vessel.

In contrast with the semi-sub as it is known today, the new container carrier should have a more “traditional” hull: the containers will be loaded through the stem of the ship. The stem of will be lifted upwards with the aid of hydraulic cylinders and then locker into place, the aviation industry already uses this as a hatch to load and unload a plane. The ship will then fill it’s ballast tanks and submerge, the afloat containers will be positioned in front of the ship and then pushed in by tugs. When the ship is loaded the ballast tanks will emptied, the vessel will then come to float. The stem will be closed and then locked with a hydraulic lock.

During the unloading of the cargo, the process is nearly the same as the loading process. While loading and unloading the vessel will stay in place with a dynamic positioning system or anchors. To make sure that the vessel has enough abeam strength the hold will be fitted with bulkheads.
7. The cargo unit

In what way can container bundling improve the cargo handling in the transport chain? This question will be answered by desk research and the interview with Mr Orgers, which can be found in appendix I. More details on the research methods can be found in appendix II.

Description

Cargo bundling
Besides looking at a new system or design of the vessel, the cargo unit itself was also a possible point of improvement.

It is a must to ensure that the port will not congest by handling cargo faster, smarter or outside the port. Besides looking at a new system or redesign of the vessel, another possibility to achieve better cargo handling, is changing the cargo units itself. These cargo units are now made up of TEU and FEU standardized containers.

What was interesting when looking at the history of the current container units was the following. First the cargo units existed of the separate collies or boxes that needed to be transported. Later these boxes where bundled on (standardized) pallets. And since 1966 those pallets where bundled within standardised containers.

With the numbers of containers being handled nowadays, it is interesting again to look at the cargo unit development. For example; a random 18,000 TEU container carrier needs to unload 2000 containers and load 1500 containers. When handling such enormous numbers it is absurd to handle one or two units at a time.

The solution to this problem is making standardized container boxes that bundle multiple containers.

Implementation

Overview
To make a system that uses these boxes work, detailed planning is needed.

A system that uses these boxes will not be suitable for last minute container shipping. The system would work like this:

When implementing the container box system, the boxes will be distributed among the ports cooperating with this system.

The boxes will be planned in advance to go to a single port that serves its hinterland and surrounding smaller ports. These boxes will wait in the port until they are (almost) full. The more containers a box contains, the cheaper the transport cost will be for each individual container.

A liner container carrier with holds suitable for container boxes will keep a standardized schedule between its port of departure, its destination and all ports between those two ports.

The liner will pick up the fully laden boxes and bring them to their port of destination.

This means it will take longer for the container to be transported but it will cost less for the consignor because of the effective handling, the lack of port costs by the carrier and the time saved by the absence of mooring, waiting in queue, pilot embarkation e.g.
In the port
Within the port a small container terminal is able to handle the container boxes. Inland vessels bring containers to the terminal where they are loaded in the box with the corresponding destination.

When the container carrier arrives just outside the port, a short sea vessel will transport the box to the carrier where it will be loaded on board. Meanwhile a different short sea vessel is transporting the boxes unloaded from the carrier to a container terminal.

In the terminal, the container will be unloaded from the box to be transported inland by train, truck or an inland vessel.

Example:
When using 18,000 TEU carrier dimensions:

Approximately 400 meters in length, 60 meters wide and 19 TEU stacked (hold and deck).

1 TEU = 6.1x2.44x2.59 meters and weighs max 27 ton.

Container box
Without box thickness and/or weight:

1 Box:  L: 4 TEU= 24.4 meters  
         B:3 TEU = 7.32 meters  
         H:4 TEU= 10.36 meters

3x3x3 TEU = 27 TEU
27 TEU x 27 ton = 729 ton.

If the box has a thickness of 20 cm and weighs 60 ton:

1 Box:  L: 3 TEU= 18.7 meter  
         B:3 TEU = 7.72 meter  
         H:3TEU = 8.17 meter

3x3x3 TEU = 27 TEU
27 TEU x 27 ton + box = 800 ton.

The weight of these boxes is a big factor in loading and unloading them.

Remarks:

- If these dimensions will be used for the TEU boxes, the current design of a carrier will not have to change much.
- A inland vessel is capable of handling these dimensions and the weight.
- These units can be combined with offshore and redesign of the ship.
- These boxes are not meant to float.
- Each box will have a power connection for reefer containers.

This concept improves the handling of cargo in different manners, but it comes with a number of problems which need to be solved.
Improvements in respect to using single containers:

- Fewer movements are needed when handling a carrier which results in faster handling.
- The box combines cargo for a specific destination, inland vessel or terminal.
- The option for the terminals to prepare container boxes based on demand/order.
  The preparing of these boxed will cost time and money, this will result in higher transport costs. But the ship will be berthed for a shorter time. This will save a lot of money. Because of this, costs of transport are not likely to increase.
- These boxes can be made to fit inside an inland vessel. This streamlines the transport chain significantly. If the container boxes can be loaded directly from the container carrier on an inland vessel or short sea vessel it drastically decreases the amount of handlings per container.

The difficulties that have to be faced with this concept are:

- The weight of the whole bundle, seeing one TEU weighs approximately 27 tons, these container boxes will be very heavy. This means heavy cranes or overhead cranes will be needed to handle these boxes.
- The box, which bundles the containers together, will also take up space on board the container carrier. In the shipping business or any other business in which the transportation of cargo plays a major role it is crucial that every last cubic meter of cargo space on board a carrier is utilised. When using separate containers this is easy. When on shore they move individually or in small groups by train or boat. So when a container is ready to be shipped it is easy to bring it to a terminal on a short notice and ship it with the first available container carrier. This is not the case with this new concept.
- This can be limited to a small amount of space by precisely calculating the necessary strength of such a box.
- The flexibility of separate containers is taken away. This is because a box will only be profitable when it is (almost) fully laden. This will mean that an individual container will have to wait in a container box until it is fully laden and thus ready for shipment.
- It will be hard to work with IMDG containers. IMDG cargo has to be easily accessible in the event of fire or other calamity’s. Some IMDG cargo combinations also have separate rules as to where to place them in respect of each other. These include:
  - 3 meters apart from each other
  - 6 meters apart from each other
  - separated by a bulkhead

  The combination of accessibility and separation is not achievable when using bundled container boxes per port.
8. Advantages and disadvantages

What are the advantages and disadvantages of these techniques? This question will be answered by desk research. More details on the research methods can be found in appendix II.

All the advantages and disadvantages of each separate technique have been listed below. These facts will be used when deciding on the design of a new system. After listing these advantages and disadvantages, interviews have been held with experts.

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spud legs</strong></td>
<td>• Highly used technology</td>
<td>• Takes up a lot of room on board the ship</td>
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<tr>
<td></td>
<td>• Vessel can still manoeuvre when spud legs are raised</td>
<td>• The legs have to be very long for deep water situations. This leads to the following disadvantages:</td>
</tr>
<tr>
<td></td>
<td>• Level of position fixation and stability is regulated with the number of spud legs</td>
<td>• The legs, when they cannot rest in a horizontal position, make the height increase drastically.</td>
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<tr>
<td></td>
<td>• Completely stable when an elevating system is being used.</td>
<td>• The legs are very heavy, stability greatly decreases</td>
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<tr>
<td></td>
<td></td>
<td>• The systems effectiveness is reliably on ground conditions and depth.</td>
</tr>
<tr>
<td><strong>Motion stabilizers</strong></td>
<td>• Existing/innovative technology</td>
<td>• Can handle only 2.0 meters of wave height</td>
</tr>
<tr>
<td></td>
<td>• Flexible and universal applications</td>
<td>• High maintenance costs</td>
</tr>
<tr>
<td></td>
<td>• Relatively compact</td>
<td>• Limited weight capacity</td>
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<tr>
<td><strong>Floating berthing place</strong></td>
<td>• Stable platform for a variety of systems</td>
<td>• Has to accommodate 400+ m carriers</td>
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<tr>
<td></td>
<td>• Offers a protective berthing place</td>
<td>• Big economic investment</td>
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<tr>
<td></td>
<td>• Mobile cargo handling system</td>
<td>• A system this size requires specialised personnel</td>
</tr>
<tr>
<td><strong>Fixed offshore platform</strong></td>
<td>• Tough</td>
<td>• Not flexible</td>
</tr>
<tr>
<td></td>
<td>• Stable platform</td>
<td>• A rather large initial investment is required</td>
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<tr>
<td></td>
<td>• Enough room for equipment</td>
<td>• Obstruction for marine traffic</td>
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<tr>
<td></td>
<td></td>
<td>• Moves the problem to a different location</td>
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<tr>
<td><strong>LASH</strong></td>
<td>• Cargo handling outside the port</td>
<td>• Crane takes up space and weigh a lot</td>
</tr>
<tr>
<td></td>
<td>• Simple design and technique</td>
<td>• Limited weather working conditions</td>
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<tr>
<td></td>
<td>• The ability to bundle containers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Implementable in smooth transport chain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Very flexible</td>
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<tr>
<td></td>
<td>• Not limited by port depth</td>
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<tr>
<td><strong>BACAT</strong></td>
<td>• Quick loading and unloading of barges</td>
<td>• Unable to sail in rough seas</td>
</tr>
<tr>
<td></td>
<td>• Available deck space</td>
<td>• Needs specialized barges</td>
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<tr>
<td></td>
<td></td>
<td>• High water resistance</td>
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<tr>
<td></td>
<td></td>
<td>• Barges need external propulsion</td>
</tr>
<tr>
<td><strong>Rail-ship combination</strong></td>
<td>• Efficient loading and unloading</td>
<td>• Train carts take up a lot of room</td>
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<tr>
<td></td>
<td>• Shorter cargo handling chain</td>
<td>• Needs specialized barges</td>
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<tr>
<td></td>
<td>• Combines marine shipping with upcoming rail transport</td>
<td>• High water resistance</td>
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<tr>
<td></td>
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<td>• Barges need external propulsion</td>
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<tr>
<td><strong>The cargo unit</strong></td>
<td>• Fewer movements when handling a carrier which results in faster handling.</td>
<td>• These container boxes will be very heavy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The box itself will also take up space on</td>
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</table>
Combining cargo for a specific destination, inland vessel or terminal. The option for the terminals to prepare container boxes on the basis of orders. These boxes can be made to fit inside an inland vessel. board the container carrier. The flexibility of separate containers is diminished
9. New container handling system

What is the best new container handling system?
This question will be answered by desk research. The rest of the methods can be found in appendix II.

Note that on the next pages the term ‘redesigned vessel’ and ‘new system’ both have a separate meaning. The redesigned vessel is of course the vessel on itself. The new system means the vessel acting in conjunction with estuary shipping and eventually, albeit indirect, the terminal.

The terms Short-sea shipping/ships and estuary shipping/ships will mean the same on the next pages.

In chapter 2, Container handling process and the congestion problem, it was mentioned that two separate and new systems will be designed; the offshore backup system and the redesigned carrier. After the research and the listing of all the advantages and disadvantages the conclusion is that an offshore system would just shift the problem to a different location, thus a floating terminal is not an option. A new carrier design is the best solution.

After all the gathering of knowledge during the desk research and the interviews, sufficient information was gathered to state the requirements of the new system.

Requirements of the redesigned vessel

The general requirements as mentioned in chapter 3:

*The solution lies in a new carrier design that will realise a new, more flexible and fast cargo handling process*

This means that a redesigned vessel should be able to:

- To relief the port and to save time for the carrier, the loading and unloading process of the carrier has to be taken outside of the port.
- Break down the bulk factor of the container load in to smaller groups prior to entry of the port
- React to delayed container carriers
- Work in cooperation with the current process
- Realise a streamlined process
- Improve the flexibility of the overall process
- Relief cranes and terminals in general
- Work together with estuary shipping

To meet these requirements the following concept was chosen:

*Improved ‘LASH’ type vessels using container boxes and an on board gantry crane.*
Redesigned vessel

Design

*Improved ‘LASH’ type vessels using container boxes and an on board gantry crane.*

To make the LASH concept usable for this implementation some important changes have to be made to the concept. Some examples of LASH vessels can be seen in the figures beneath.

![Figure 12 Lash crane](image1)

![Figure 13 Lash vessel](image2)

![Figure 14 Lash vessel](image3)

The basic outlay of the ship will remain the same but some important factors will change as listed below.
Basic design

Instead of a conventional container carrier as seen in figure 15, the new lash carrier would look like a vessel shown in figure 16. The crane can be seen clearly in standby position just after the superstructure.

Figure 15 Conventional container carrier

Figure 16 Redesigned lash carrier

Basic lay out

- The accommodation and bridge will be placed on the front of the vessel. The crane will not be able to go over the superstructure. For it to be able to move freely over all the boxes the superstructure has to be placed in front.
- The engine room and funnel will move to the front to give abeam room for a heavier crane. To make the square hold possible and to avoid obstructing a heavy lift crane that will be bigger than the ones used on old lash vessels.
- The hold will be as square as possible and dimensioned around the container boxes. The square hold will create as much as possible space for the standardized boxes.
- Holds will be fitted with cell guides as seen in current day container carriers. These cell guides will make loading and fastening the container boxes easier.
- Reefer container boxes will be placed in the first row against the super structure. This ensures easy inspection and short power supply lines.

Cargo

- Instead of using Lighters of 340 metric tons, which are basically barges, the vessel will use container boxes. These boxes are not meant to float and will weigh approximately 800 tons each while carrying 27 TEU containers of 27 ton each. Chapter 7 contains more info about these boxes.
Loading and unloading operations

- Crane capacity will be increased
  The crane has to lift 800 metric ton container boxes instead of the 340 metric ton lighters used on board older lash vessels.
- The legs on which the crane stands on the after ship, see figure 6.1 and 6.2, will be placed higher.
  This has to be done to provide enough height clearance for estuary ships to ‘berth’ on the stern side of the ship. This will not be a problem as the ship’s dimensions, including the height of the upper (crane) deck will increase as this vessel will carry a comparable amount of containers as present day container carriers.
- The legs on the stern of the ship will have to be strengthened to withstand the weight of the crane and a container boxes.

Propulsion

- Instead of one or two propellers on the stern side of the ship, the new lash vessel will use two azipods on the aft ship and one bow thruster.
  This way the ship can be equipped with Dynamic Positioning systems to make loading and unloading possible without anchoring.
- The ship will be fitted with diesel electric propulsion systems
  - It will be needed for a DP system
  - With azipods the ship will not need a propeller shaft running from fore to aft, increasing square hold space.
  - Diesel electric propulsion has numerous economic and environmental advantages. Some of these are: fewer limits to the lay out of the ship, in some cases improved fuel efficiency, linkable with azipods and dynamic positioning systems.

With this redesigned vessel the overall process of approaching a port, loading and unloading will greatly differ from the process with a conventional container carrier. This is when the numerous advantages of the new system will come in to play to tackle the problems as stated in the problem description and to meet the requirements as stated in chapter 3, general requirements.

Implementation

Redesigned vessel

Arrival

- The redesigned vessel will communicate with port authorities to make sure estuary shipping services are standing by upon arrival.
- The redesigned vessel will arrive at the port.
- The redesigned vessel will position itself a mile or so outside the port and use dynamic positioning systems to stay fixated in that position.
- The crane will be made ready for the cargo handling process.

Loading and unloading

- Using a planned list of estuary ships (from here on called ships) to load or unload, the vessels loading master will communicate with the ships.
- A ship will berth at the stem of the ship.
- The crane will pick up one container box and place it in the hold of the ship.
This process will be repeated until the ship and ships are loaded or unloaded

**Estuary shipping**

**Loading and unloading at redesigned vessel**

- After loading a container box at the redesigned vessel just outside of the port, the ship will return to one of many container terminals in the port that is able to accept a estuary ship.
- Unloading at redesigned vessel
- The ship will pick up the container box(es) and bring them to the redesigned vessel just outside of the port.

A basic overview of the loading process can be seen in figure 17.

**Figure 17 Operation**
The main improvement in respect to the system with a conventional container carrier, breaking down the bulk factor of the load prior to entry of the port can clearly been seen in figure 18 and figure 19.

In figure 18 it is clear that the conventional container carrier can only be handled by the 3 deep water terminals at the entrance of the port. This means the carrier has to rely on the terminal to be ready to handle it and the terminal has to rely on the carrier to arrive on time, otherwise the port would congest.

Figure 18 Conventional container carrier

Figure 19 show that the redesigned vessel does not have to rely on just a couple of terminals but has numerous terminals that could handle its cargo. This is because the cargo enters the port in container boxes on short sea ships. This means that even if the redesigned vessel is delayed, it will simply send the cargo to another terminal if the originally planned terminal is occupied.

Figure 19 Redesigned vessel
One of the requirements of the new system is that it works in conjunction with existing systems. This can be seen in the following example. The cargo unloaded from the redesigned vessel can still go to the deepwater terminals.

Normally one big conventional container carrier, with only a small percentage of its cargo being for the port it is at, will take up a lot of space. Instead, when using the new system, the terminal is able to accept numerous small short sea ships at its quay that only carry cargo to be handled by the port it is at. This can been seen in figure 20a and 20b. The green cargo is to be unloaded. The number of short sea ships at the terminal is vastly exaggerated.

Advantages and disadvantages

Advantages

- The vessel does not have to enter the port meaning:
  - No (port) pilot service necessary
  - The vessel does not have to berth
  - Fewer administrative tasks
  - Fewer security precautions have to be taken
- The vessels unloading and loading operation is not dependent on available quay space at deep water terminals.

Disadvantages

- The system has no protection against weather or sea.
- Unloading and loading 800 Mt container boxes cannot be done in rough weather.
- There are no berthing systems available that are able to quickly secure a ship to the stem of the redesigned vessel.
- The ship and the redesigned vessel will both move independently of each other (unless properly secured) making loading and unloading very hard.
- The heavy lift crane has one container box higher than the deck cargo. This will negatively affect the abeam stability of the redesigned vessel.
Evaluation

1. To relieve the port and to save time for the carrier, the loading and unloading process of the carrier has to be taken outside of the port.

The vessel is theoretically able to load and unload cargo without entering the port itself. However, the cargo handling process is so dependent on good weather conditions and sea state that it is not realistically implementable without any protection from the sea.

2. Break down the bulk factor of the container load into smaller groups prior to entry of the port

The redesigned vessel uses container boxes to divide the container bulk load and is able to distribute these to numerous smaller vessels without having to enter the port.

3. React to delayed container carriers

Not directly applicable. The new system is a carrier on its own. It does however, take the need of being able to react to delayed container carriers away at the terminal. Since the cargo of one container carrier can be distributed among a larger amount of (smaller) container terminals, the few deepwater terminals that exist in the port can be relieved and do not have to handle all the cargo.

4. Work in cooperation with the current process

The new process still requires cranes to load and unload the estuary ships that carry the container boxes. This means that the system has to work in cooperation with the current systems. Also, some shipowner might prefer the conventional carrier design over the redesigned carrier. This means that the deep water terminals will still have ‘customers’ but that the need for new, bigger, deeper and larger terminals is taken away.

5. Realise a streamlined process

As can be seen in figure 21, one more step was added to the part of the transport chain this project covers. When streamlining a process or, in this case, a transport chain, steps are normally removed to make the process shorter and easier. In this project the problem was between the two existing parts seen below, the container carrier and the container terminal. This problem is solved by adding one more part to the chain; the short sea carrier. This makes the process more streamlined.

Figure 21 Transport chain
6. Improve the flexibility of the overall process

This system does improve the flexibility of the overall process. If a vessel is too late it is not a problem anymore.

7. Relief cranes and terminals in general

Using this system, the cranes will only have to handle the smaller short sea ships instead of the enormous container carriers. This will eventually lead to downsizing trend instead of the current continuing upsizing trend in container cranes. The terminals in general will be relieved because they do not have to facilitate the big container carriers. The cargo can be distributed amongst numerous terminals with this system which also reliefs the terminals.

8. Work together with estuary shipping

The implementation of estuary shipping or short sea shipping is essential in this shipping. Without these ships the new carrier design is unable to load or unload cargo.
10. Conclusion

Solving a problem like port congestion in container handling means looking at numerous aspects of the problem. After extensive research of the topic a list of requirements was made up together with two sectors for further research; the offshore sector and a redesigned ship. Listing all the advantages and disadvantages made it obvious that only a system using a redesigned vessel would improve upon the current situation and answer the main question of this research:

*How can the port congestion, caused by container handling, be solved through a technical solution?*

The new system in which the CC-vessel, the Combined Container vessel, uses the new cargo handling method is a big step towards improving the cargo handling process in the ship-shore limits.

The systems offers some great improvements that can surely help in solving and preventing port congestion. Making sure that the vessel is not always bound to entering the port, making the vessel independent of the few deep water terminals in a port and breaking down the bulk factor of the container load are the most important aspects of the new system.

Unfortunately, the new system is not without any disadvantages. The space occupied by the boxes and the added weight of the crane(s) and the cargo unit will be a great setback, especially for travelling long distances without calling many ports. For liners that call on a lot of ports the faster cargo handling processes and the absence of port costs will outweigh the setbacks of the new system.

For the new system to work, all the points in chapter 9 have to be worked out. Only then would a new system, using the CC-vessel have a chance of succeeding in improving the current situation.

This means that this research does not lead to one solution that would solve port congestion. This is because some technology, essential for this system, just does not exist yet and some topics still require further research.

The solution suggested would work if the recommendations as listed below are followed. The system would then offer a solution to port congestion. It also offers a platform that can gradually grow in conjunction with cargo volumes, container carrier sizes and customer demand all steadily increasing in size.
**Recommendations**

All drawbacks of the new system that could form an objection against implementing such a system have been mentioned and explained in appendix IV. Those drawbacks have been listed below.

1. IMDG cargo
2. Weather conditions
3. Berthing of the ships
4. Cargo bundling
5. Liner routes
6. Force distribution

Possible solutions have been added to three of the possible. This is not a final solution to the drawbacks but offer a direction as to what way the problem could be solved. These possible solutions are explained in chapter 9 on the design and are summarized below.

1. IMDG cargo
   - Separate IMDG cargo container boxes, customized for IMDG containers.
   - Segregation of IMDG cargo by using the standard containers on a separate deck on the vessel, in conjunction with an added container crane.

2. Weather conditions
   - Creating a protected hub for cargo handling operations
   - Motion stabilizing systems for the crane.

3. Berthing of the ships
   - A fast, rigid connection between the redesigned vessel and the short-sea ships

These factors form an immediate problem with the system and will have to be solved for the system to work. The other 3 factors; cargo bundling, liner routes and force distribution are not direct problems but are factor that need further research. These factors decide how the system would be economically and structurally feasible if the first three problems; IMDG cargo, weather conditions and berthing of the ships would be solved.

This concept sets the basic outlay of a new system that could solve port congestion in container handling but further research is needed on the various aspects of the new system, including the redesigned vessel.
List of literature


Appendix

Appendix I Interview with Mr. Orgers, APM Terminal Rotterdam

1. What is your role at APM?
   Gerrit Orgers is an execution supervisor at the APM terminal. He organizes the planning for the loading and unloading of mainliners and inland ships. Gerrit Orgers is in charge of the operation while on duty.

2. In what ways do you notice the port congestion?
   It is noticeable in numerous ways, namely when the inland ships and trucks are late or cannot leave the terminal in time. Another cause for the port congestion is the adverse weather this either cause the mainliners to come in late or the terminal cannot work as it should because of the wind.

3. Does your company research the port congestion? If so what kind of research?
   Yes, the APM terminal does research on the subject of port congestion. The branch in which Gerrit Orgers works is constantly busy improving the work process, to improve the planning. The last consist mainly in finding space to handle the large carriers, this is done by to split the work load with other terminals. The challenge is to distribute the available quay space among the mainliners and the inland ships. The terminal is also looking at how the personnel can work more efficiently. Gerrit Orgers likes to call his job advanced Tetris.

4. Did you notice any technical improvements in and around the terminal to solve the port congestion?
   The technical improvements are difficult to notice, there are many factor that need to be considered, the main factor is money, new terminals offer new technologies but cost a large sum of money a good example of a more modern terminal is the Maasvlakte 2, it is fully automate. At other terminals they work with automated trucks. But the most important improvements are large cranes, they are needed because the carriers keep on getting bigger, if a terminal does not invest in lager cranes the vessels simply will not fit.
   APM can handle carriers up to 20.000 TEU, by making sure bigger cranes are available the terminal does not have to worry about not being able to handle the bigger carriers.

5. Where lie the biggest bottlenecks in the container handling process?
   The biggest bottleneck lie with the gates of the terminals, the roads are not large enough to handle the large number of trucks going in and out og the terminal. It happens that vessels have to wait for containers that are delayed because of the gates. But is you look at the “sea” side of the process the biggest bottleneck lies with the act of god, for example carriers which have to wait for the high tide to be able to leave the port. The frequency of arrival of the mainliners becomes higher this causes the available quay space to be used up quickly and there is eventually not enough spaces for the small inland ships, this is why APM works with other terminals. To minimize this problem APM plans two days ahead.
6. Is there a demand for a new solution or product? At the moment the terminals and ship owners are busy to find a solution. But port congestion is a constant issue that constantly has to be addressed. It cost a lot of money and resources. APM does not work with an automated terminal to remain flexible.

7. How does the APM terminal react to delayed carriers? APM has to cope with delayed vessels but there are only a few ways to deal with this. It really comes down to a big puzzle, how can you fit in all of the carriers into the planning and a big part of this puzzle is distributing the load with other terminals, you cannot say no to your customers.

8. What are the biggest factors in the delay in carrier arrival or port congestion? The biggest factor for the delay are the holidays, the terminals do not function during the holidays. The terminals would like the reason of the delays but not all shipping companies share this.

9. Do you have an estimate of the number of ship that are delays? And an estimation of the cost that this brings? It is not that simple to give an estimation about these things but the Maersk vessels come on time for 85%. An estimate of the costs is also not all that easy to give but the biggest factor in the costs are the salaries (about 1500 euro a person per 8 hour shift) the number of containers also play a role. The APM terminal is the most efficient terminal in Europe, this is because APM works with a crew instead of an automated terminal. This also results in a higher bill for the shipping companies.

10. What are your thoughts on the Ship-Shore, Shore-Ship processes at the moment? Could you describe the process? (ship-shore, shore-ship process at APM) Approximately 29 containers per hour per crane. Mostly single lifts. But we have two twin lifts for 20 feet and one 40 feet container.

11. What changes would you like to see within your company? How do you expect to notice the changes? Being able to stack containers higher, but for that you need higher cranes and these cause tremendous back pains, this is why they will be automated. Another problem with higher cranes is the wind, so if terminals want to use higher and bigger cranes they will need to construct something to “break” the wind. And in increase in the number of containers we can handle at the terminal.

12. At this point of the interview we asked Mr. Orges what his thoughts were on our concept we discussed the two following designs; - a heavy lift crane in plain sea which discharges a mainliner directly onto multiple feeders and/or inland ships. - a floating terminal, which is based on a floating dock. A dock in which a mainliner is moored and the discharging would also be directly done onto smaller. Mr.Orgers can see these concepts work but not in anytime soon over period of about 50 years, because people need to get used to the new concept and that can be a bit unsettling. It need to be accepted around the world. China already is using similar concepts but more research needs to be done especially regarding the logistical part.

13. How do you imagine the future of the port of Rotterdam? The port will probably expand, Maasvlakte 3, and will get busier.
Appendix II Research methods

During our projects a number of different research methods have been used to find the answers to our sub-questions. These research methods are:

Field research and desk research

Information collected from these research methods can be classified in the two categories named and described below:

1. Qualitative
   This research method relies on describing a situation in specific details. With this method you rely on interviews, surveys, observations etc.. It focuses on gathering “verbal” data instead of measurements

2. Quantitative
   This research method relies on the understanding of assumptions inherent within different statistical models. The results that come forth through this type of research consist of numerical data or information that can be converted into numbers.

As stated before the project group will use the different research methods to find the answer to our sub-questions. In other words the project group has related these methods to the sub-questions.
Sub question 1: What is the container handling process and where lies the congestion problem?

Desk research
Literature: Internet and books.
Qualitative

Field research.
Interviews with mr. Orgers from APM and more.
Qualitative

Sub question 2: What are the general requirements of a new system?

Desk research
Literature: Internet and books.
Qualitative and Quantitative

Field research
Offshore fare on 28 and 29 of October
Qualitative and Quantitative

Sub question 3: How can short sea and inland shipping be implemented in a new system?

Desk research
Literature: Internet and books.
Qualitative and Quantitative

Field research
Qualitative and Quantitative

Sub question 4: In what way can techniques from offshore installations improve the cargo handling in the transport chain?

Desk research
Literature: Internet and books.
Qualitative and Quantitative

Field research
Offshore fare on 28 and 29 of October
Qualitative and Quantitative

Sub question 5: In what way can the redesign of the ship improve the cargo handling in the transport chain?

Desk research
Literature: Internet and books.
Qualitative and Quantitative

Field research
Qualitative and Quantitative
**Sub question 6:** In what way can container bundling improve the cargo handling in the transport chain?

Desk research
Literature: Internet and books.
Qualitative and Quantitative

Field research
Qualitative and Quantitative

**Sub question 7:** What are the advantages and disadvantages of these techniques?

Desk research
Qualitative
Field research
Qualitative

**Sub question 8:** What is the best new container handling system?

Desk research
Qualitative
Field research
Qualitative
Appendix III Remarks on the design

There are some problems with this system, some minor and some major, that have not been dealt with in this project. These will be listed and explained below.

1. IMDG cargo

IMDG cargo has to be easily accessible in the event of fire or other calamity’s. Some IMDG cargo combinations also have separate rules as to where to place them in respect of each other. These include:

- 3 meters apart from each other
- 6 meters apart from each other
- separated by a bulkhead

The combination of accessibility and separation is not achievable when using bundled container boxes per port.

There are a couple of possible solutions for this problem.

One solution would be to let the first couple of short sea ships to load at the redesigned vessel take IMDG container boxes. These boxes will have fewer containers in them, include separation ‘bulkheads’ and will be equipped with firefighting systems. The drawback of this system would be that all the IMDG cargo for all the ports to be attended have to be loaded in the same container boxes. The short sea ship will have returned the IMDG container box by the time the cargo handling operation at the redesigned vessel is nearly complete. The IMDG container box will be the last to be loaded.

Another solution would be to slightly reconfigure the design of the vessel and put the separate IMDG containers on the stern of the ship and add one extra container crane to load these containers directly into short sea ships that are waiting at one of the sides of the ship. This can be seen in figure 22.

Figure 22 Added crane

This system would lessen the room available for container boxes and the crane will decrease the stability in combination with the vessels already high centre of gravity due to the heavy lift crane for the container boxes.
2. Weather conditions

When handling cargo the short-sea ship and the redesigned vessel will both move independently of each other (unless properly secured), container boxes of 800 Mt have to be handled by a crane and the redesigned vessel has to stay in the same position while doing so. These factors make the cargo handling process very dependent on good weather conditions and sea state. It is not realistic to think that such operations could take place with waves higher than 2.5 meter or wind forces above 5 or 6 Beaufort. (these are estimated values) This is even dangerous for the ship with the height of the crane, this heightens the centre of gravity and will be a big wind surface.

There are two possible solutions for this problem

One is to build some kind of sea wall to protect the redesigned vessels and the other ships involved in the cargo handling process from wind and sea. This would make a ‘hub’ like zone were the redesigned vessel would be assigned a position which they maintain with dynamic positioning systems. Then the cargo handling process could start safely. When looking at the Port of Rotterdam for example it is an option to just make the outer ring and adapt it as a sea wall. This is however some kind of ‘port’ and one of the requirements is that the vessel is able to load and unload outside of the port. When working in a protected ‘hub’ congestion could arise again in the form of a queue for usage of the protected zone.

The other solution is to mount the gantry crane on a motion stabilizing system like the one mentioned in the offshore chapter. This would counteract movements of the ship, which are caused by sea and wind, to keep the crane steady, but this system is not applicable on heavy lift gantry crane.

3. Berthing of the ships

The ships that load and unload cargo at the redesigned vessel need to be fixated in position at the stern of the ship. Normal mooring operations with winches, fore- and aft lines and spring lines take too long and are way too complicated to do on sea. This means that a system has to be invented to secure the ship fast and nearly unmovable to the stern of the ship. As long as such a system is not invented, the redesigned vessel would only be able to operate in zones protected from wind and sea like the ‘hubs’ mentioned at problem two, weather conditions.

4. Cargo bundling

The redesigned vessel is designed around the usage of container boxes as mentioned in chapter 7 and in this chapter at ‘design’. This was decided because it was assumed that the advantages (fewer delays, no port costs for the carrier, lower shipping cost due to bundling) outweighed disadvantages(more movements per container, less flexibility per container). To safely conclude that the container boxes would indeed not have a negative economic effect on the cargo chain a separate research has to be done to this topic. If the negative economic effect is too great, the redesigned vessel would not be feasible because it is constructed around the usage of the container boxes.
5. Liner routes

The redesigned vessel also has a drawback in terms of cargo space. Where in a conventional container carrier the maximum amount of cargo space and maximum cargo weight can be used. In the redesigned vessel, the space required for the boxes itself has to be taken in account. The crane(s) and the boxes will also add weight to the vessel. This means that for the same outside dimensions of the vessel, the redesigned carrier will eventually be able to carry less cargo then a conventional container carrier. The redesigned vessel will also have a higher fuel consumption due to the added weight when carrying the same amount of cargo as a conventional container carrier. This stands in respect to the fast loading and unloading processes and an absence of port costs. This means that the redesigned vessel will be ideal for liners that enters a lot of ports on their line. Container carriers that sail long distances without entering any ports will most likely be better off with a conventional container carrier.

6. Force distribution

It is imperative for the safety of the crew, the vessel and the cargo that further research is done to the effect of using a heavy lift crane with cargo units of up to 800 Mt. Shifting heavy lift around like that on the deck will affect the stability of the ship enormously. The forces on the ship when moving the crane with a fully laden cargo unit could damage the ship if it is not strong enough.

This also goes for the cranes and the cargo unit itself. These need to be kept as light as possible without being too weak. This especially goes for the cargo unit, as these will take up a lot of space in cargo holds if not properly dimensioned.