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Deliverable 4.3 Cargo systems development

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CONTENTS

List of abbreviations

AGV	Automated guided vehicle
CEMT	Conférence européenne des ministres des Transports (Classification of European Inland Waterways)
CESNI	European Committee for drawing up Standards in the field of Inland Navigation
CTP	Cargo Transfer Platform
ES-TRIN	European Standard laying down Technical Requirements for Inland Navigation vessels
FCST	Floating Container Storage & Transhipment Terminal
GM	Metacentric height
ISO	International standard organisation
IWS	inland waterway shipping
IWV	Inland waterway vessel
KPI	Key performance indicators
Lolo	Lift-on lift-off
PWC	Pallet wide container
Roro	Roll-on roll-off
Roro-CTP	Roll-on roll-off cargo transfer platform
SSS	Short sea shipping
ToR	Terms of reference
WP	Work package
VT	Vessel Train

1 EXECUTIVE SUMMARY

The NOVIMAR project researches the vessel train (VT) concept, a waterborne platooning concept featuring a manned lead ship and a number of follower ships that follow at close distance by a control system. The potential benefit of the vessel train is the economy of scale that can be achieved with limited size vessels by operating several units in a coordinated operation. Manning is a major cost for all shipping operation and the NOVIMAR project will investigate the possibility to reduce the manning of the vessels in the vessel train

Work package 4 addresses the design of the vessels making up the vessel train. Initially it is assumed that the concept of vessel train potentially can be relevant for inland waterway, sea-river and short-sea shipping operations.

This deliverable is the third deliverable in WP4 of the NOVIMAR project. The first deliverable, **Deliverable 4.1 Specific requirements WP4**, addressed the general requirements for vessels that will operate in a vessel train. The second deliverable, **Deliverable 4.2 Cargo Systems Analysis**, presents the current available cargo system technology and analysis the pros, cons and limitations. This deliverable, **Deliverable 4.3 Cargo systems development** describes solutions to problems that were identified in the earlier work in the work package.

1.1 Problem definition

The need of transport will continue to grow. For a sustainable future the increased need of transport must to large extent be accommodated by waterborne transport. Improved waterborne transport will attract cargo from the road. Highly utilized efficient ships with small crew will be a requirement for competitive waterborne transportation as well as fast and cost-efficient cargo transfer between the different transport modes.

In task 4.2 Cargo Systems analysis, the logistic chain for waterborne transport was analysed and hurdles for improving the efficiency was identified. Some of the hurdles are on a global logistic level, other hurdles are more related to the specific characteristics of the waterborne system and the ships and equipment used in the system.

The waterborne system needs to work within the physical boundaries defined by e.g. available water depth in fair ways, sizes of locks, channels and height under bridges.

The system needs also to work within the economical boundaries which means that the operation must be competitive and attractive within the given conditions. The utilization of the waterborne transport systems must increase in order to reduce the environmental impact from transport and not least to accommodate the predicted growth in transport volumes.

In NOVIMAR deliverable 4.2 Cargo systems analysis it was stated that a successful intermodal transport system must have

1. high capacity utilisation in each voyage
2. high utilization of the ship i.e. minimizes the time in port
3. high utilization of the terminal and cargo handling equipment

1.2 Technical approach and work plan

In the task 4.3 Cargo systems development the focus has been to find technical solutions for improving the cargo systems to enable an increased used of waterborne transport further out in the distribution /supply chain.

Based on project description and the conclusions from the earlier work tasks in work package 4, a cargo system based on roro handling has been be developed.

1.3 Results

The following benefits compared to a conventional system have been achieved.

- Improved flow of cargo (containers as well as trailers and other wheeled cargo) through the terminals which will reduce the total transport time
- Improved possibility for cross docking, where cargo can be transferred directly from one vessel to another
- Reduced required terminal land area
- Faster and less expensive cargo handling which means that the most efficient vessel can be used for each stretch (short sea vessels on the open sea, larger inland waterway vessels (IWVs) in larger rivers, smaller IWV in smaller rivers.
- Improved cargo density onboard the vessels compared to existing roro vessels.
- Only one type of cargo handling vehicle is needed to service terminal gate, stacking area and loading-unloading of vessels

The improved cargo system is based on three corner stones

1) The roro cross transfer platform
2) The NOVIMAR cargo handling vehicle
3) Roro principles for sea river and inland waterway vessels

The roro cargo transfer platform (Roro-CPT) and the NOVIMAR cargo handling vehicle is presented in this deliverable.

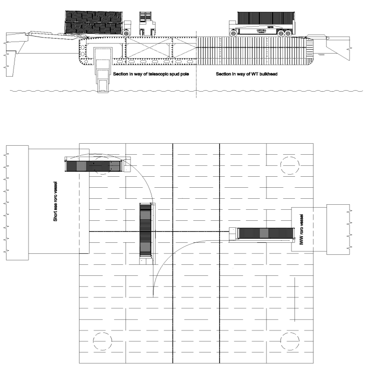

Figure 1, The roro cargo transfer platform CPT)

Figure 2, NOVIMAR cargo handling vehicle

The cross-transfer platform will provide the ability to transfer cargo from short sea vessels to inland waterway vessels in a fast and cost-efficient manner.

The NOVIMAR cargo handling vehicle provides the ability to pick up and drop of a container from the ground or cargo deck without the need for an intermediate cargo carrier such as a cassette or roll trailer. It also has the ability to load and unload the container from a semi-trailer eliminating the need for any other cargo handling equipment in the terminal

In the following task in WP4, task 4.4 Vessel concepts, the vessel will be designed so they are compatible with the increased use of pallet wide container, PWC as well as fully utilizing the potential in roro handling with the NOVIMAR cargo handling vehicle and the roro cross transfer platform concepts

1.4 Conclusions and recommendation

The attractiveness of waterborne transport vs road transport can be significantly improved by implementing a roro concept that reduces the friction in mode-to-mode transfer and the door-to-door transport time.

A “fast track lane” for roro cargo to be established where the full benefit of the fast cargo handling feature of the roro cargo concept is fully exploited. This means that all unnecessary obstacles are removed, and that the cargo is kept on the move with minimum dwell time

- The adoption of the roro cargo transfer platform concept can provide a short-cut through otherwise congested terminals eliminating double handling and dwell time
- The adoption of the NOVIMAR cargo handling vehicle has several benefits
    - the cargo space utilization is improved on a roro ship through the elimination of the intermediate cargo carrier and through more efficient block stowage capability.
    - The dual function of the NOVIMAR cargo handling vehicle of both unloading/loading containers from/to trailers at the gate and loading/unloading ships at the quay enables efficient roro handling with only one type of cargo handling equipment. This reduces the critical volume of cargo that is needed to establish a terminal operation. The consequence is that more and smaller terminals further out in the distribution/supply network can be established with deeper penetration of waterborne transport and reduction of the distance of the first/last “mile”.

The roro cross transfer platform and the NOVIMAR cargo handling vehicle are cost efficient concepts that will provide speed in the cargo handling as well as increased cargo space utilization and enable shift of cargo from land based transportation modes to waterborne transport.

2 INTRODUCTION

2.1 Task 4.3: Cargo system development

The deliverable 4.3 Cargo systems development presents the results from task T4.3: Cargo systems development

The task objectives are:

- Multi modal cargo system concepts with enhanced stowage and turn-around capabilities
- Roro cargo system variants for sea-river and inland operations

For task 4.3 the following sub-tasks were envisaged in the project description

- Sub-task T4.3.1: Using the ToR from T4.2.4, determine design parameters for cargo systems for sea-river and inland operations, including new unitised multi-modal cargo concepts and roro variants
- Sub-taskT4.3.2: Design/develop multi-modal cargo systems concept alternatives for sea-river and inland operations with roro variants
- Sub-taskT4.3.3: Assess the concepts from T4.3.2 using the KPI's and selection criteria developed in T4.2.2
- Sub-taskT4.3.4: Select the most suitable cargo concept(s) for sea-river and inland operations
- Sub-taskT4.3.5: Develop ToR for the corresponding vessel(s) concepts covering sea-river and inland-only operations for various crewing levels.

2.2 Analysis

The NOVIMAR project researches the VT, a waterborne platooning concept featuring a manned lead ship and a number of follower ships that follow at close distance by automatic control.

Almost all systems benefit from economy of scale and that is true also for waterborne logistic system. Cost per transported unit can be reduced if the vessel is increased in size assuming that the utilization factor of the vessel is not reduced. The continued increase of the capacity of fairways, ports, canals and locks are enabling the sea going vessels to grow. The same development is not taking place for inland waterway vessels. To achieve economy of scale for waterborne transport on inland waterways, the NOVIMAR project is investigating the possibilities of VT. A great application for the VT is to provide an economy of scale effect for smaller vessels operating in trains. Smaller vessel will have fewer physical limitations to reach further out in the logistic system (can navigate shallower water, pass smaller locks and lower bridges) which will reduce the distance of the "last mile" which for most transport mission must be done by truck.

A door-to-door transport including a waterborne section will mean that it almost always will be a multimodal transport chain, i.e. there will be one or several transfers of goods between different modes of transport. This will be a complication compared to a single mode truck transport operation. The complication will be both administrative and physical. In this work task, solutions for improved and streamlined physical cargo transfer have been developed in order to increase the cargo transfer speed, reduce the cost and enable waterborne transport to be attractive and cost efficient further out in the distribution and supply chains.

2.3 Approach

Task 4.3 Cargo systems development is the third task in the Work Package (WP) 4 Vessel and cargo systems. It was started in month thirteen and is completed in month twenty-four. This deliverable is due at the end of the work task.

The majority of the work in this task is conceptual and functional design work including targeted research and calculations together with 2D/3D drafting and modelling, considering the terms of references that was defined in task 4.2 and presented in Deliverable 4.2 Cargo Systems Analysis in month 15.

3 PLAN

3.1 Objectives

The objectives of task 4.3 are:

- Development of
    - Multi modal cargo system concepts with enhanced stowage and turn-around capabilities
    - RORO cargo system variants for sea-river and inland operations

3.2 Planned activities

T4.3.1: Using the ToR from T4.2.4, determine design parameters for cargo systems for sea-river and inland operations, including new unitised multi-modal cargo concepts and roro variants

T4.3.2: Design/develop multi-modal cargo systems concept alternatives for sea-river and inland operations with roro variants

T4.3.3: Assess the concepts from T4.3.2 using the KPI's and selection criteria developed in T4.2.2

T4.3.4: Select the most suitable cargo concept(s) for sea-river and inland operations

T4.3.5: Develop ToR for the corresponding vessel(s) concepts covering sea-river and inland-only operations for various crewing levels considering the transport mission determined in task T4.1.

3.3 Resources and involved partners

The distribution of the activities among partners in Task 4.3 are as follows:

- ScandiNAOS AB (task leader)
  Determined the cargo system design parameters, developed cargo system alternatives and assesses and selects the most suitable concepts for sea-river and inland-only operations.

- Technische Universiteit Delft
  Develop the ToR for the vessel to be developed in task 4.4 by define the "functional modules" needed to replace a crew member

- University of Belgrade
  Prepare a technical report investigating the breadth of inland vessels necessary for safe and efficient handling and transport of pallet wide containers

- Plimsoll Szolgaltato KFT
  Prepare a compilation about the dimensions of the locks in Danube

- Universiteit Antwerpen
  Integration of WP4 cargo system model into WP2 logistic model

4 PLAN EXECUTION

4.1 Performed activities

T4.3.1: Determine design parameters for cargo systems for sea-river and inland operations

The terms of references defined for in task 4.2.4 for **Vessel design and CEMT standard** have significant impact for determining the design parameters for cargo systems for sea-river and inland waterway operations.

For a cargo system, for sea-river and inland operations, to be an attractive alternative to long distance road truck service, it must be able to provide an easy-to-use, regular, frequent service at a competitive cost and with a transportation time door-to-door that is comparable to the truck service.

Local collection and distribution will almost always have to be done by truck. The challenge is to provide a waterborne alternative as close to the origin and destination as possible. Larger vessels will have lower cost per transported unit, but smaller vessels can reach further out in the arteries of the inland waterway system. Efficient cargo handling is very important for the competitiveness of intermodal transport but it is also important for maximum use of the waterborne transport because it allows the most efficient vessel to be used for each stretch and allow the quick and inexpensive transfer of cargo from larger to smaller vessels that can reach deeper into the inland waterway network.

Carefully designed vessels, cost-efficient systems for cargo transfer and minimum manning will increase the competitiveness and by that the utilization of waterborne transport.

T4.3.2: Design/develop a multi-modal cargo systems concept for sea-river and inland operations with roro variants

The terms of references defined for in task 4.2.4 for **Cargo handling** and **Cargo Transfer Platform(CTP)** will impact the design and development of a multi-modal cargo systems concept for sea-river and inland operations with roro variants.

A roro cargo system has been developed applicable to short sea, sea river and inland waterway vessels. The cargo system is based on three corner stones

1) The roro cargo transfer platform
2) The NOVIMAR cargo handling vehicle
3) Roro principles for sea river and inland waterway vessels

A hurdle that was identified in task 4.2 was the limited cargo space utilization in roro vessels. It was identified as an important issue to improve in order to make roro concept feasible for inland waterway services.

The roro cargo transfer platform and the NOVIMAR cargo handling vehicle which is a very versatile container handling vehicle has been developed in this task.

The design and equipment of sea river and inland waterway vessels need to fulfil certain requirements in order to fit into the roro cargo systems. The terms of reference(ToR) for the design and equipment is presented in this deliverable as well. The actual design of roro compatible sea river and inland waterway vessels will be developed in task 4.4 presented in the deliverable 4.4 Vessel concepts

T4.3.3: Assess the concept from T4.3.2 using the KPI's and selection criteria developed in T4.2.2

The key performance indicators (KPIs) identified in task 4.4.2 and presented in deliverable 4.2 Cargo System Analysis have been used to compare the developed roro cargo system and to conventional lolo cargo systems for smaller terminals

T4.3.4: Select the most suitable cargo concept(s) for sea-river and inland operations

An evaluation has been made to identify which cargo concept to use for different size terminals and vessels.

T4.3.5: Develop ToR for the corresponding vessel(s) concepts covering sea-river and inland-only operations for various crewing levels

ToR for the design of vessels that can sail with as little crew as possible.

5 RESULTS

5.1 General

Inland waterway transport is fundamental for the transport of goods in Europe. For low value goods such as bulk and liquid cargo, the waterborne service on the inland waterways is the preferred mode of transportation due to its low cost and high capacity. In addition to bulk and liquid cargo, a significant number of containers are transported. Rolling cargo such as trucks, trailers and new built vehicles are utilizing the waterborne inland transportation to limited extent.

The cargo volumes will grow, and to avoid that the environmental footprint and road congestion problem is escalated beyond control, a large part of the increased cargo volumes need to be accumulated by the waterborne transportation.

Inland waterway operations need to attract cargo from the road. To compete with road transport, the services must be frequent, regular, dependable and cost efficient. Speed can in some cases be a critical parameter but for a lot of cargo, a longer transport time can often be accepted if the client can depend on that a given delivery time always will be met.

To set up a successful shipping service, a critical cargo volume needs to be available to justify the investment. A transport system that efficiently can handle a large diversity of cargo units will have better prerequisites chances to reach the required critical amount. A modal shift from truck to ship is always associated with additional handling of cargo, administration and cost, prior loading the ship. Once there, the waterborne transport is very cost effective, due to its scale and volume. It reduces also the environmental impact. To further develop inland waterway shipping (IWS) and improve its competitiveness versus land transport for unitized cargo, transport chains involving IWS must be stream-lined and current hurdles related to cargo transfer between transport modes, minimized.

The work in task 4.2 Cargo Systems Analysis has been the baseline for the cargo system development performed in this task.

In task 4.2 Cargo Systems analysis, the logistic chain for waterborne transport was analysed and hurdles for improving the efficiency was identified. Some of the hurdles are on a global logistic level, other hurdles are more related to the specific characteristics of the waterborne system and the ships and equipment used in the system.

In NOVIMAR deliverable 4.2 Cargo systems analysis it was stated that a successful intermodal transport system must have

1. high capacity utilisation in each voyage (stowage factor)
2. high utilization of the ship i.e. minimizes the time in port
3. high utilization of the terminal and cargo handling equipment

In the task 4.3 Cargo system development the focus has been to find technical solutions for improving the cargo systems to enable an increase used of waterborne transport further out in the distribution and supply chain

5.2 Results for task 4.3.1 Design parameters for cargo systems for sea-river and inland operations

5.2.1 High capacity utilisation in each voyage

High capacity utilisation in general in a transport system means that the weight and volume of the packaging (cardboard box, container, cassette) is small compared to the weight and volume of the actual product (ore, coal, sneakers, iPhones). Cargo can be space or weight critical. Steel slabs and steel coils are typical weight critical meaning that the maximum weight that the truck, train or ship can carry is reached before the cargo fills the available volume of the cargo space. For weight critical cargo it is important that that packaging unit (container, bolster, rack etc.) as well as the ship itself has minimum weight. High value cargo such a most consumer products is normally volume critical, i.e. the limitation is the physical space not the weight of the cargo. For volume critical cargo the challenge is to minimize the volume between the actual products i.e. to increase the density. To reach high density, the modules of individual package/boxes need to match the larger aggregated units i.e. pallets, containers and vessel cargo space.

Matching dimension chains

One problem on the global logistic level is the dimension miss-match of euro pallets and ISO containers which has a simple technical solution in the introduction of the pallet wide container, PWC. The slightly wider PWC will however impact the cargo system cargo handling equipment, stowage pattern and by that also the dimensions of the ships. The current dimension miss-match of euro pallets and ISO containers reduces the capacity utilisation of the container. The PWC eliminates this miss-match and increases the capacity utilisation of the container but the wider container will not fit into the stowage pattern in the current container cargo system. For full capacity utilization, the cargo system and the dimensions of container carrying ships need to be reviewed. For the purposes of the NOVIMAR project, a report has been prepared on how this would affect inland waterway vessels, NOVIMAR Technical report 4.3 [1]

The PWC has an outside width of 2500 - 2550 mm compared to the 2438 mm of the ISO container. This extra width enables the stowage of 2 or 3 euro-pallets abreast inside the container (euro-pallet size L = 1200 mm B = 800 mm). However, the extra width also makes the container difficult to handle efficiently in a standardized container handling system.

The width of a CEMT class Va vessel is 11400 to 11450 mm. This enables the stowage of four ISO containers abreast in the cargo hold with a width of the side deck of 675 mm. Based on the overview of lock policies, it seems that the greatest breadth of the vessels in the 12 m wide locks is 11450 mm.

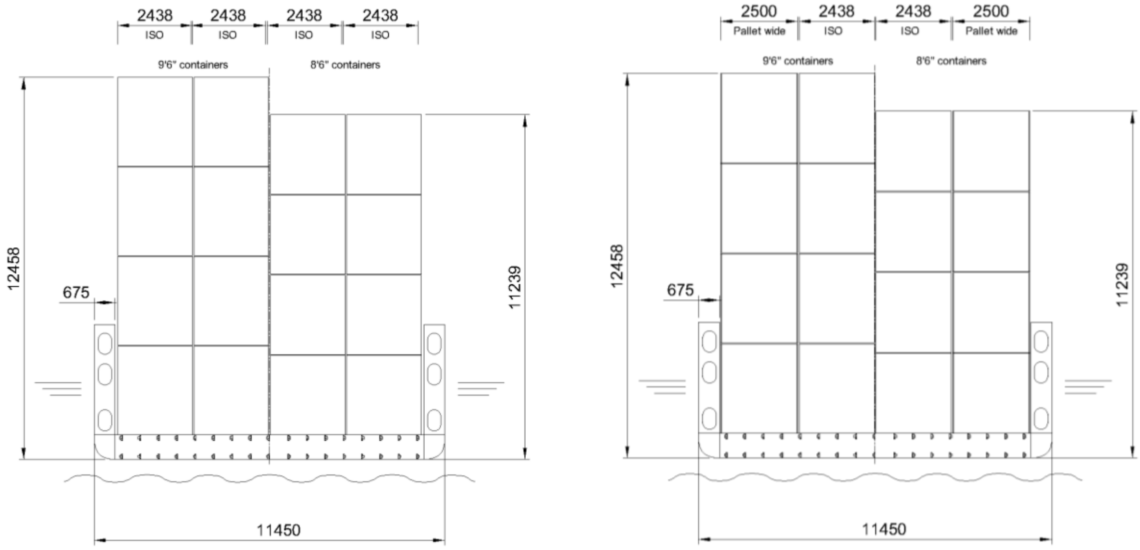

Figure 3, Two "lanes" of pallet wide containers can be stowed within the width of a CEMT class V vessel

The minimal clear width of the side deck is as defined by ES-TRIN regulations (European Standard laying down Technical Requirements for Inland Navigation vessels), is 650 mm. The minimum width of a vessels to take 4 PWC abreast inside the cargo hold is 11 550 mm in order to comply with CESNI[2]. In the foreseeable future it will be quite seldom that a full load of PWC containers will be handled. The mix of ISO and PWC containers will enable 4 rows of containers also in vessels of 11 450 mm width however it will add another aspect to the stowage planning and sorting. The Port Feeder Barge [3] can accommodate this sorting function.

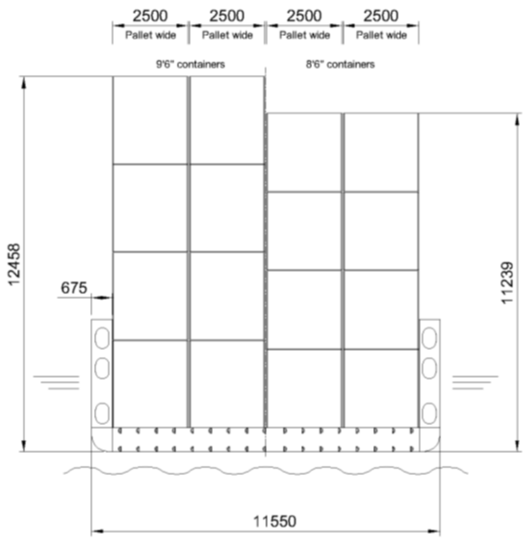

Figure 4, To stow a full load of PWC the breadth of the vessel will have to be increased

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To make CEMT class Va vessels fully compatible with pallet-wide containers either the regulations to enter the locks need to be adjusted to allow 11 550 mm wide ships or the CESNI regulations[2] need to be adjusted to allow 50 mm narrower double sides. This will generate some problems regarding structural strength and access along the ship.

The more specific effects on the actual ship design will be further analysed in the following task in WP4, task 4.4 Vessel concepts

Optimized stowage arrangement

Another important factor is how dense the stowage arrangement onboard can be arranged. There is a typical trade-off between high stowage factor and loading speed. Nothing beats the cargo density that can be achieved in a general cargo vessel with carefully stowed break bulk cargo. The introduction of the container increased the loading speed drastically. The stuffing of the cargo in containers reduced the cargo density but the fact that the cargo could be stacked in several layers on deck off-set the reduced cargo density and the total dead weight of the vessel could still be utilized. However, when stowing containers on deck in several layers the containers need to be planned and organised so that the heavier containers are stowed in the lower layers, so the centre of gravity is kept within the limits for minimum GM requirements.

The cargo handling speed can be further improved by introducing roro handling. The horizontal handling of cargo over ramps is much quicker than the handling with container cranes. The traditional limitation of horizontal handling (roro) is the problem to get the cargo stowed compact enough (high stowage factor). This is due to the fact that containers need intermediate cargo carriers such as cassettes and or roll trailers and the difficulty to handle a stack of more than two containers.

A novel design of cargo handling vehicle has been developed in NOVIMAR. The vehicle can pick up a stack of two containers from the ground and transport the package into the ship and position it in the cargo hold. The first significant benefit is that is eliminates the need for an intermediate cargo carrier that steals volume and dead weight. It also eliminates another logistic problem that comes with the intermediate cargo carrier namely the need to keep them in a balanced circulation in the system.

CEMT class I to IV vessels can be efficiently handled by reach-stackers. Reach-stackers are versatile vehicles that can be used for unloading/loading trucks as well as unloading/loading the vessels. The system will require very little from the port infrastructure. A 100 m long quay strong enough for the container and vehicle load, with a water depth of about 3 m will be enough to provide a service.

5.2.2 High utilization of the ship i.e. minimizes the time in port

The main purpose of the ship is to transport cargo between ports. The profitability of a ship operation is dependent on how much cargo that is transported. Higher speed can increase the transport capacity, but speed is limited by fairway conditions, regulations, weather and when it would be possible to increase the speed of the ship, the cost to do this is very high in the form of increased fuel consumption.

Reduced time at port will increase the transport capacity of the waterborne transport system.

The time a ship needs to stay in port depends on several things.

Flow of cargo through the port to and between terminals is dependent on the regional infrastructure and the operators of the logistic system. Shorter port time of ships can be achieved if the port and terminal infrastructure are arranged with minimum port time in mind. However, it should also be taken into account that the logistic system is a service to the society for transport of goods and people. Care need to be taken when optimizing logistic systems, so that it will not have negative effects of other functions in the society.

In this deliverable we are not proposing any changes to the fixed existing infrastructure but rather focus on the floating assets on the water and the moving assets in the terminals.

As concluded in task 4.2, a floating platform for collection and distribution of cargo between terminals provides an additional level of flexibility that can be utilized for keeping the ships in the port as short time as possible.

The principle is simple. Instead of the ship making a journey between different terminals, the floating cargo transfer platform (e.g. a Port Feeder Barge[3]) will make this work. By doing this, the ship will only have to make one call at a port (i.e. docking to the cargo transfer platform) instead of several calls to different terminals. This will save time for the ship and quicker get it back on the route to next river port. The utilization of cross transfer platform requires collaboration and a planning tool that can handle the additional complexity for timely collection, distribution and rendezvous with inland waterway vessel.

Concepts for Floating Container Storage & Transhipment Terminal has been developed in different research and development projects i.e.

- Floating Container Storage & Transhipment Terminal (FCST) planned for Scapa Flow in Orkney
- Grand Port Maritime de Guyane is developing a floating multi-use terminal.
- Port Feeder Barge, Port of Hamburg

In the port of Hamburg, a Port Feeder Barge[3] has been developed. The barge is self-contained with propulsion and crane capacity and provides a time efficient alternative to multi-terminal calls for the river barge and cost-efficient alternative transfer of containers between terminals by truck.

The Port Feeder Barge is an existing Cargo Transfer Platform (CTP) concept that can have a potential to improve the overall efficiency of the inland waterway system by reducing the time the individual barges have to spend navigating between and waiting in terminals.

The above concepts are all utilizing traditional lolo handling technology for the transfer of containers. However, the cross-transfer platform can also be designed for roro handling and by that open up for the utilization of quicker and less expensive cargo handling.

5.2.3 High utilization of the terminal and cargo handling equipment

Traditional lolo handling provides efficient space and deadweight utilization of a ship but since the cargo handling speed is low the ship is tied up at port for long periods, which reduces the total utilization of the ship. For IWVs, the problem is emphasized by the fact that seaport terminals give priority to the deep-sea vessels before the short sea vessels and the short sea vessels before the IWVs, contributing to long waiting time. Longer time at port gives shorter time for transit and means that the speed needs to be increased to maintain a given schedule or the number of trips per year will be reduced which effects the earning.

Terminals with high cargo throughput can invest in efficient container handling equipment such as quay cranes, reach stackers, straddle carriers and/or terminal trailers. This result in an efficient system, but it requires high investments in many different types of specialized equipment and a high and steady flow of cargo to make the cost per container move reasonable. Most terminals away from the main cargo flows have a cargo flow that neither regular nor steady. They might only have a handful of ships per week that will call the port, but the shipping company still require high capacity in the cargo handling. This means that the investment is high, but the utilization factor is low and the cost per move high.

Roro solutions can provide a more scalable system where the equipment is cheaper, more flexible and the cargo transfer speed is higher.

In NOVIMAR deliverable 4.2 Cargo System Analysis WP4[4] it was concluded that roro handling concepts have the potential to improve the utilization of terminal and cargo handling equipment in smaller terminals. Improved roro handling in inland waterway shipping can enable new cargo flows to utilize water borne transport. To maintain low cost for the waterborne transport itself, the stowage density for roro ships needs to be improved.

5.3 Results sub-task 4.3.2. Design/develop multi-modal cargo systems concept alternatives for sea-river and inland operations with RORO variants

5.3.1 General

A door-to-door transport including a waterborne section will mean that it almost always will be a multimodal transport chain, i.e. there will be one or several transfer of goods between different modes of transport. This will be a complication compared to a single mode truck transport operation. The complication will be both administrative and physical. In this work task solutions for improved and streamlined physical cargo transfer have been developed in order to increase the cargo transfer speed, reduce the cost and enable waterborne transport to be attractive and cost efficient further out in the distribution and supply chain to minimize the final distance in the door-to-door service were no alternative to truck service normally can be found.

For regions with a seaport, the vast majority of the import and export will be by sea transport. For all seaports with an inland waterway connection the potential of inland waterway shipping must be fully exploited in order to make the transport sector move towards sustainability.

Two new concepts have been developed for a roro cargo system applicable to short sea, sea river and inland waterway vessels. The concepts are:

- The roro cargo transfer platform
- The NOVIMAR cargo transfer vehicle

5.3.2 The roro cargo transfer platform. RoRo-CTP

At the seaport the sea going vessels are unloading the cargo which is then picked up by another mode of transportation. Due to its flexibility, availability and low cost, the truck alternative is too often the only alternative considered. However, the truck alternative creates congestion both in the harbour and on the road network and contributes to a significant negative environmental impact with emission of greenhouse gases, NOx and PM.

If transfer of cargo, between short sea and inland waterway operations can be arranged directly from ship to ship or via a cargo transfer platform the pressure on the terminals and road infrastructure in the larger port areas can be reduced.

The RoRo-CTP will enable cross docking of vessels, i.e. direct transfer of cargo between short sea vessels and inland waterway vessels. The RoRo-CTP in combination with the NOVIMAR cargo handling vehicle will make the cargo handling fast and inexpensive enabling the development of smaller terminals /distribution hubs servicing various sizes of inland waterway vessels.

The RoRo-CTP can essentially be independent from other terminal operations. For cargo transfer to smaller IWVs where the roro concept might be less efficient, the RoRo-CTP system also allows containers to be handled by means of a reach-stackers.

The RoRo-CTP will typically be built as a floating structure without own propulsion, but it can also be self-propelled. It will have at least one mooring position for a larger roro vessel, i.e. a short sea roro vessel and one or several mooring positions for smaller vessels.

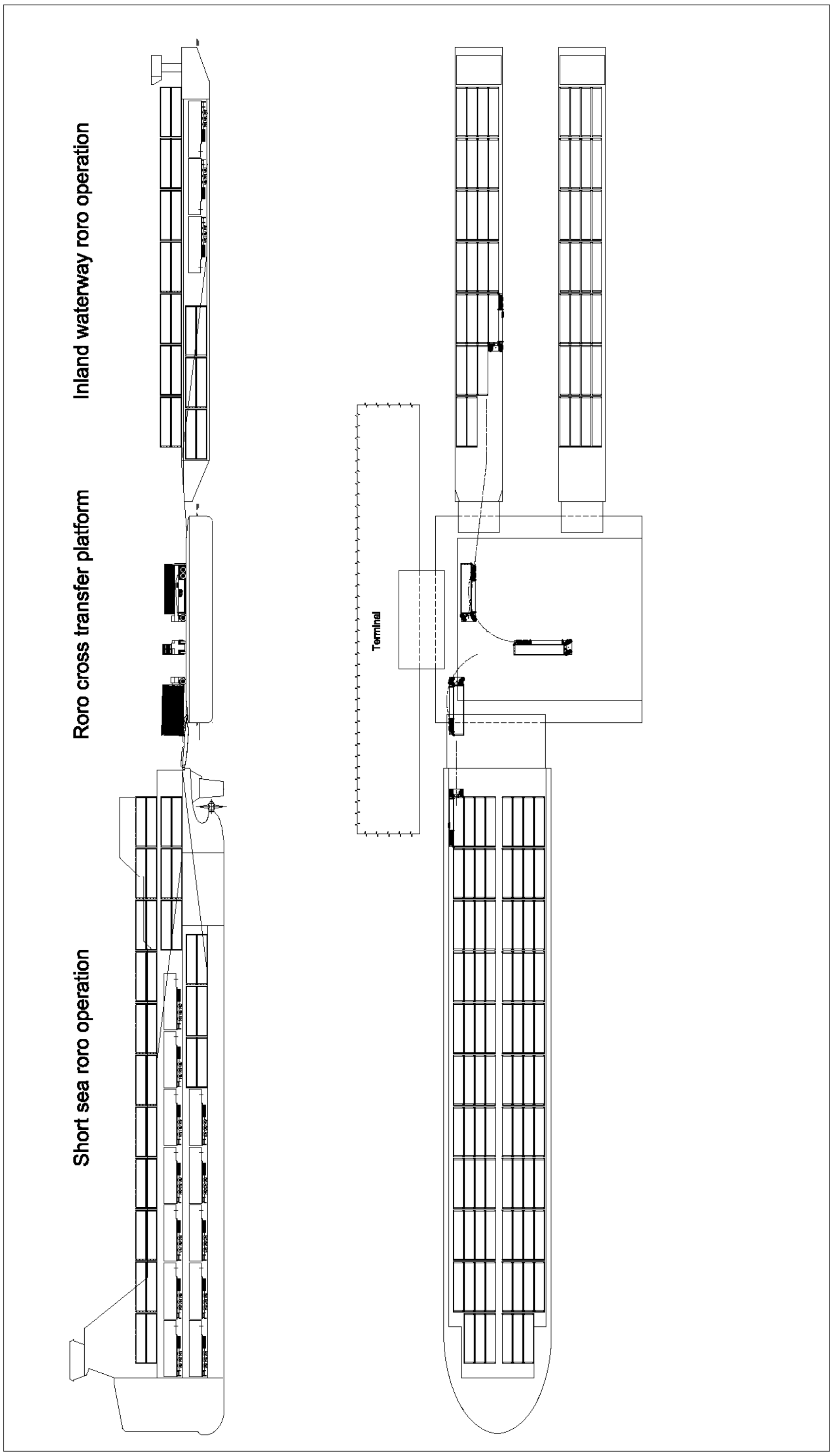

Figure 5, Cargo transfer platform with SSS roro vessel, IWV roro vessel and NOVIMAR cargo handling vehicle (http://www.scandinaos.com/NOVIMAR/D4.3Fig05.pdf)

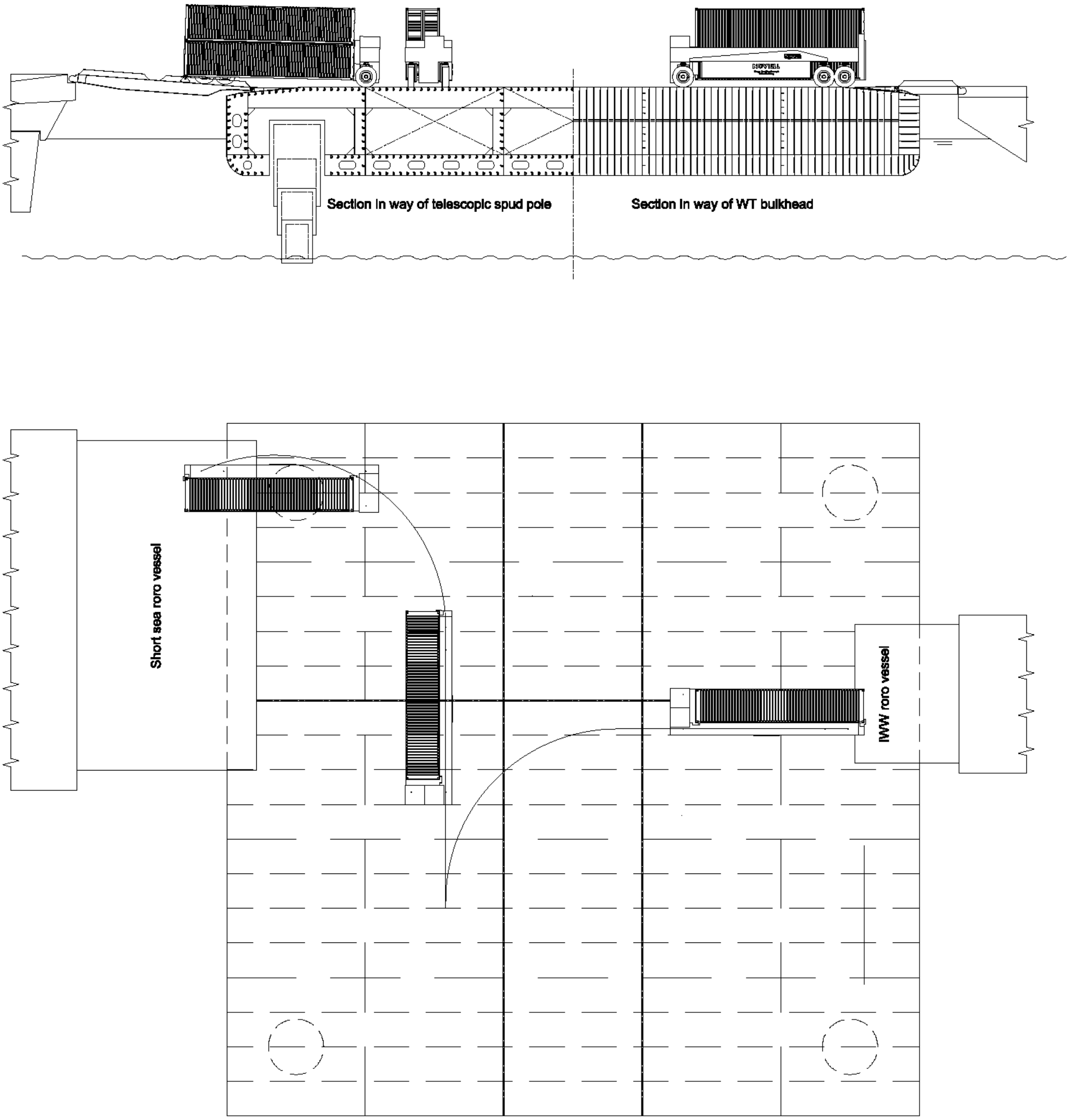

Figure 6, Plan and section of the roro cargo transfer platform

(http://www.scandinaos.com/NOVIMAR/D4.3Fig06.pdf)

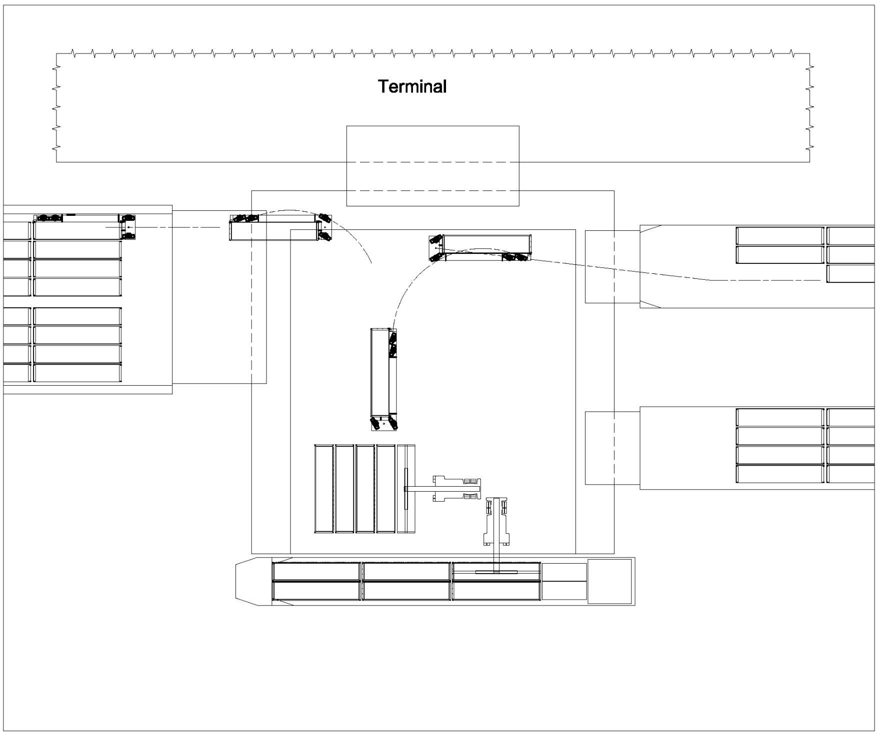

Figure 7, Roro cargo transfer platform servicing roro vessels and reach stacker loading of a CEMT class II barge (http://www.scandinaos.com/NOVIMAR/D4.3Fig07.pdf(

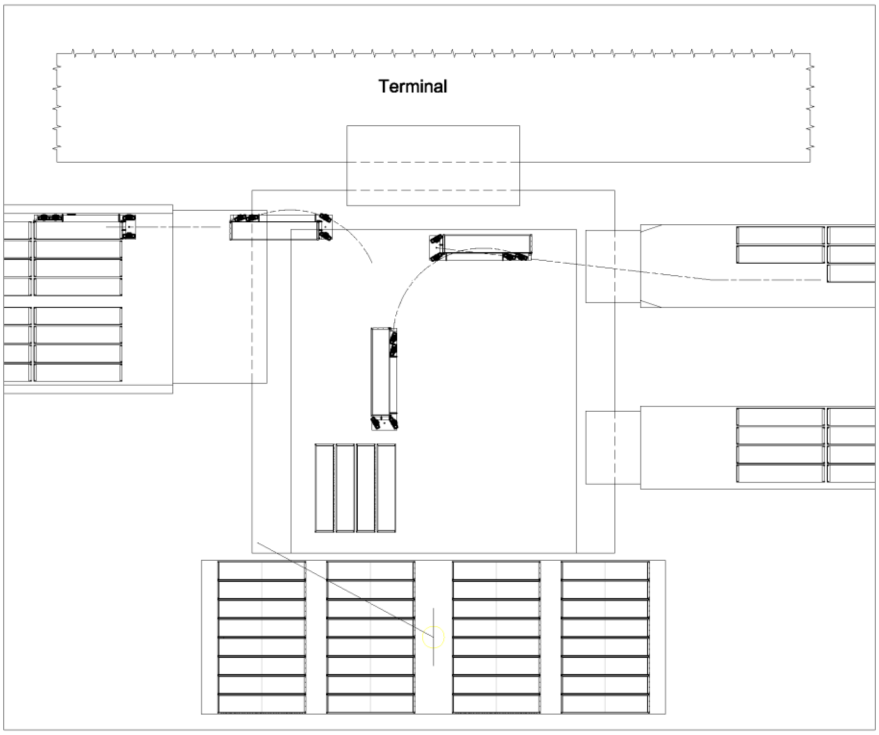

Figure 8, Roro cargo transfer platform servicing roro vessels and a port feeder barge

(http://www.scandinaos.com/NOVIMAR/D4.3Fig08.pdf)

5.3.3 NOVIMAR cargo handling vehicle

By providing technology that can make the cargo transfer operation quicker and less expensive the threshold to move cargo from road to water is lowered. The technology will also enable the establishment of more distribution hubs further inland where transfer can be made from larger inland waterway vessels to smaller, in order to reach as far out in the distribution system as possible with waterborne transport.

The main drawback of the current way of handling containers in roro operations is the additional equipment that is required to travel with the container, i.e. terminal trailers or cassettes. The volume and weight of this equipment reduces the payload capacity of the ship. An obvious improvement of the roro concept is to develop a system that eliminates the need of terminal trailers or cassettes.

There are current examples of road trailers with the ability to load unload containers off the ground both transversally and longitudinally. The problem is that the process is slow and cumbersome. A terminal cargo handling vehicle need to make the operation fast with no or very little manual handling

Figure 9, Container trailer with side loading

Figure 10, Container trailer with end loading

In order to improve the cargo utilisation of a vessel for roro handling, a new cargo handling vehicle was developed in work package 4.3. Cargo systems development.

The vehicle will have the capacity to pick up a double stack of containers from the ground, transport it across the terminal area into a roro ship and put it down in the cargo space.

NOVIMAR deliverable 4.2 Cargo System Analysis stated the following requirements

Basic requirements

1. Direct pick-up of two double stacked containers that are standing on the terminal ground (stack) in less than 1 minute
2. Transfer of containers from stack to a ship cargo space negotiating ship-shore ramps and internal ramps. Speed in the terminal 30 km/h speed in the ship 10 km/h
3. Place the double stack at a pre-defined space in the ship in less than 1 minute including required cargo lashing.

Optional requirements

4. Self-propelled with drive through capability
5. Autonomous with drive through capability

Vehicles used today to lift loaded containers, such as reach stackers and straddle carriers, are lifting from the top. None of them can handle a double stack, none of them can operate in a roro ship cargo space.

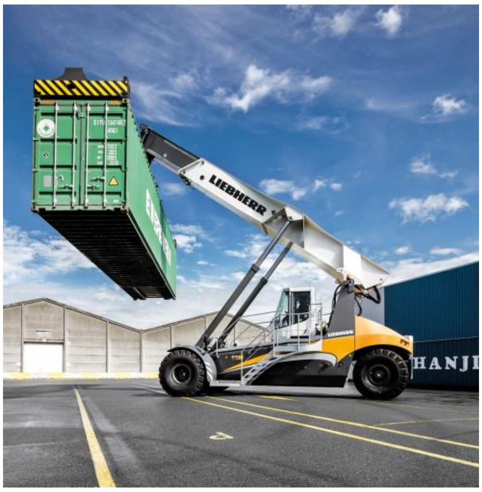

Figure 11, Reach stacker

Figure 12, Straddle carrier

The initial idea was to develop some kind of vehicle inspired from a Container trailer with end loading, the translifter wagon and the TTS roro automated guided vehicle (AGV) see Figure 13 and Figure 14

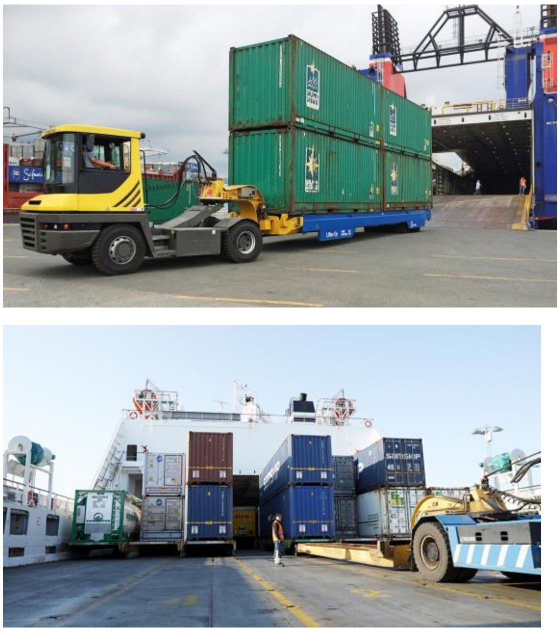

Figure 13, Translifter and cassette for horizontal handling of containers

Figure 14, Automated guide vehicle, AGV and cassette for horizontal handling of containers

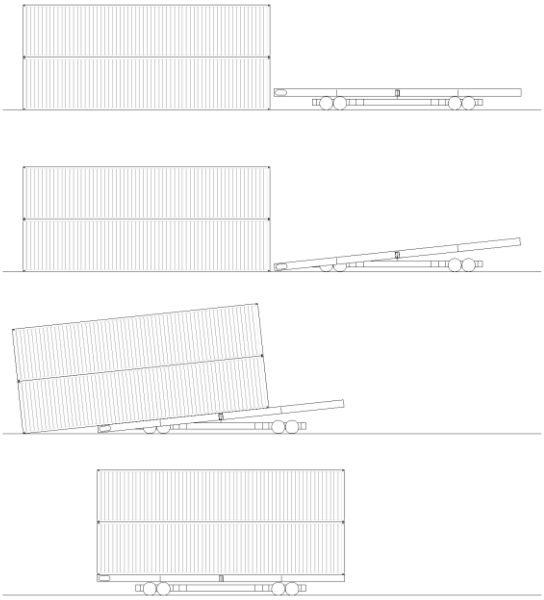

Figure 15, Initial idea of NOVIMAR cargo handling vehicle

After some brain storming and further thoughts the vehicle changed shape. A fundamental part of the concept is to utilize the stiffness of the container itself. The racking strength allows a loaded container to be lifted from the side. This concept enables the following abilities

1) A low built vehicle can pick up a container from the ground or from a truck without an over-head spreader
2) It is possible to use of an asymmetrical vehicle that only needs space at one side of the container. This in turn allows for pick up and drop off to/from a compact stack

The ability to pick up from the ground directly and put down on a cargo deck and vice versa eliminates the need for intermediate cargo carriers such as cassettes or roll trailer and by that increases the utilization of the cargo space and the deadweight of the ship. The ability to block stow the contains on board the ship further increases the utilization of the cargo space and reduces the need for lashing. The functionality of the NOVIMAR cargo handling vehicle reduces the traditional shortcomings of the roro concept by increasing the utilization of the cargo capacity of the ship and maintain the benefits of roro handling which is the high speed and low cost. These are critical features to make the roro concept viable for increased use in smaller vessels such as inland waterway vessels.

The ability to unload and load trailer at the terminal eliminates the need for special equipment for this function. The versatility of the vehicle reduces the investment cost for the terminal and increases the utilization of the vehicle. This enables the introduction of waterborne transport for services that otherwise would be under-critical to justify the investment required to establish a waterborne transport operation.

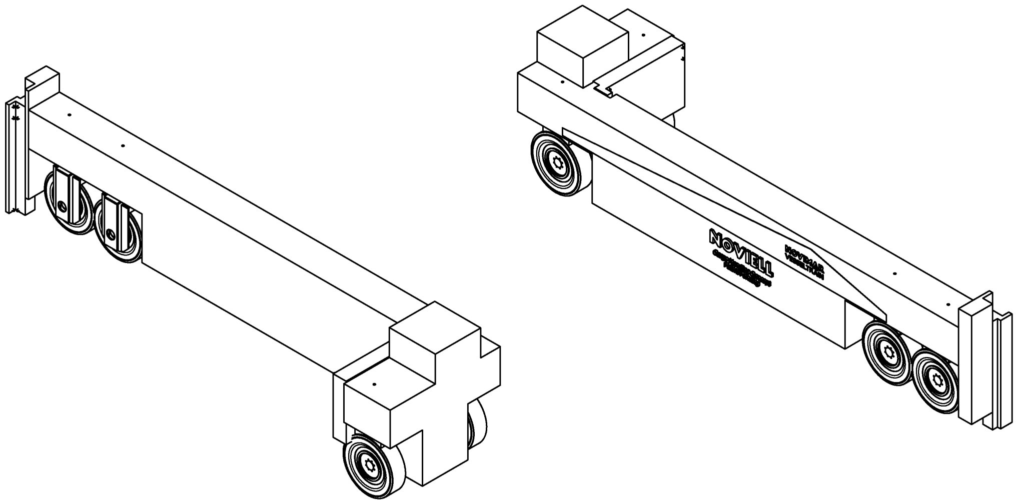

Figure 16 NOVIMAR cargo handling vehicle. The asymmetric design provides a number of benefits such as pick up directly from the ground and block stowage in the ship.

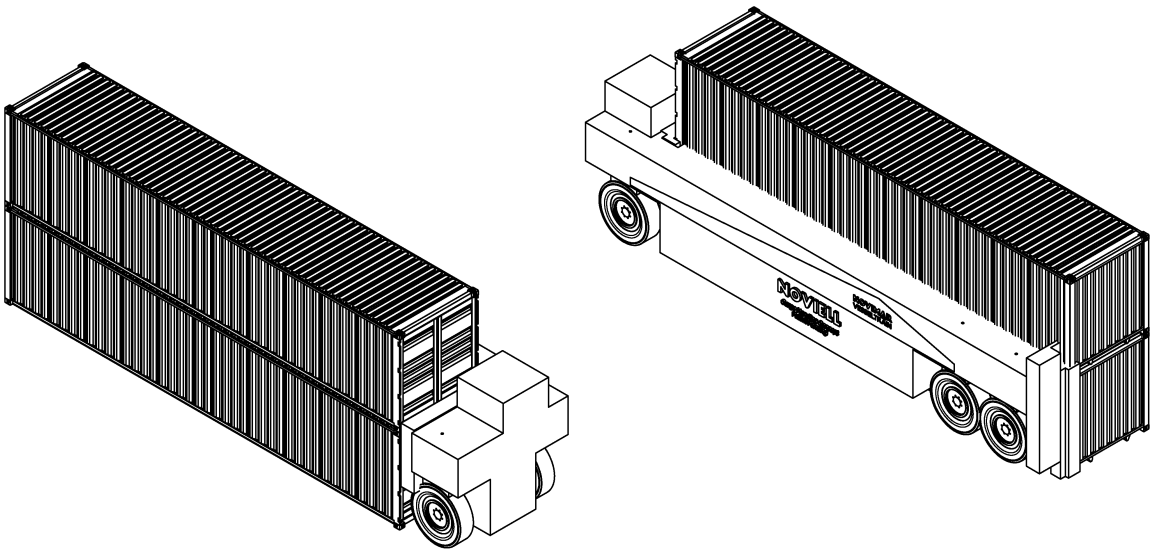

Figure 17 NOVIMAR cargo handling vehicle with double container stacks

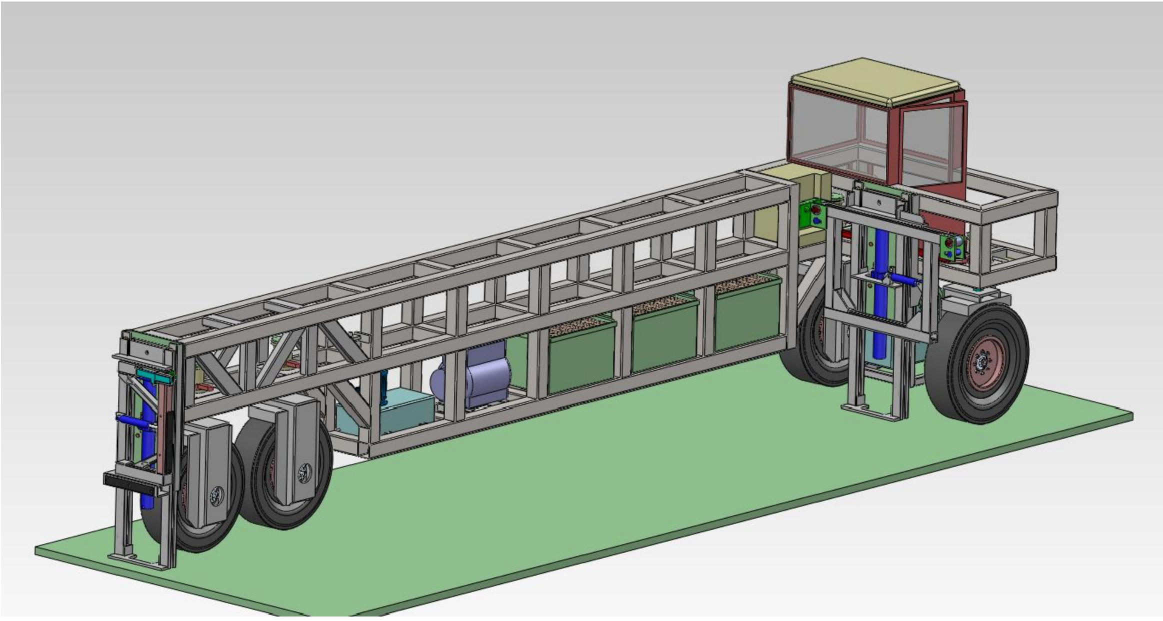

Figure 18 A complete functional design has been developed for NOVIMAR cargo handling vehicle version 1.0

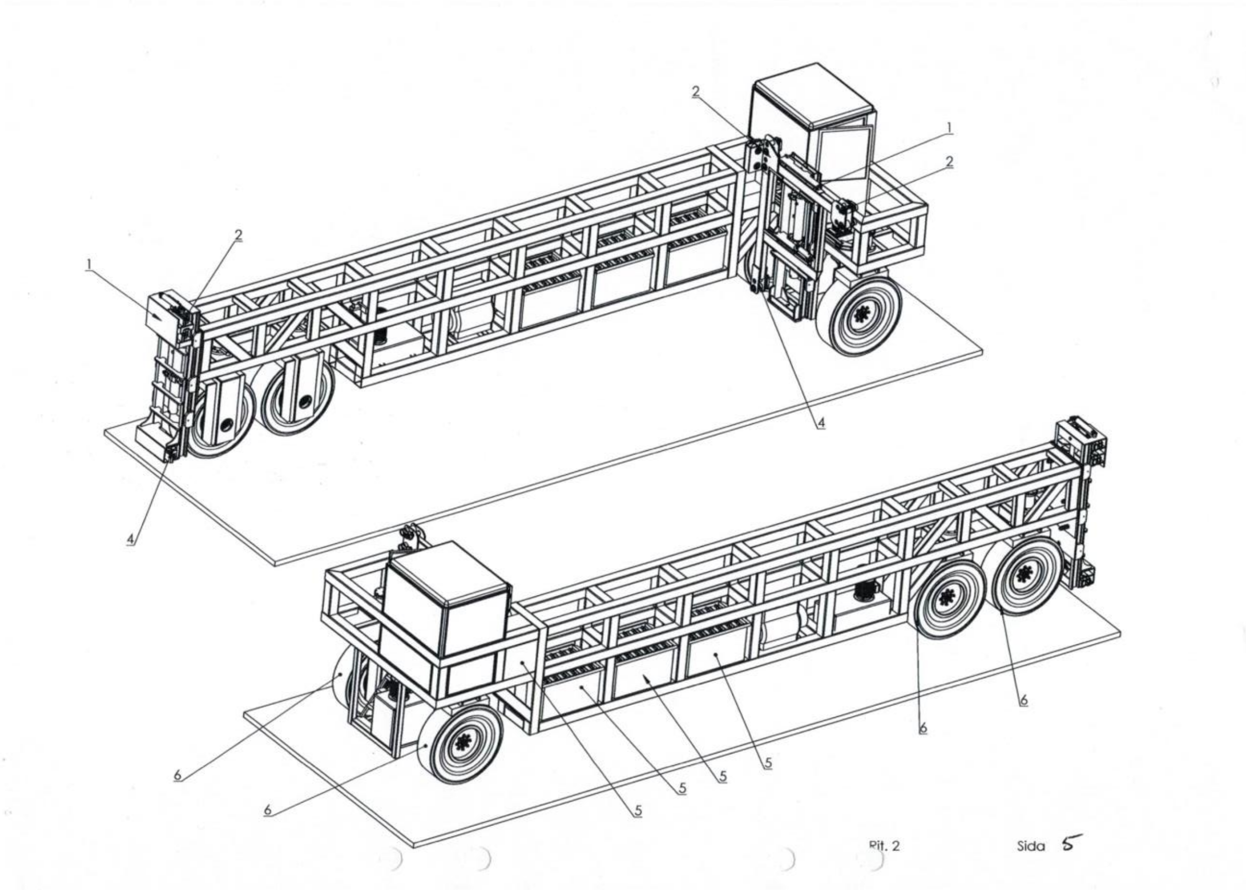

Figure 19 A patent application has been filed for the NOVIMAR cargo handling vehicle

5.4 Results sub-task 4.3.3. Assess the concept from T4.3.2 using the KPI's developed in T4.2.2

The Key Performance Indicators (KPIs) from task 4.2

Handling performance

- Terminal cost
    - Terminal area
    - Annual lease cost per m2
    - Annual throughput
- Handling cost
    - Capital cost terminal equipment
    - Maintenance cost terminal equipment
    - Consumables
    - Manning cost
    - Cargo moves per year
    - Cost per move, gate to stack
    - Cost per move, stack to stow
- Handling efficiency
    - Availability
    - Waiting time for drop of pick up
    - Dwell time
        - Time for arrival to departure
    - Guarantee moves per hour
        - Time per unit from stack (place of rest in the terminal) to stow (onboard
    - Lead time for the cargo unit (gate to gate)
    - Number of damage cargo

In the European Community founded project TRAPIST, the Deliverable D 8-6, Cargo Handling Performance [5], compares the traditional short sea container terminal Tivoli in Cork with the roro terminal Baseport in Gothenburg. The Tivoli terminal uses container quay cranes and straddle carriers and the Baseport terminal uses terminal tractors and translifters.

According to the report the average performance of the container quay crane is loading/unloading 25 units per hour. In addition to the crane, 3 straddle carriers are needed for the transport of containers between the quay and the stacking area. This was compared to a single roro handling equipage that made 15 roundtrips per hour between the container stack area and the cargo hold. The equipage was carrying 2 units in each round trip so each equipage was loading/unloading 30 units per hour.

The Novimar cargo handling vehicle is expected to have similar performance as the roro handling equipage in the report (tug master and translifter trailer). For loading operations where the loading height is limited to two units high, one single Novimar cargo handling vehicle will have a higher cargo handling capacity than the combination of one container quay crane and the approx. 2-3 straddle carriers or reach stackers needed for the transport of containers between the quay and the container stack. The cost of the Novimar cargo handling vehicle will be a fraction of the cost of one container crane. The roro concept is also very scalable were more units can be utilized without interference and by that multiply the total terminal handling capacity.

In the below table, a summary of the comparison of a lolo and roro terminal is presented. The cost of the Novimar cargo handling vehicle is expected to be similar to the cost of a translifter equipage.

Table 1 Comparison between a lolo terminal and a roro terminal from the TRAPIST project and Deliverable D 8-6, Cargo Handling Performance

	Tivoli container terminal			Base port roro terminal		
Terminal						
Terminal area	72300	m2		64000	m2 (for SECU handling)	
Departures						
Annual departures	400			300		
Days in a year with departures	293			300		
Volumes						
TEU per year (import + export)	130000			170000		
Average number of TEU per departure day (import + export)	443			587		
Handling equipment		Unit cost	Total cost		Unit cost	Total cost
No of Gantry cranes	2	€ 6 000 000	€ 12 000 000			
Number of straddle carriers	6	€ 600 000	€ 3 600 000			
No of translifter equipages				6	€ 270 000	€ 1 620 000
Number of reach stackers				4	€ 380 000	€ 1 520 000
Number of roro cassettes				350	€ 20 000	€ 7 000 000
Total equipment investment	€ 15 600 000			€ 10 140 000		
Deprecication period	15	years		15	years	
Interest	5%			5%		
Annuity	€ 1 502 940			€ 976 911		
Cost per TEU	€ 11,6			€ 5,7		
Cargo handling personnel						
Cargo inspector	1					
Gantry drivers	2					
Straddle carrier drivers	6					
Relief Gantry/Straddle drivers	3					
Supervisor	1					
Checkers	2					
Foreman dockers	1					
Dockers	5					
Traffic control				2		
Translifter equipage				6		
Cargo transfer operators				4		
Total	21			12		
Length of shift	13	hours		6	hours	
Hourly cost	€ 30			€ 30		
Cost per shift	€ 8 190			€ 2 160		
Cost per TEU	€ 18,5			€ 3,7		
Cargo handling capacity						
Theoretical cargo handling capacity	40	TEU per hour		360	TEU per hour	
Acheived cargo handlign speed	32	TEU per hour		98	TEU per hour	

Note: Costs are from 2004 but still valid for relative comparison

The KPIs from task 4.2.2 and this table can be used as a baseline for assessing the performance of the roro concept developed in task 4.3.2 and described in section 5.3 of this deliverable.

Terminal cost

To get the full benefits of a roro cargo handling concept, the cargo needs to be on the move with minimum time in container stacks at terminals. The space required for a terminal is more related to the dwell time of the containers than the actual throughput. However, from Table 1 it is seen that for a given terminal area the Baseport roro terminal can achieve a considerable higher throughput than the Tivoli lolo terminal.

With the roro cargo transfer platform, the need for terminal area is further reduced and for pure cross docking it can be eliminated. Pure cross docking operations is probably not required very often so the typical application for the roro cargo transfer platform would be to use the roro cargo transfer platform as an extension or complement to an existing terminal.

Handling cost

From Table 1 it is further seen that

- A quay container crane is about 20 times more expensive than a conventional roro handling vehicle (tug master and cassette wagon)
- The quay cranes need to be complemented with a reach stacker or straddle carrier to transport the containers between quay and stack as well as between stack and gate.
- The straddle carrier is about twice the price and a reach stacker is about 50% more expensive compared to a roro handling vehicle
- A roro terminal can operate with less personnel
- Cost per handled cargo unit is much lower for the roro Baseport terminal

Further qualitative evaluations not directly expressed in the table

- The quay crane, reach stacker, straddle carrier and a roro handling vehicle have about the same number of moving parts so maintenance cost is quite similar
- The quay crane will typically operate on electric grid power whereas the other vehicles typically will operate with combustion engines but the total cost of consumables, per handled unit, is not significant different between lolo and roro handling
- The introduction of the NOVIMAR cargo handling vehicle have the potential to reduce the relative handling cost further compared to the cost of handling in the Baseport terminal.
    - The need for roro cassettes is eliminated
    - It will have dual functions with the ability to perform the work done by the terminal tractor/translifter equipage and the reach stackers.

Handling efficiency

The KPIs related to handling efficiency have more to do with the overall organisation of the terminal and available cargo flow than selection between cargo system concepts

5.5 Results sub-task 4.3.4. Select the most suitable cargo concept(s) for sea-river and inland operations

The roro concept developed in task 4.3.2 has the potential to contribute to the improved competitiveness of waterborne transport and attract more cargo from land to water. The roro concept is mainly suitable for the larger inland waterway vessels that are large enough to accommodate the ramp arrangement that is necessary.

Smaller inland waterway vessels of CEMT class I to III will not directly benefit from roro handling since the ramp arrangement will steal too much of the cargo space. Class IV vessel can benefit from the NOVIMAR roro concept when it is combined with reach stacker loading of the third tier of containers.

Reach stackers are efficient versatile cargo handling vehicles which mainly are used for unloading/loading trailers, container transport and house-keeping in the terminal. The reach stacker can also be used as a cost-efficient alternative to quay cranes for loading/unloading containers to/from smaller vessels such as the CEMT classes I to IV, see Figure 20

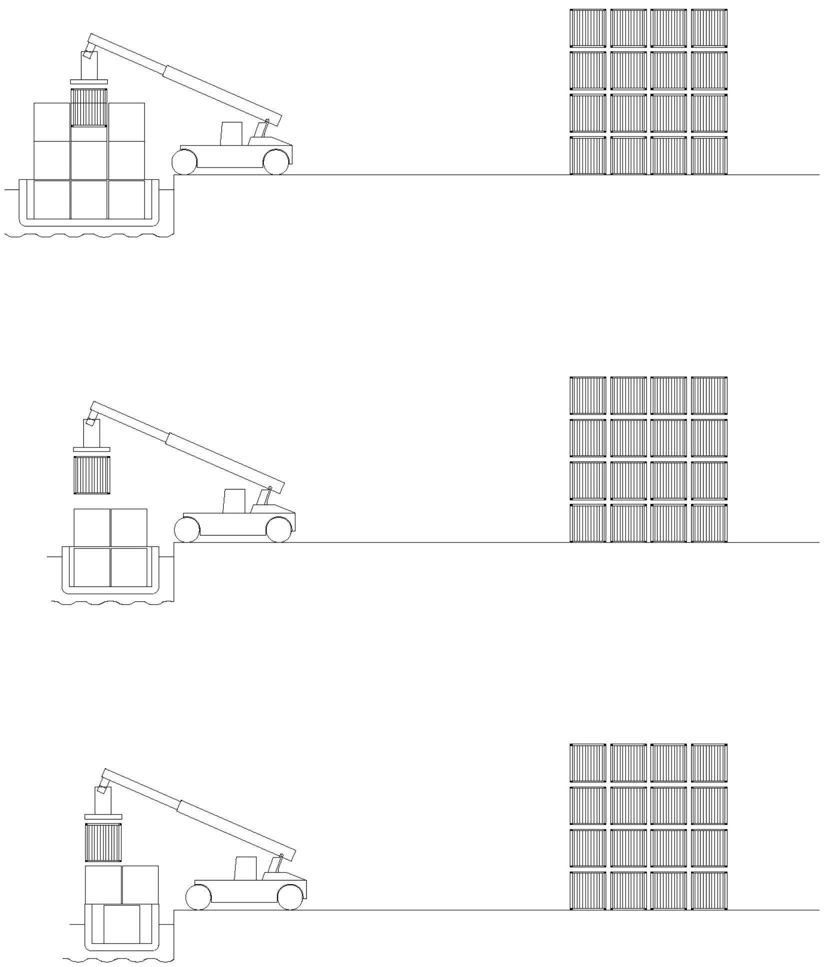

Figure 20, Reach stackers provides a resource efficient handling of containers for class CEMT I to IV vessels in small to medium sized terminals

CEMT class V vessels are too wide and deep to service with a reach-stacker but they can be arranged for efficient roro handling. The benefits with both the reach-stacker and the roro handling is that is eliminates the dependency and need for ship-to-shore quay cranes.

A lot of attention has been paid to the handling of containers but one of the very important features of a roro operation is that it provides a very easy direct access for road trailers to be loaded onboard an inland waterway vessel. For a regular, frequent, dependable service this will be an attractive alternative for long haul trailer services. The driver will drop off the trailer in the terminal, the trailer will be loaded onto the roro IWV, transported and unloaded at the terminal close to the final destination. The driver who dropped off the trailer will pick up a trailer that has arrived at the terminal and take this trailer the “last mile” to its final destination.

Trailer traffic to and from a seaport must often pass through heavily congested urban areas. By arranging a trailer terminal up-stream from the seaport terminal, a roro IWV service can reduce the trailer traffic through the urban area by connecting the sea port to the hinterland road network.

In order to attract rolling cargo, and by that ease the pressure on the road network, the threshold to transfer the trailer to waterborne alterative needs to be as low as possible. A roro solution provides the lowest threshold. As mentioned earlier, for a service to be attractive, it must be regular and frequent. The more frequent departures the more attractive will the service be. It is necessary to gather an initial critical mass of cargo to establish a service that can be regular and frequent enough to attract more cargo. The benefit of roro services is that they can combine rolling cargo with containers. Roro services will potentially be more efficient, to handle containers, than conventional lolo operations for small to medium volume terminals.

5.6 Results sub-task 4.3.5. Develop ToR for the corresponding vessel(s) concepts covering sea-river and inland-only operations for various crewing levels

As part of task T4.3.5 the ToR for the vessel concepts have been defined. The aim is to design vessels that can sail with as little crew as possible. This means that it is necessary to decrease the crew's workload on the ship, for example by increasing the level of automation.

The adjustments on crewing level will have limited impact on the vessel design regarding the cargo system and cargo handling. Reduced crew resources can be compensated with stevedoring resources available in the terminal when required for cargo handling.

One of the main aims of the project is to remove the navigational and situational awareness tasks from the follower vessels. These tasks will take place on the lead vessel. In WP3 the exact details of this system are investigated.

For all other tasks, no such determination has been included in the project. To investigate the design of low-manned ships, an analysis of the effect of automating specific tasks on the crewing levels is required. A functional analysis has been conducted to identify the tasks of the crew with respect to the ship's functions. For each of these functions, an analysis will be performed to identify the technical solutions that could negate the use for human involvement for that specific task. For each of these solutions both the technical feasibility and the economic viability will be investigated.

6 ANALYSIS OF RESULTS

6.1 Summary of results

In NOVIMAR task 4.3 Cargo Systems development some of the hurdles that today limits the efficiency and competitiveness of waterborne transport have been addressed. An analysis has been performed concluding that increased use of pallet wide containers can significant increase the space utilization in the transport system. The whole system needs to be adopted and be made flexible to handle the slightly wider pallet wide containers in parallel with ISO standard containers. This will affect the width of the cargo space in the CEMT class V vessels. For the vessels to still be able to pass certain locks, one of following adjustments need to be made

- Modifications to the rules regarding minimum double side width and width of walkways on deck
- Modifications to the clearance between hull and lock so that the slightly wider ships can pass the existing locks

- Increase the width of the 12 m wide locks to allow wider vessels

The pallet wide container provides a potential for better capacity utilization in the whole transport system but for increased utilization of a waterborne transport system, high cargo handling speed and high cargo space utilization need to be combined. The NOVIMAR cargo handling vehicles combine the high cargo handling speed typical for roro handling with good cargo space utilization. Since no intermediate cargo carrier is needed and that efficient block stowage can be achieved with the asymmetric handling, the space utilization is much improved compared to other roro concepts.

The NOVIMAR cargo handling vehicles is also versatile and can handle both loading/unloading of trailers as well as loading/unloading of a roro ship which makes it an enabler of efficient multimodal (truck-ship-truck) transport systems.

The roro cargo transfer platform, Roro-CTP, provides many potential improvements to the multimodal transport system. By enabling cross-docking between ships, e.g. SSS vessels and IWVs, the Roro-CTP can ease the pressure on the terminal handling equipment, reduce need of double handling, keep the cargo on the move and reduce waiting time for the inland waterway ships. The Roro-CTP also fits very nicely into to the vessel train (VT) concept. The cargo from a short sea ship can be distributed to several inland waterway vessels with different final destinations. The inland waterway vessels will operate in a vessel train and each individual vessel will make deviations along the route to its assigned destination.

6.2 Analysis of results

The objectives of task 4.3 were:

- Multi modal cargo system concepts with enhanced stowage and turn-around capabilities
- RORO cargo system variants for sea-river and inland operations

By the development of the roro cargo transfer platform concept and the development and design of the NOVIMAR cargo handling vehicle the objectives have been met.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The attractiveness of waterborne transport vs road transport can be significantly improved by implementing a roro concept that reduces the friction in mode-to-mode transfer and the door-to-door transport time.

The concepts developed in NOVIMAR task 4.3 can provide the benefits of roro handling such as high cargo handing speed combined with low cost per handled unit and at the same time maintain high cargo space utilization. This will improve the competitiveness of waterborne transport. With fast and cost-efficient system in operation that combines transport of containers, trailers and other rolling cargo, it should be easier to convince cargo owners and freight forwarders of the benefits of waterborne transport both for their own organisations as well as for the environment and the society.

The NOVIMAR cargo handling vehicle can directly replace terminal tractors and translifters/Mafi trailers in roro terminals.

The adoption of the roro cargo transfer platform concept can provide a short-cut through otherwise congested terminals eliminating double handling and dwell time. The roro cargo transfer platform must be considered in more holistic port and terminal planning aspects in order to find its most efficient shape and function.

7.2 Recommendations

Based on the work and conclusions in NOVIMAR task 4.3 following recommendations are made

- The NOVIMAR cargo handling vehicle to be further exploited and stake holders with interest for providing opportunities and funding for development of a demonstrator should be identified. Stake holders can be terminal operators, cargo owner and equipment suppliers.
- The potential of the roro cargo transfer platform to be further analysed
- NOVIMAR task 4.4 to take into consideration the concepts of the NOVIMAR cargo handling vehicle and the roro cargo transfer platform so that the design of the vessels and the interface for cargo handling is fully compatible with these concepts.

8 REFERENCES

[1] S. Rudaković and M. Kalajdžić, "The breadth of inland vessels necessary for safe and efficient handling and transport of pallet - wide containers," 2019.

[2] CESNI, "European Standard laying down Technical Requirements for Inland Navigation vessels," 2019.

[3] "www.portfeederbarge.de." [Online]. Available: http://www.portfeederbarge.de.

[4] B. Ramne and P. Fagerlund, "NOVIMAR Deliverable 4.2 Cargo systems analysis," 2018.

[5] B. Ramne and H. Ramne, "Deliverable D 8-6, Cargo Handling Performance," 2004.

9 ANNEXES

9.1 Annex A: Public summary

Deliverable 4.3 Cargo system development describes solutions to problems that were identified in the earlier task in the work package.

In NOVIMAR deliverable 4.2 Cargo systems analysis it was stated that a successful intermodal transport system must have

- high capacity utilisation in each voyage
- high utilization of the ship i.e. minimizes the time in port
- high utilization of the terminal and cargo handling equipment

In the task 4.3 Cargo system development the focus has been to find technical solutions for improving the cargo systems to enable an increased use of waterborne transport further out in the distribution and supply chain.

The improved cargo system is based on following corner stones

The roro cargo transfer platform

- The adoption of the roro cargo transfer platform concept can provide a short-cut through otherwise congested terminals eliminating double handling and dwell time

The NOVIMAR cargo handling vehicle

- The adoption of the NOVIMAR cargo handling vehicle has several benefits
  - The cargo space utilization is improved on a roro ship through the elimination of the intermediate cargo carrier and through more efficient block stowage capability.
  - The dual function of the NOVIMAR cargo handling vehicle of both unloading/loading containers from/to trailers at the gate and loading/unloading ships at the quay, enables efficient roro handling with only one type of cargo handling equipment. This reduces the critical volume of cargo that is needed to establish a terminal operation. The consequence is that more and smaller terminals further out in the distribution/supply network can be established with deeper penetration of waterborne transport and reduction of the distance of the first/last “mile”.

The roro cargo transfer platform and the NOVIMAR cargo handling vehicle are cost efficient concepts that will provide speed in the cargo handling as well as increased cargo space utilization and enable shift of cargo from land to water

Responsible partner: ScandiNAOS AB

Responsible person: Bengt Ramne

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9.2 Annex B: Record of submitted patent application

PRV
PATENT- OCH REGISTRERINGSVERKET

MEDDELANDE OM FASTSTÄLLD INGIVNINGSDAG

Beslutsdatum 2019-02-25

Patentansökan nr 1900036-3

Kent Börjesson med firma Kent
Börjesson Teknik
Bagaregatan 3
442 30 Kungälv

Sökande: Kent Börjesson med firma Kent Börjesson Teknik

Ombud: Ref:

Benämning: L-lastare

Patent- och registreringsverket (PRV) har fastställt ingivningsdag för er patentansökan till 2019-02-25.

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J-18 (2018-04-26) 1 (3)

Beslutsdatum 2019-02-25 (ans.nr 1900036-3)

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Emma Högberg
Formaliahandläggare
Tel växel: 08-782 28 00, direkt 08-782 26 90