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D.4.6.

Reliable train-truck horizontal transhipment prototype with NMLU technology

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Abstract

Legal Disclaimer

Abbreviations and Acronyms

Acronym	Definition
EC	European Commission
PO	Project officer
GA	Grant Agreement
WP	Work Package

Table of Contents

List of Figures

Executive Summary

The horizontal transhipment process is seen by Clusters 2.0 as one of the enablers to shift containers to rail also at smaller distribution terminals (goal: low capital and infrastructure investment loading and unloading systems for small intermodal terminals), it is clear that the technique must be low-cost, reliable and easy to use.

The purpose for 4.4. and 4.6. therefore was to make the horizontal transhipment technique more reliable and more easy to use by further automating the transhipment process.

The first model of the InnovaTrain ContainerMover 3000 for horizontal transhipment, which came out in 2012, was operated by a state of the art wireless remote control enabling the driver of the truck to initiate and control all movements of the transhipment by remote control.
Operational experience with a first series of ContainerMovers learnt that this great freedom of controlling all movements by the driver was also a possible source for errors and incorrect use of the technique, causing damages and greater tear and wear to the equipment.

As InnovaTrain had already realized the automation of parts of the process, we have concentrated on the automation of the remaining manual steps of the transhipment process with the purpose to create one loop of sequential processes to perform the whole transhipment.

This goal is finally reached by tackling the most difficult part: recognizing and detecting the position of Wagon-Adaptor on the railway wagon in relation to the position of the ContainerMover truck.

The solution is based on using the method of digital image reading with a special camera in combination with image processing software. The software is able to deliver an accurate relative position of the camera against an object it sees and as a result we were able to automatically position the so called “contact bridges” on the wagon.

In this report (Delivery 4.6) the focus was on the tests with the new system and especially on the timing.

The test were done in Switzerland with a new ContainerMover that was installed on a new full electric vehicle. The ContainerMover was equipped with the solution of HD-object-recognizing Cameras. The time measurements were done on roundtrips, starting empty, then picking up the container with the ContainerMover from the railway wagon and driving it with container out of the gate. Then returning with the container to the transhipment area and shifting the container back on the railway wagon, and finally leaving the area empty again via the gate.

Summary of Results:

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time		time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:01:15	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:39	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : “ready to drive“	0:04:30	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:48	duration
			Total duration	**0:07:13**	duration
6	Vehicle exit from Hub / End of sequence		End time		time

The total time for a complete run (starting at the gate – transhipment of container – coming back at the gate) was 7 minutes and 13 seconds
The transhipment part at the wagon itself took on average 4 minutes and 30 seconds.

Comparison horizontal direct transhipment with classic transhipment methods (public terminal):

Terminal area (public terminal)	Duration of total handling (min.)
Basel port terminals	60 – 120 min
Inland terminal	30 minutes

The relatively long total terminal times are mainly caused by waiting times due to overload of the terminals.
But even if we take the 30 minutes as a benchmark for the "gate in – gate out" time of a public terminal, the Container-Mover hub is still 5 times faster, and therefore much more efficient in time.

Lessons learned / further steps:

The solution for full automatic transhipment based on the used HD-object-recognizing Cameras proved to be working, but was arr. one minute slower than the semi-automatic version. Furthermore it became clear that the system was quite sensitive to blinding effects from strong incoming sunlight. The level of these negative side effects makes the system unreliable and therefore not fit for a normal operational use.

Innovatrain will therefore continue the search for a reliable solution for automating the horizontal transhipment. A new approach - based on concept with inductive proximity sensors in the contact bridges - was started in January 2020.
We were able to perform complete lab-tests with this solution in January and February. For a full test of this new idea it will be necessary to equip again a new ContainerMover with these extra sensors. This will be done at a future moment and is therefore not part of Clusters 2.0 anymore.

Advantages of using direct horizontal transhipment on smaller Hubs (Chapter7):

In comparison to the use of special transhipping vehicles like classic reach stackers the horizontal direct transhipment has the following advantages:

1. 60% less surface is needed to operate: The hor. transhipment is very efficient in M2-use
2. 47% less total equipment costs , including diesel consumption costs
3. one man operation (no waiting for other processes or other equipment or personal)

1. Introduction

1.1 Purpose of Document

The horizontal transhipment process is seen by Clusters 2.0 as one of the enablers to shift containers to rail also at smaller distribution terminals (goal: low capital and infrastructure Investment loading and unloading systems for small intermodal terminals), it is clear that the technique must be low-cost, reliable and easy to use.

With Delivery 4.4, the design and first (dry) tests for the full automatic version of the horizontal transhipment system were covered. The purpose for this report D.4.6 was to upgrade an existing half-automatic ContainerMover into a full automatic one and to perform operational tests. The tests were performed at the operational hub of SmartRail Logistics GmbH in Emden (D), a customer of InnovaTrain AG

ContainerMover 3000 - background

InnovaTrain AG develops and markets innovative technical solutions;

- for intermodal freight transport by rail (especially to help shift time critical (FMGC) products from road to rail, at lower daily volumes and in situations where there is a lack of operational space), and
- for on-site container logistics and transhipment of containers.

Figure 1 – ContainerMover 3000 controlled by wireless remote control

The horizontal transhipment technology by InnovaTrain has been continuously developed further since the beginning in 2012, starting with a version for the transhipment of smaller units like the C745 swap body and the 20 foot standard container, up to the model CM-4000 for heavy and large containers (30' - 45' and up to 34 tons), available in future.

The first model of the ContainerMover 3000, which came out in 2012, was operated by a state of the art wireless remote control enabling the driver of the truck to initiate and control all movements of the transhipment by remote control.
Operational experience with the ContainerMover technique at customers during 2012-2015 showed that this great freedom of controlling all movements by the driver was also a possible source for errors and incorrect use of the technique, causing damages and greater tear and wear to the equipment.
During the period 2016-2017, InnovaTrain was able to automate part of the horizontal movements and to build in checks and controls so that the transhipment process became much more controlled and smooth, however the goal of a full-automated horizontal transhipment was not yet reached.

As the horizontal transhipment process is seen by Clusters 2.0 as one of the enablers to shift containers to rail also at smaller distribution terminals, it is clear that the technique must be low-cost, reliable and easy to use.

Based on the positive experiences with the partly automatization of the horizontal movements, a logical next step was to look at possibilities to fully automate the complete horizontal transhipment.

As advantages of a full-automated horizontal transhipment we see:

- Suppress human errors due to inexperience and distraction of the operational personnel,
- Control the movement forces on the equipment,
- Adjust movement speeds to optimal values,
- Install electronic interfaces with operational site software to receive orders and to deliver performance data back (container number, weight, slot number on train, etc.)
- Opening the possibility to combine the transhipment technology with AGVs (Automated Guided Vehicles) in order to arrive at completely automated transhipment processes on local terminals.

The aim of the task of WP 4.6 was to perform operational tests as described by WP5: Delivery 5.4 “Innovative Cluster Handling Technology Scoping Document” (JDR).
The tests were performed at the operational hub of railCare AG (CH), a client of InnovaTrain AG

The steps of the positioning process of the vehicle at the railway wagon are not part of the project (see D. 4.4.)

1.2 Intended Audience

The document is addressed to the Clusters 2.0 project partners and the interested public.

2. Horizontal Transhipment with the ContainerMover

2.1 ContainerMover 3020: mayor parts explained

The ContainerMover 3020 System is a new and revolutionary way of loading and unloading containers on trains. A truck with a ContainerMover 3020 System is capable of the direct horizontal transfer of standard containers like:

Standard 20' containers

Standard swap-bodies
(EN-Norm: 7.45 m / 7.15 m / 7.82 m)

Figure 2 – type of containers for the CM 3020

- ✓ The same truck you use for transport and distribution is used to transfer a container in just 3 minutes to and from the railway wagon. The system is operated by a remote control.
- ✓ You only need a road or asphalted area of minimum 3 meters width, parallel to the railway-tracks.

Dependent on the truck dimensions, the Container-Mover 3020 can transfer weights up to 18 tons.
The 3-axle truck, equipped with a ContainerMover-system, is capable of transporting up to 16 tons.

✓ On the wagon, a simple steel frame is mounted. This frame has the size of a 20' container and is fixed on the normal 20'-container-pins of the container-wagon.

Figure 3 – Wagon adaptor frame on 20' position

ContainerMover 3020 Module

The main device is the ContainerMover module which is to be mounted on a truck-chassis.

It is build up the following way:

Two ***mover*-consoles** with ***mover-beams***, lift the container using hydraulic and pneumatic power. Then the hydraulic powered chain system moves the container horizontally from the truck to the container wagon or vice versa.

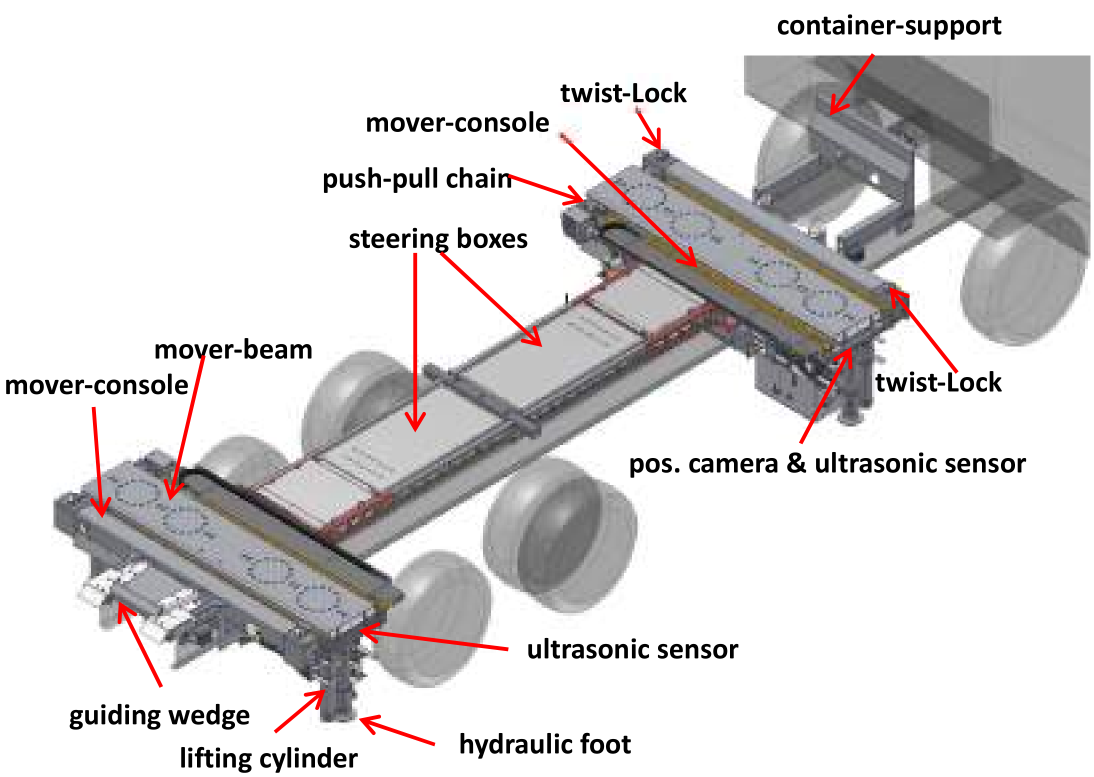


Figure 4 – the mayor parts of the CM3020 Module

Contact Bridges

The Container Mover is equipped with two “contact bridges”, equipped with steel rolls, which actually form the transfer bridges between truck and railway wagon. These bridges support the container during the horizontal transfer.

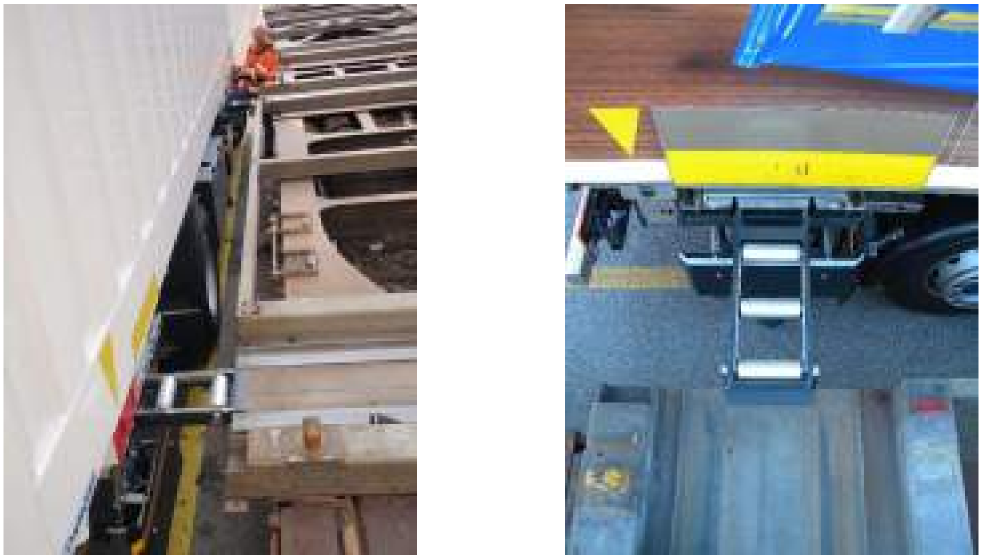


Figure 5 – The two “contact bridges” between truck and railway wagon

ContainerMover 4000 Module

The design for the heavy version CM-4000, capable of transhipping weights up to 35 tons, is ready and at the moment InnovaTrain can agree with a possible customer for first operational tests, this version will be build. The functioning and steering of the system will be the same as for the CM 3020.

Figure 6 – CM-4000 for weights up to 35 tons (45’ container)

2.2 Horizontal Transhipment in sequences (steps), status 2017

The sequence of the horizontal transhipment steps, after a first upgrade of the software in 2016/17, is as follows:

A. Positioning of the ContainerMover at the right lateral position rel. to the wagon (Six sequential steps)

Figure 7 – Wagon adaptor with “cross hairs sign” for positioning

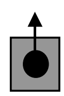
	Where to act / to look	joy-stick	What action to do
1.	**Screen in Cab**		◆ switch to side camera for positioning at the railway waggon (at cross hairs sign)
2.	**Remote Control**		◆ switch to : height Mover-Console
3.	**Marking line on platform**		→ drive parallel to the marking line on the railway platform
4.	**Choose right slot on railway wagon (screen in cab)**		● halt in front of container slot ◆ lift the Mover-Console until you see the level of the wagon adaptor on the screen
5.	**To position the ContainerMover truck exactly at the container slot (screen in cab)**		→ slowly advance with truck ◆ steer the truck in parallel position (both front and rear distances should be equal) ◆ place the cross on screen on the cross hair sign of the wagon adaptor (figure1)
6.	**Block the ContainerMover truck**		◆ initiate the parking brake

Figure 8 – procedure for positioning the vehicle at the wagon

Figure 9 – Screen shot (ready for transhipment)

When the cross of the screen is on the hair sign cross of the wagon adaptor and the measured distances to the wagon adaptor at the front and back are the same (with 1cm tolerance), the system is ready for transhipment

After the positioning of the ContainerMover truck, the driver takes the remote control and steps out of his cab to start the next phase: ***the horizontal transhipment***

B. The horizontal transhipment

For the horizontal transhipment, there are two situations:

1. Transhipment of a container from the truck to railway wagon, and
2. Transhipment of a container from the railway wagon, to the truck.

These two movements, with its actions to be taken by the driver, are described in detail on the next two pages.

Figure 10 – The remote control, the driver is using

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8 Steps to shift a container or swap body from the ContainerMover to the wagon:

	Steps (to initiate)	*Switch-mode*		*Procedure/Action*	S	*step selection joy stick*	S	*Important to watch/note*
1.	**open twist-Locks**	**Twist-locks**	fr + r	open twist locks				check if all twist locks are in open position
2.	**Lower hydraulic feet**	**Hydr. Feet**		short push to joy stick upwards then let go				conical wedge at the rear of truck will go down
			all	push joy stick upwards again and holt it until feet are firmly down				all feet are on the ground and vehicle is pushed up 4 cm
	align Mover Consoles	*Mover-Consoles*	fr + r	*alignment to horizontal position*		***automatic execution***		If necessary you can interfere to change angle
3.	**to connect the contact bridges to the waggon adaptor**	**Contact Bridge**	fr + r	push joy stick upwards and holt it (automatic stop)				Attention: check the relative height position of contact bridge to waggon adaptor! Commence with 3 cm above wagon adaptor
		Mover-Consoles	fr + r	push joy stick downwards until the contact bridges are down on the waggon adaptor				Attention: lower both contact bridges onto wagon adaptor. Look at front and rear contact bridge, and apply just a light pressure with contact bridge.
4.	**Lift SB/Container**	**Mover Beam-Lift**	fr + r	push joy stick upwards until sign is green (full lift container)				Container will be lifted from pins Attention: Level 1: container up to 10t / Level 2: 11- 16 tons.
5.	**Transhipment of SB/Container to the waggon**	**Mover-Transhipment**	fr + r	push joy stick upwards and holt it (automatic stop)				Transhipment is halted at 2/3 of stretch in order to automatically adjust the rel. level of Mover against Wagon adaptor (caused by tilt-movement of wagon)
			fr + r	*intermediate level check*		***automatic execution***		
			fr + r	push joy stick upwards again holt it (automatic stop)				Mover will automatically stop when container is exactly over the 4 pins on waggon adaptor
6.	**Lower SB/Container on Waggon**	**Mover Beam-Lift**	fr + r	short push downwards to joy stick and release				Moverbeams (+container) will be lowered. Container descents onto the 4 pins. Check if this is the case at all 4 corners
7.	**returning the Mover-beams back to the truck**	**Mover-Transhipment**	fr + r	push joy stick downwards until automatic stop				Mover Beams will run back to the truck (last 10 cm automatically in slow motion)
8.	**returning the contact bridges to the truck + retraction of hydraulic. feet + lowering mover consoles (tidying up in order to drive away)**	**Contact Bridge**	fr + r	push joy stick downwards until automatic stop				Contact bridges are automatically retracted
			all			***automatic execution***		*hydraulic feet are automatically retracted* *automatic lowering of mover consoles*
				Ready for driving!				

Figure 11 – 8 Steps to shift a container from the ContainerMover to the wagon

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8 Steps to shift a container or swap body from the wagon to the ContainerMover:

	Steps (to initiate)	*Switch-mode*		*Procedure/Action*	S	*step selection joy stick*	S	*Important to watch/note*
1.	**Lower hydraulic feet**	**Hydr. Feet**		short push to joy stick upwards then let go				conical wedge at the rear of truck will go down
			all	push joy stick upwards again and holt it until feet are firmly down				all feet are on the ground and vehicle is pushed up 4 cm
	align Mover Consoles	*Mover-Consoles*	**fr + r**	*alignment to horizontal position*		***automatic execution***		If necessary you can interfere to change angle
2.	**to connect the contact bridges to the waggon adaptor**	**Contact Bridge**	**fr + r**	push joy stick upwards and holt it (automatic stop)				Attention: check the relative height position of contact bridge to waggon adaptor! Commence with 3 cm above wagon adaptor
		Mover-Consoles	**fr + r**	push joy stick downwards until the contact bridges are down on the waggon adaptor				Attention: lower both contact bridges onto wagon adaptor. Look at front and rear contact bridge, and apply just a light pressure with contact bridge.
3	**Push moverbeams from CM under container on waggon adaptor**	**Mover-Transhipment**	**fr + r**	push joy stick upwards and holt it (automatic stop)				Mover will automatically stop when beams are exactly symetrical under the container
4.	**Lift Container**	**Mover Beam-Lift**	**fr + r**	push joy stick upwards until sign is green (full lift container)				Container will be lifted from pins on waggon Attention: Level 1: container up to 10t / Level 2: 11- 16 tons.
5.	**Transhipment of Container to the waggon**	**Mover-Transhipment**	**fr + r**	push joy stick upwards and holt it (automatic stop)				Transhipment is halted at 2/3 of stretch in order to automatically adjust the rel. level of Mover against Wagon adaptor (caused by tilt-movement of wagon)
			fr + r	*intermediate level check*		***automatic execution***		
			fr + r	push joy stick upwards again holt it (automatic stop)				Mover will automatically stop when container is exactly over the 4 pins on ContainerMover
6.	**Lower Container on ContainerMover**	**Mover Beam-Lift**	**fr + r**	short push downwards to joy stick and release				Moverbeams (+container) will be lowered. Container descents onto the 4 pins. Check if this is the case at all 4 corners
7.	**Returning the contact bridges to the truck**	**Contact Bridge**	**fr + r**	push joy stick downwards until automatic stop				Contact bridges are automatically retracted
	retraction of hydraulic feet		***all***			***automatic execution***		*The hydraulic feet are retracted automatically*
	lowering of consoles		**fr + r**			***automatic execution***		*Consoles are lowered automatically*
8.	**Closing of twistlocks**	**Twist-locks**	**v + h**	closing				check if all twist locks are in closed position
	Ready for driving!							

Figure 12 – 8 Steps to shift a container from the wagon to the ContainerMover

2.3 Measuring horizontal distances between truck and waggon

Up to now we were able to measure the horizontal distance between ContainerMover and wagon (wagon adaptor) accurately using standard ultrasonic sensors. Since 2015, InnovaTrain has been using them on all its delivered ContainerMovers.

Figure 13 – The screen in the cab and one of the ultrasonic sensors

The relative distance to the wagon is automatically measured both at the front and at the back of the ContainerMover.
This distance is then used to determine the necessary length the contract bridge has to be ejected towards the wagon adaptor to cover the distance between ContainerMover and wagon adaptor. As the contact bridge is pushed out by hydraulic cylinder, we can use integrated cylinder position measurement (linear encoder) to arrive at the exact position at the wagon adaptor.

Figure 14 – the linear encoder for measuring the exact distance the contract bridge is ejected.

2.4 Steps taken to come to fully automatic transhipment

Introduction
As can been seen from the two handling-processes for the horizontal transfer in the previous paragraph, the driver is initiating the different steps of the transhipment process, but the system then runs the steps itself and ends a movement automatically when an end-position is reached. After each step is finished, the driver initiates the next step.
In order to come to a fully automatic loop it would only be necessary to connect the different actions in one single movement. This would be possible if there was not one action that still needed active guidance by the driver.

Problem to overcome
The only action where an active control form the driver is required is when the contact bridge is to be positioned on the wagon adaptor. This needs to be done with active eye surveillance and active steering of the height of the consoles and the relative length of both the contact bridges.

Figure 15 – The contact bridge between ContainerMover and Wagon Adaptor

The reason it took long to automate this step was the fact that the relative height of the wagon against the truck is not a fix parameter, but differs with the wagon type and the local situation of street surface height against the rail tracks.
We were able to measure the horizontal distances between the truck and the wagon accurately, but not its relative vertical height against the wagon.

To perform this step of positioning the contact bridge onto the wagon adaptor the active surveillance of the driver was still required:

The vertical positioning of the two contact bridges on the wagon adaptor,
Which is presented on the next picture:

Figure 16 – Adjusting the height of the two “contact bridges”

2.5 The use of an “intelligent” Camera

As explained in the previous paragraph, the steering of horizontal position of the contract bridge has been solved. The greater challenge was the steering of the vertical position of the contract bridge against the relative height of the wagon adaptor.

After much discussion and extensive research on this topic, we decided on the use the method of digital image reading. This method is used in the industry to help robots to position their tools and recognize objects and their relative position. If we would be able to define the exact position of the “cross-hair-sign” on the wagon adaptor, we would also be able to position the ContainerMover system in a three dimensional way.
The process would be the same as done previously by the driver: Instead of the human eye and brain, the camera and the software are giving the information for the steering.

It is necessary to perform this measurement at both sides (front and rear) of the truck, so there are two cameras needed. The steering and controlling of the height at the front console and that of the rear console must be done independently from each other as there is no guarantee that road and rail track are 100% parallel to each other.

After some discussions with suppliers and first tests, we decided on a high-resolution VCXG-53M.I camera from the manufacturer Baumer Electric AG (Switzerland) in combination with the image reading and image analysis software from National Instruments.

In a next step, we have equipped a new ContainerMover with a complete set of two cameras and further necessary hardware:

- 2x Baumer Industry camera VCXG-53M.I
- 2x IP-hardcover for protection
- 2x Lens: Kowa LM8HC 8mm/f1.4
- 2x Filter <780nm block 1“-32 H2,5mm
- 2x Infra-red led light
- 1x Industry PC Fabrimex S-SPC-352019022018200
- necessary cables and plugs

Figure 17 – Industry camera Baumer VCXG-53M.I

Having extensive experience with the use of normal digital cameras for the manual position we also decided to use the infrared light-spectrum in addition to the normal spectrum. The reason for this is that the ContainerMover has to operate in all weather conditions, at night times as well in full sun light conditions. Especially for the last situation, with its possible sunlight reflections, the infrared spectrum gave us very good and stable results.

3. Full automatic horizontal transhipment

3.1 New process of automatic horizontal transhipment

A. Positioning of the ContainerMover at the right lateral position rel. to the wagon

The procedure of the positioning of the ContainerMover truck is not affected by the automation, because we will not interfere with the steering and driving of the truck. The positioning procedure of the vehicle is done manually by the driver.

Figure 18 – Wagon adaptor with “cross hairs sign” for positioning

Process of Positioning the ContainerMover-Truck at the railway wagon

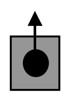
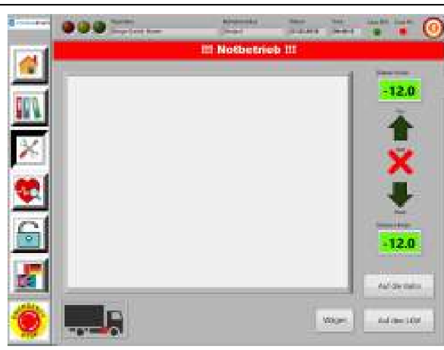
	Where to act / to look	joy-stick	What action to do
1.	**Screen in Cab**		◆ switch to side camera for positioning at the railway waggon (at cross hairs sign)
2.	**Marking line on platform**		→ drive parallel to the marking line on the railway platform
3.	**Choose right slot on railway wagon (screen in cab)**		● halt in front of container slot ◆ lift the Mover-Console until you see the level of the wagon adaptor on the screen
4.	 To position the ContainerMover truck exactly at the container slot (screen in cab)		→ slowly advance with truck ◆ steer the truck in parallel position (both front and rear distances should be equal) ◆ The correct position is reached at the moment the red cross appears on the screen
6.	**Block the ContainerMover truck**		◆ initiate the parking brake

Figure 19 – Process of Positioning the ContainerMover-Truck at the railway wagon

After blocking the ContainerMover with its parking brake the process of automated horizontal transhipment can be started.

B. The horizontal transhipment automated

The process is started from the screen (tablet):

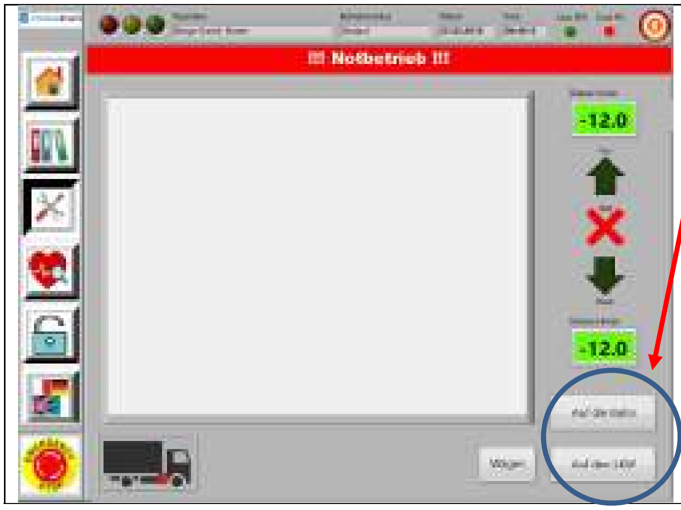


Figure 20 – starting transhipment

The transhipment is started with the push on this button. At the same time, the joystick on the remote control must be held in the forward position.

The moment, the driver lets this position of the joy stick go, the transhipment will stop immediately.

	Steps	*Switch-mode*	*operation performed*
0.	**Start Transhipment by pushing the start button on the screen**	**keep joystick in forward position**	Transhipment is started
1.	**Open twist locks**	¦	the 4 twislocks are autoatically opened
2.	**Lower hydraulic feet**	¦	conical wedge at the rear of truck will go down, all feet are on the ground and vehicle is pushed up 4 cm
3.	**Align Mover Consoles**	¦	If necessary you can interfere to change angle
4.	**Connect the contact bridges to the waggon adaptor**	¦	The contact bridge is pushed the exact length to the wagon adaptor in a position of 2 cm above the contact plate of the wagon adaptor . In a next step, the two consoles are lowered untill the contact bridge is on the wagonadaptor.
5	**Push moverbeams from CM under container on waggon adaptor**	¦	Mover will automatically stop when beams are exactly under the container
6.	**Lift Container**	¦	Container will be lifted from pins on waggon
7.	**Transhipment of Container to the waggon**	¦	Transhipment is halted at 2/3 of stretch in order to automatically adjust the rel. level of Mover against Wagon adaptor (caused by tilt-movement of wagon) Mover will automatically stop when container is exactly over the 4 pins on ContainerMover
8.	**Lower Container on ContainerMover**	¦	Moverbeams (+container) will be lowered. Container descents onto the 4 pins. Check if this is the case at all 4 corners
9.	**Returning the contact bridges to the truck**	¦	Contact bridges are automatically retracted
10.	**retraction of hydraulic feet**	¦	The hydraulic feet are retracted automatically
11.	**lowering of consoles**	¦	Consoles are lowered automatically
12.	**Closing twist locks**	**let loose of joystick**	check if all twist locks are in closed position
	Ready for driving!		

Figure 21 – Process of automatic transshipment

During the transhipment procedure, the 12 above steps will be displayed on the screen:

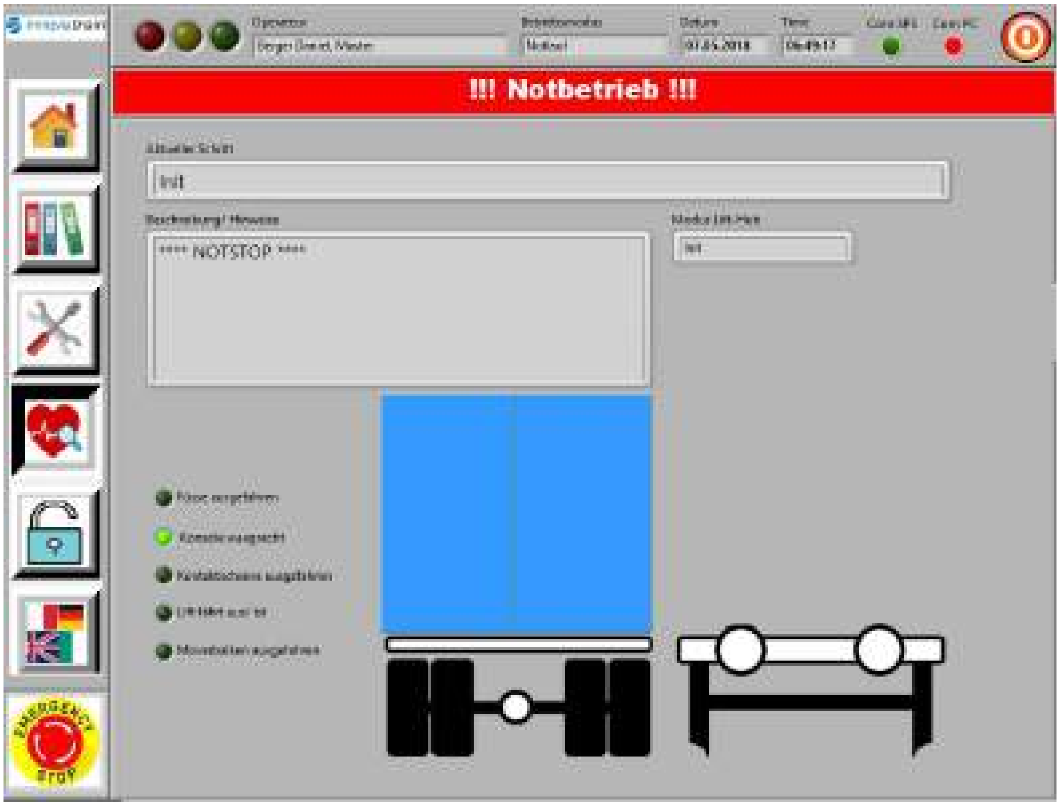


Figure 22 – lay out of the screen in the cab

4. Preparing the full-automated ContainerMover

4.1 A new ContainerMover with newest hard- & software.

In Conjunction with an order of a mayor client, a new ContainerMover was installed on a new full electric vehicle of the client (manufacturer: Gaussin (F). As both the vehicle and the ContainerMover were prototypes, it took from March up to November 2019 to have the complete vehicle ready and functioning.

Figure 23 – ContainerMover 3040 (Picture railCare)

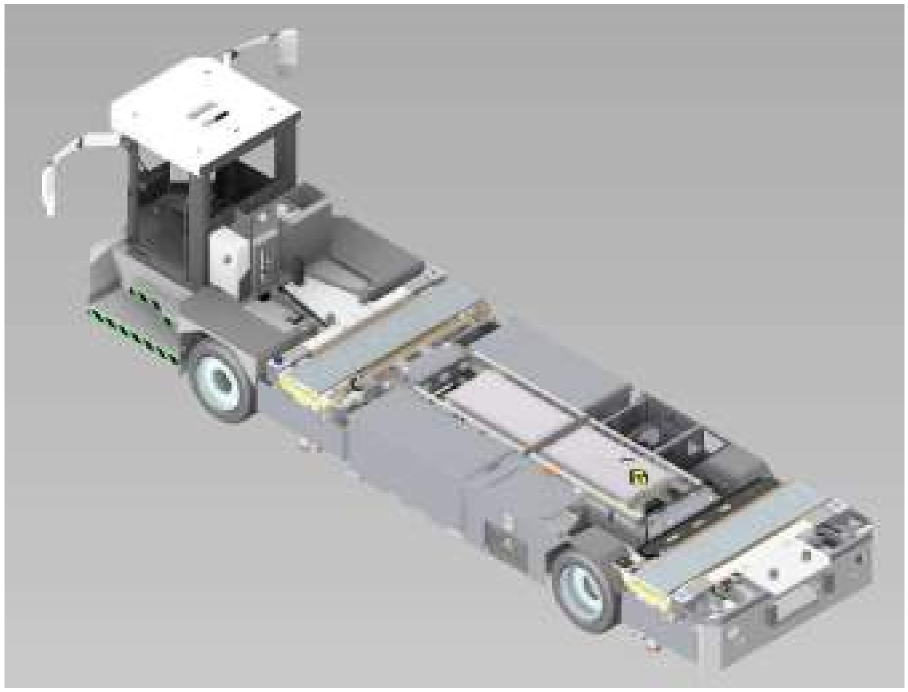


Figure 24 – ContainerMover 3040 (Picture railCare)

4.2 Installing new HD Camera's and extra ultrasonic sensors

	
New HD video cameras	Extra sensors for height measurements of the consoles

Figure 25 – HD Cameras and ultrasonic sensors (Picture InnovaTrain)

4.3 Performing first try-out at the wagon

Figure 26 – Positioning at the railway wagon container slot

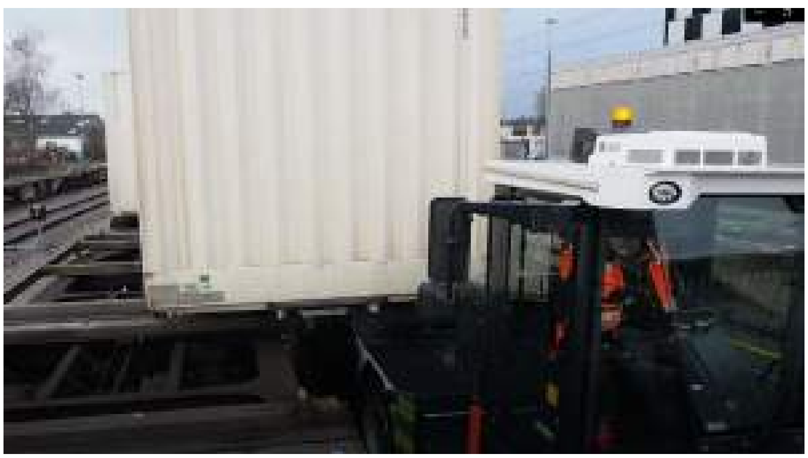


Figure 27 – automatic transfer

Figure 28 – driving away with container

Clusters 2.0

5. LL3 Tests with automatic horizontal transhipment

5.1 Testing Plan

We did 2 roundtrips, starting with driving with an empty ContainerMover through the gate to the tranship area and picking up the container by the ContainerMover from the railway wagon and driving it with container out of the gate. Then turning around and returning with the container to the transhipment area and shifting the container back on the railway wagon, and leaving the area empty again via the gate.
The distance between the gate and transhipment area was around 600 meters.

I. Transfer of container from rail to road

Rail to Road

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time	**0:00:00**	time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:00:00	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:00	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : “ready to drive“	0:00:00	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:00	duration
			Total duration	**0:00:00**	duration
6	Vehicle exit from Hub / End of sequence		End time	**0:00:00**	time

II. Transfer of container from road to rail

Road to Rail

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time	**0:00:00**	time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:00:00	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:00	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : “ready to drive“	0:00:00	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:00	duration
			Total duration	**0:00:00**	duration
6	Vehicle exit from Hub / End of sequence		End time	**0:00:00**	time

5.2 Results of the 4 runs

1. Rail to Road

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time	**10:14:00**	time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:01:10	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:49	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : "ready to drive"	0:04:21	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:48	duration
			Total duration	**0:07:08**	duration
6	Vehicle exit from Hub / End of sequence		End time	**10:21:08**	time

2. Road to Rail

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time	**10:34:30**	time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:01:24	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:33	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : "ready to drive"	0:04:38	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:54	duration
			Total duration	**0:07:29**	duration
6	Vehicle exit from Hub / End of sequence		End time	**10:41:59**	time

3. Rail to Road

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time	**11:04:00**	time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:01:09	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:25	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : "ready to drive"	0:04:35	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:43	duration
			Total duration	**0:06:52**	duration
6	Vehicle exit from Hub / End of sequence		End time	**11:10:52**	time

4. Road to Rail

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time	**11:23:00**	time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:01:19	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:50	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : "ready to drive"	0:04:25	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:49	duration
			Total duration	**0:07:23**	duration
6	Vehicle exit from Hub / End of sequence		End time	**11:30:23**	time

Summary of Results (Averages)

Step Nbr	Item Description	Description of moment of Start	Description of moment of End	Duration in seconds (difference)	Notes
1	Vehicle Enty on Hub / Start of sequence		starting time		time
2	Vehicle going to container slot at waggon group	driving from arrival point	stopping at slot at wagon	0:01:15	duration
3	wagon-positioning procedure	start of driver using side camera	vehicle correctly positioned	0:00:39	duration
4	automatic horiz. transhipment	Start of initiating the aut system	End of aut transhipment. System : "ready to drive"	0:04:30	duration
5	vehicle driving from wagon slot to exit of hub	Starting driving at wagon	Passing exit gate hub	0:00:48	duration
			Total duration	**0:07:13**	duration
6	Vehicle exit from Hub / End of sequence		End time		time

Figure 29 – summary of testing results

5.3 Comment on the test-results

The total time for a complete run (starting at the gate – transhipment of container – coming back at the gate) was 7 minutes and 13 seconds
The transhipment part at the wagon itself is 4 minutes and 30 seconds, which is around one minute longer than the transhipment with the semi-automatic version (3020) where the driver is initiating the intermediate process steps.

The reason why the incoming drive of the vehicle to the wagon takes more time than the returning drive in direction of the gate is:
At this compact hub, the ContainerMover - when coming to the wagon - needs to turn around to be able to position itself parallel with the right side to the wagon.

For the fact that the automatic transhipment takes more time than the semi-automatic version, we have the following explanation:

1. Extensive data processing by the special software: As explained in 2.4. and 2.5, the system is equipped with two high definition cameras and one high performance PC. As there is only one central PC, the calculations for the automatic height adjustments to level the contract bridge with the wagon adaptor takes its time and is done in sequence: first the front, then the back. This takes time.

2. Safety margin when lowering containers: The lowering of the container on the truck or wagon, after the horizontal shift is done by letting the air out of the air cushions situated in the mover beams. The exact moment that the full weight of the container is away from the two mover beams and on the 4 twist locks, cannot easily be determined. (In case of the semi-automatic ContainerMover, it is the driver who can determine this moment.)
   In order to be sure that the container is fully separated from the mover beams and fully on the twist locks we have chosen for a minimum extra time of 30 sec to be elapsed after the air pressure has dropped to 1 bar (normal atm. air pressure).

3. Sequential use of electric power: The special full electric vehicle was so programmed that the 3 mayor energy users (driving / hydraulic pump / air-pump) could only be used in sequence, not in parallel mode. So you can't do a hydraulic height adjustment to the CM when driving, or the air pressure tanks can only be filled when the two other utilities are not used. With less air-buffer tanks in this vehicle than on the diesel driven ContainerMovers. This caused a slow air system.

5.4 Extra remarks about the camera solution for positioning of contact bridges on the wagon

We have been using the high-resolution VCXG-53M.I camera from the manufacturer Baumer Electric AG (Switzerland) in combination with the image reading and image analysis software from National Instruments.

Apart from the longer transhipment time due to the slow processing of data in the automatic system, the test results revealed that the camera system is quite sensitive to the provision and sources of light and the stability of it. On the one hand it is sensitive for blinding effects from strong incoming sunlight and especially in the early morning or late afternoon (dawn/dusk), on the other hand we have seen disturbances during night time, when spotlights and headlights from other vehicles cause problems.

This makes the system too unstable and too unreliable to be used in normal day to day operations in all kinds of weather circumstances. A result which is not satisfactory.

5.5 Conclusion and comparison with durations on public terminals

The conclusion is therefore that the actual tested prototype of a fully automatic version of the ContainerMover is at least one minute slower than the existing semi-automatic version. Therefore the total time for a run (gate in - gate out) with the semi-automated version on the test hub would be around 6 minutes. It must be the goal to reach this duration also for the fully automatic version.

What is interesting and important to know is what the duration of a run (truck arriving at the entrance gate / transhipment at terminal / truck at exit gate) at a public terminal normally is.

The actual transhipping speed of an overhaul gantry crane or reach stacker at the moment the truck is served by the crane can be very fast: one to max two minutes for an ISO container. Transhipping a swap body by using the four grapple-arms by crane or reach stacker takes much more time (minimum 10 minutes).

Figure 30 – reach stacker using crappler arms for a swap body
Source: http://the-mediarail-chronicles.blogspot.com

It hard to get trustworthy information from the terminals themselves about the average duration of a terminal handling: “gate in – gate out”.

We have asked a local transport company from the Basel area. This was the reply:

Terminal area (public terminal)	Duration of total handling (min.)
Basel port terminals	60 – 120 min
Inland terminal	30 minutes

These long total terminal times are mainly caused by waiting times due to overload of the terminals.

But even if we take the 30 minutes as a benchmark for the “gate in – gate out” time of a public terminal, the Container-Mover hub is still 5 times faster, and therefore much more efficient in time.

6. New approach in the final months of Clusters 2.0.

6.1 Introduction

Motivated by the disappointing results of the solution with the two HD-cameras and special software, InnovaTrain has come up with a new idea to tackle the problem of determining the relative height between ContainerMover (contact bridge) and the wagon and the subsequent process of realignment of the ContainerMover with the wagon adaptor (wa).

6.2 Using inductive proximity sensors

The new idea is to make the tip of the contact bridge sensitive for its distance to steel, by using an inductive proximity sensor in its tip. The big advantage of this technique is the fact that these sensors are not disturbed by dirt or bad weather conditions. So the idea is that the ContainerMover, instead of looking for the vertical distance to cover in order to reach the height of the wagon, it will be feeling the moment it reaches the wa.

This can be done with inductive proximity sensors like from SICK AG (Germany):

Housing	Cylindrical thread design
Housing	Short-body
Thread size	M30 x 1.5
Diameter	Ø 30 mm
Sensing range S_n	15 mm
Safe sensing range S_a	12.15 mm
Installation type	Flush
Switching frequency	500 Hz
Connection type	Male connector M12, 4-pin
Switching output	PNP
Output function	NO
Electrical wiring	DC 3-wire
Enclosure rating	IP67 [1]

Figure 31 – Adjusting the height of the two “contact bridges”

The logic of the process is as follows:

As the horizontal distance between the ContainerMover and the wagon adaptor is already measured in a reliable way with the installed technique via ultra-sonar-sensors, we need to concentrate on the vertical position of the contact bridge against the wa.

We are looking at step three (see figure 10, page 13), resp. step two (see figure 11, page 14) of the sequence where - in the semi-auto version - the driver uses his eye sight to steer the contact bridge downwards to the wa:

Steps (to initiate)		Switch-mode		Procedure/Action	S	step selection joy stick			S	Important to watch/note
2.	to connect the contact bridges to the waggon adaptor	Contact Bridge	fr + r	push joy stick upwards and holt it (automatic stop)						Attention: check the relative height position of contact bridge to waggon adaptor! Commence with 3 cm above wagon adaptor
		Mover-Consoles	fr + r	push joy stick downwards until the contact bridges are down on the waggon adaptor						Attention: lower both contact bridges onto wagon adaptor. Look at front and rear contact bridge, and apply just a light pressure with contact bridge.

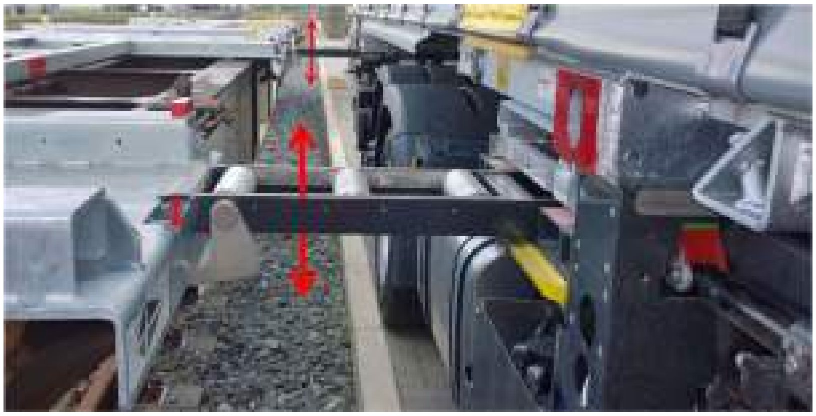


Figure 32 – Adjusting the height of the two “contact bridges”

After consulting possible suppliers of inductive sensors we learned that these sensors work with a magnetic field that they produce themselves and in difference with ultra-sonar-sensors, the metal-detecting range is limited in the distances it can detect metal objects.

6.3 Positioning of the inductive proximity sensors

An optimal position for the sensor would be a vertical one, as it primarily needs to detect the wa from above. But, due to the construction of the contact bridge it is impossible to arrange the sensor in a vertical position. So we were left with the only option to install the sensor in a horizontal position and also mounted flush to the back side in the tip. This position also reduced the choice of type of sensor and as a consequence limited the detecting range to 15mm.

We took the tip of the contact bridge and with the aid of a sensor with max range of 15mm, we did the following test in our workshop in the last week of January 2020:

Figure 33 – Test Lab picture 1

Clusters 2.0

Out of 8mm S355 steel we produced two central parts:

- the tip of the contract bridge, with appropriate 30mm hole for the censor
- the central sector of the wagon adaptor unit where the contract bridge supports on.

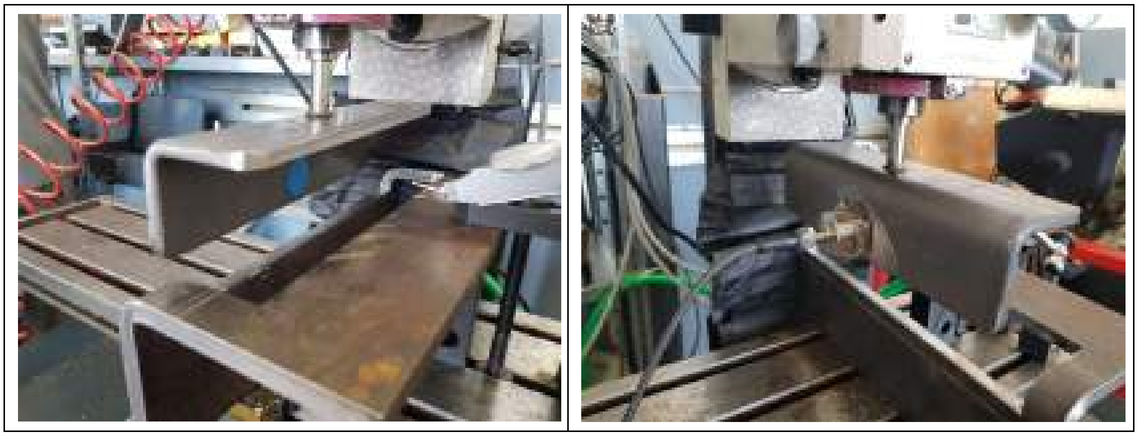


Figure 34 – Test Lab pictures 2 & 3

With the help of a CNC-milling machine, capable of moving objects in 3D directions in high precision, we were able to simulate the movements of the tip of the contact bridge against the central part of the wa.

The tip of the contact bridge was then moved in X and Z direction, according to figure 33:

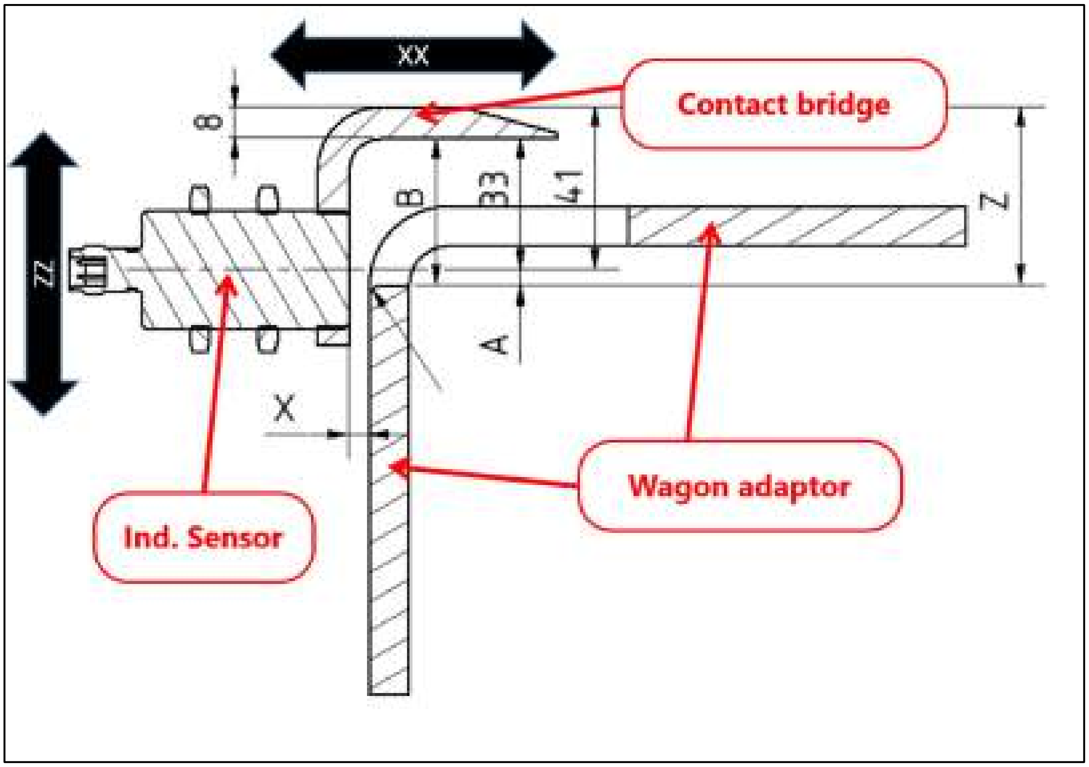


Figure 35 – drawing of tip of the contact bridge and wagon adaptor sector

We started in a position of the tip on a level high over the wa with X=0. X=0 means that its horizontal position is equivalent as to just touching the wa vertically when coming down along the Z line.

The CNC Machine was so programmed that it lowered the bridge-tip with a speed of 16 mm per second. The machine was simply stopped by the sensor itself at the moment the sensor signalled the metal of the wa.

After the sensor then reacted and stopped the downwards movement, we measured the vertical distance Z which was th easiest to measure. The distance B is the roughly the distance the contact bridge still has to go in order to lay flat on the contact bridge.

Distance B = Z – 8 mm (thickness of the used steel plate)

The bridge-tip was then moved up again, the horizontal X distance was increased with one mm and the downward movement was activated again until it was again stopped by the sensor.

This was repeated until the sensor didn't react anymore because the wa was out of reach of its limit. The test was done with two different sensors: one with reaction distance (switch point) of 10mm and one with 15mm.

In total we did 2 runs with both sensors and also lowered the speed of the vertical movement to see if that had any effect.

6.4 Results

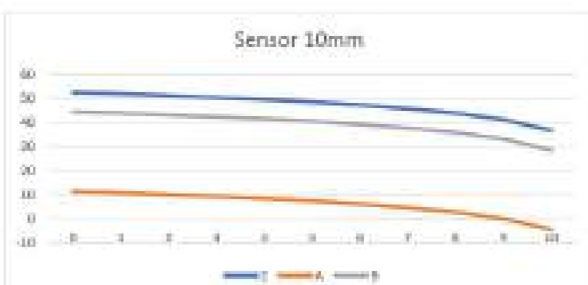
Messdaten

Sensor 10 mm

X	Z	A	B
0	52.3	11.3	44.3
1	51.8	10.8	43.8
2	51	10	43
3	50.2	9.2	42.2
4	49.4	8.4	41.4
5	48.4	7.4	40.4
6	47.1	6.1	39.1
7	45.6	4.6	37.6
8	43.8	2.8	35.8
9	41.1	0.1	33.1
10	36.6	-4.4	28.6
11	-	-	

Sensor 15 mm

X	Z	A	B
0	56.9	15.9	48.9
1	56.4	15.4	48.4
2	55.9	14.9	47.9
3	55.4	14.4	47.4
4	54.9	13.9	46.9
5	54.5	13.5	46.5
6	53.85	12.85	45.85
7	53.15	12.15	45.15
8	52.6	11.6	44.6
9	51.7	10.7	43.7
10	50.7	9.7	42.7
11	49.75	8.75	41.75
12	48.75	7.75	40.75
13	47.2	6.2	39.2
14	45.7	4.7	37.7
15	43.6	2.6	35.6
16	40.7	-0.3	32.7
17	36.4	-4.6	28.4



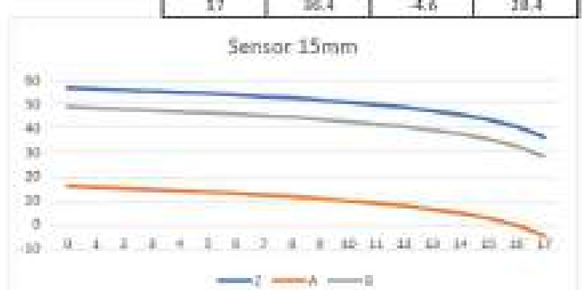


Figure 36 – switching moments of the sensors (distance B) against horizontal distance X

As can be seen from the above results, the contract bridge stops coming down at a distance dependent on its horizontal distance X to the wa. For instance, the sensor with switch point 15mm stops the contact bridge at almost 5 cm above the wa when he is horizontally very close to the WA. The moment the horizontal distance X reaches the 15mm he stops later and deeper (around 30 mm above the wa).

It came out that the repeating results were less than half an mm apart. This means that the sensors are very stable when it comes to their switching moment.

6.5 Further steps to take

The current semi automatic version 3020 of the ContainerMover software is already capable of positioning the tip of the contact bridges at 0.5 cm horizontally from the wagon adaptor (wa).

In the tested setting, using a 15mm Sensor and with an X horizontal distance of 5mm to the wa, the contact bridge will stop at 46.5 mm (B) above the wa.

It seems possible (there is room) to shift the position of the sensor 10 mm up in the tip of the contact bridge. If we do so, this will lower the switching moment (B) of the sensor with 10mm, so it will then stop at 36.5 mm above the wa.

If the ultrasonic sensors really work within a small tolerance (less than 5 mm) and we are sure that the contact bridges will therefore stop at a vertical distance B of 36.5 mm above the wa, we can program the software in a way that - after the stop by the sensor - the system continues the downward movement of the contact bridge over 36.5 mm in order to get it level with the wa.

So the next step to take, should be

1. to adapt a ContainerMover with two new contact bridges, each equipped with the 15mm inductive switch sensor,
2. adapt the software in such a way that;
    a. after the positioning of the vehicle, the two mover consoles are placed in high (safe) position, then
    b. the two contact brides will be pushed out at a position with horizontal distance of 5 mm from the wagon adaptor, then
    c. the consoles will go down at around 15-20 mm per sec, then
    d. the proximity inductive sensor stops the this vertical movement when the contact bridge is at appr. 36.5mm above the wa., then
    e. the gap of around 36.5 mm is then automatically closed by the software, then
    f. the next full automated step (sideward movement of the container) can start.
3. do a test over a longer period and in all kind of weather situations.

7. Addendum: Small IM-terminals: Low operational costs at low annual volumes

7.1 Introduction: The stalemate

In order to reduce CO2 and other emissions and to avoid local and overall road congestion, it would be desirable to load and unload containers directly on the rail at a cluster point or even better, close to the point where the container is loaded or discharged with its cargo.

Theoretically, the maximum local rail usage would be realised with a classic single railway-wagon load system where single wagons are dispatched and picked up with shunting machines to and from local railway sidings.
The experience however at all mayor cargo railways is that such a system is expensive, slow and doesn't fulfil further requirements of modern logistics like temperature control.

The use of public and semi-public intermodal transports and the IM networks of IM-operators is an option to shift loads to the rail, but then there needs to be such a public terminal in the vicinity of both the shipper and recipient of the cargo, plus the desired connection must be offered by an operator.

For big retail or logistical companies who generate high volumes on certain transport relations a company-owned terminal could be an interesting option at least at one side of the chain. But this company-terminal seems only possible with high investments in special infrastructure and transhipment equipment. How can all these investment be paid back via services in a manageable period?

In most cases the answer is: they cannot, because:

1. without the costs of the terminal, the price for rail transport per container alone is already close to the price for the road transport alternative (so how are we going to pay for the terminal) and,
2. we don't know how long we are able to support the foreseen train-connection with enough load. (what if the volume breaks away in the near future?)

So how could this stalemate be overcome?

7.2 To overcome the stalemate

To overcome this stalemate of "desiring an intermodal solution but not being able to come up with a solid business case for it", can only be solved if input-parameters for the business case will get more attractive. In other words "coming closer to the advantages of road transport".

Advantages of road transport:

- Low investment / shorter payback period
- Flexibility concerning location

7.3 Lower investment / shorter payback period

How to get lower investment / shorter payback period?

A Cost-comparison between Reach Stacker and ContainerMover-4000

Basic parameters of the desired small hub:

- handling one, max two 500-600 m trains a day
- 600 m rail track alongside a loading area
- arrival of 30 to 40 containers a day by train → 60 to 80 transhipments a day
- daily average of 70 transhipments
- container weight maximum 34 tons (40ft. or 45ft.)
- no need to stack containers
- no need to handle different container sizes within one single process

ContainerMover type CM-4000 for horizontal transhipment on a three axle trailer, to be driven with a normal diesel tractor. 	

Figure 37 – ContainerMover-4000 and Reach Stacker

Surface needed:

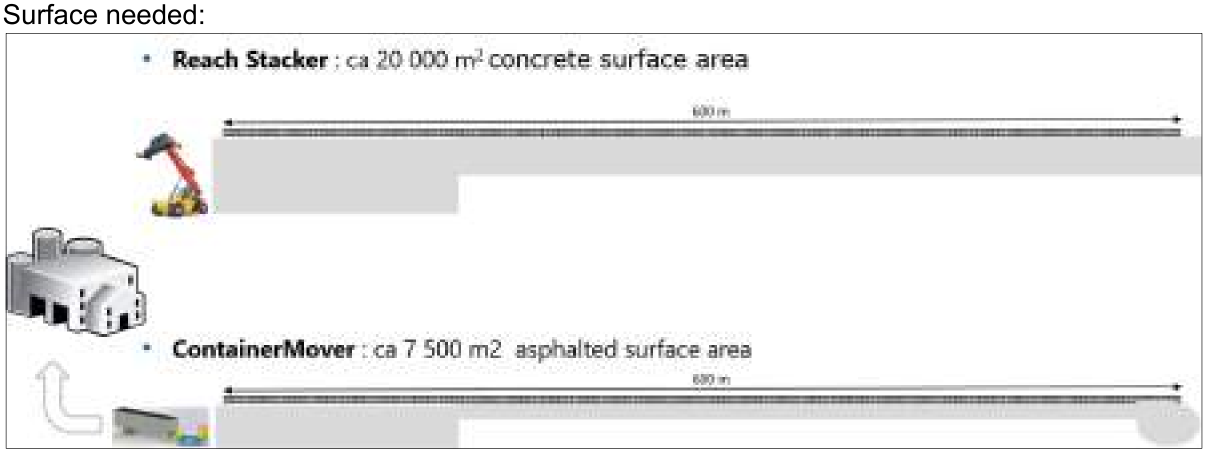


Figure 38 – working surface for a ContainerMover-4000 and for a Reach Stacker

The ContainerMover needs 60% less surface to operate

Comparison of investment costs, recalculated in annual costs:

RS = Reach Stacker **CM = ContainerMover** **70 moves/day**

					depreciation	interest	annual	
cost estimate area surface preparation				**investment**	**10**	**4%**	**total**	
		price/m2	m2					
RS	concrete : 30 m x 600 m + 2000 m2	€ 110	20000	€ 2'200'000	€ 220'000	€ 40'808	€ 260'808	RS
CM	asphalt : 7 m x 400 m + 4800 m2	€ 75	7600	€ 570'000	€ 57'000	€ 10'573	€ 67'573	CM
	cost advantage CM:			**€ 1'630'000**	**€ 163'000**	**€ 30'235**	**€ 193'235**	

equipment purchase				**price**	**subsidy?**	**8 years**	**4%**	**total**	
			Nr.	100%	0%				
RS	Reach Stacker	€ 460'000	2	€ 920'000	€ 920'000	€ 115'000	€ 18'400	€ 133'400	RS
CM	CM-4000 on 40 ft. trailer	€ 330'000	2	€ 660'000	€ 660'000	€ 82'500	€ 13'200	€ 95'700	CM
CM	road tractor	€ 90'000	2	€ 180'000	€ 180'000	€ 22'500	€ 3'600	€ 26'100	CM
CM	Wagen Adaptor Units	€ 3'500	40	€ 140'000	€ 140'000	€ 17'500	€ 2'800	€ 20'300	CM
CM	Container Docking Stations	€ 18'000	10	€ 180'000	€ 180'000	€ 22'500	€ 3'600	€ 26'100	CM
CM	total			€ 1'160'000	€ 1'160'000	€ 145'000	€ 23'200	€ 168'200	CM
	cost advantage RS:				**-€ 240'000**	**-€ 30'000**	**-€ 4'800**	**-€ 34'800**	
	Invest. cost advantage CM on balance:				**€ 1'390'000**			**€ 158'435**	

Figure 39 – Comparison of investment costs, recalculated in annual costs

Figure 40 – Comparison of operational costs for Diesel fuel and maintenance:

RS = Reach Stacker **CM = ContainerMover**

fuel cost estimate				**70 moves/day**					**annual**	
		price	l/hour	hours	Nr.	days a year				
RS	diesel	€ 1.30	20	10	2	250			€ 130'000	RS
CM	diesel	€ 1.30	7	10	2	250			€ 45'500	CM
	cost advantage CM							**Diesel**	**€ 84'500**	

tyres and maintenance cost estimate				**70 moves/day**					**annual**	
			H / Nbr.	Nr.						
RS	maintenance	250	10	2	€ 15.00	per hour		€ 75'000		RS
RS	tyres		6	2	€ 3'500	per tyre		€ 42'000		RS
RS	total maintenance							€ 117'000	€ 117'000	RS
CM	maintenance	250	10	2	€ 7.50	per hour		€ 37'500		CM
CM	tyres, incl tractor		18	2	€ 350.00	per tyre		€ 12'600		CM
CM	Container Docking Stations maintenance			10	€ 500.00	per year		€ 5'000		
CM	total maintenance							€ 55'100	€ 55'100	CM
	cost advantage CM							**maint.**	**€ 61'900**	
									€ 146'400	

The difference between the operational costs comparing ContainerMover and reach stacker:

Diesel & Maintenance, 70 moves a day / 250 days a year	**RS**	CM	**cost advantage CM hub**	**difference**
Annual diesel + maintenance costs	€ 247'000	€ 100'600	**€ 146'400**	**59%**

Figure 41 – difference in operational costs for Diesel / Maintenance

Summary of total annual costs (without staff)

annual costs estimate CM hub vs Reach Stacker (excl. staff)			
70 moves a day / 250 days a year with 10 Container Docking Stations	**RS**	**CM**	**cost advantage CM hub**
area preparation (asphalt CM/concrete RS)	€ 260'808	€ 67'573	**€ 193'235**
equipment purchase	€ 133'400	€ 168'200	**-€ 34'800**
fuel costs	€ 130'000	€ 45'500	**€ 84'500**
tyres and maintenance	€ 117'000	€ 55'100	**€ 61'900**
total costs per year	**€ 641'208**	**€ 336'373**	**€ 304'835**
costs per move 70 moves a day	**€ 36.64**	**€ 19.22**	**€ 17.42**

Conclusion:

Based on above parameters there is a cost reduction of 47% on all equipment use when using the horizontal transhipment technique instead of reach Stackers.

This cost advantage plus the 60% less land-use, makes the horizontal technique clearly much more suited for smaller terminals.

7.4 Flexibility concerning location

Using large equipment like overhead gantry cranes or reach stackers for an intermodal terminal makes the terminal immobile. It becomes very costly if you want to move the terminal equipment to another location.

This is very clear for the overhead gantry cranes, but also in the case of a reach stacker there are considerable costs:

- a Reachstacker has a death weight of 40 – 50 tons and has oversize dimensions
- you need concrete floor to operate, due to massive axle pressures of the front wheel (100 tons) when lifting and transporting containers

Instead, when using the horizontal transhipment technique, where a more or less standard trailer is used, a normal asphalted floor will do.

Furthermore, the horizontal technique like the ContainerMover of InnovaTrain can be homologated for the public road and therefore be used at different locations on the same day. This capability is used by railCare AG in Switzerland, where ContainerMovers are used at daytime in Thun and in the night in Bern.