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Comparative evaluation of transhipment technologies for intermodal transport and their cost

Final Report

Written by
PricewaterhouseCoopers
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BERATEN PLANEN UMSETZEN

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1. Structure of the report

This document is the final report of the study on the comparative evaluation of transhipment technologies for intermodal transport and their cost. This is the sixth deliverable submitted by PricewaterhouseCoopers EU Services and KombiConsult GmbH to the Directorate General for Mobility and Transport (DG MOVE) of the European Commission.

The objective of this study is to provide a technical and economical comparative analysis of intermodal loading units (LU) and transhipment technologies (TT) as one of the foundations of intermodal transport and their operating and total system costs which will support the European Commission in future legislative and financial initiatives to increase sustainability in the transport sector through modal shift.

To this end, the technical specifications, necessary investments, operational costs and effectiveness of different intermodal loading units and transhipment technologies were identified. Furthermore, combinations of loading units and transhipment technologies in intermodal transports are compared within each other and with road-only unimodal transports.

The study is divided into four main technical tasks aiming to establish the following set of information:

- a detailed list of all different types of loading units and transhipment technologies in intermodal transport (Task 1);
- costs and investments needed for all different transhipment technologies (Task 2);
- EU and Switzerland intermodal network data (Task 3);
- comparative analysis of different transhipment technologies (Task 4).

The present report shows the results addressed in carrying out the above-mentioned Tasks. In particular Chapter 3 will provide the results addressed in performing Task 1 and Task 2, Chapter 4 is dedicated to Task 3 and finally Chapter 5 will present the results of Task 4.

2. Introduction

Freight transport and logistics are essential for the economic activity in the Single Market and quality of life in Europe at large. In 2019, the sector generated approximately EUR 675 billion of gross added value (GVA) or about 5% of the EU's total Gross Domestic Product. With more than EUR 1089 billion spent on transport-related items by private households (13% of total consumption) and more than 1.2 million enterprises active in transport and logistics, it is clear that the sector is fundamental to the EU economy.[1]

The global breakdown of the freight transport sector by mode, useful to understand which branch is more impacted by legislative measures concerning loading units and, broadly speaking, innovative transhipment technologies, reveals that of the 108 trillion tonne-kilometres transported worldwide, 70% is done by sea, 18% by road, 9% by rail, 2% by inland waterway, and less than 0.25% is shipped by air.[2] When analysing the latest statistics available for inland transport in the EU, it is clear that road transport has the largest share of all transport modes in EU. With around 2000 billion tonne-kilometres, it accounted for 75.3% of the total inland freight transport in 2017. From this, ca 55% is long-distance road transport on distances on more than 300km. In that same year, rail accounted for 18.7% or 416 billion tonne-kilometres, while transport over inland waterways accounted only for 6% of the total inland freight transport.[3] Furthermore, in 2017 the transport and logistics sector employed more than 11.7 million persons in the EU, which amounts to 5.3% of the total EU-28 workforce.[4]

In addition to that, global freight traffic for inland modes is expected to triple by 2050[5]; Moreover, it is projected that surface freight traffic will grow by 53% by 2050 in the EU.[6]

[1] European Commission. (2019). EU transport in figures - Statistical pocketbook 2019, pp. 19, 25.
[2] OECD - International Transport Forum. (2019). ITF Transport Outlook 2019, p. 38.
[3] Eurostat. (2020). Energy, Transport and Environment Statistics: 2020 Edition, pp. 51-52.
[4] European Commission. (2019). EU transport in figures, Statistical pocketbook 2019, pp. 19, 25.
[5] OECD - International Transport Forum. (2019). ITF Transport Outlook 2019, p. 39.
[6] European Commission. (2018). In-depth analysis in support of Commission Communication COM (2018) 773 - 'A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy', p. 82.

3. Identifying a detailed list of all different types of loading units and transhipment technologies in intermodal transport

For the purpose of the following analysis, this task lists the different intermodal loading units and transhipment technologies to be investigated; furthermore, fact sheets containing technical information for each loading unit and each transhipment technology were prepared. The two lists were matched in a matrix form in order to easily depict the suitability of a certain transhipment technology in transhipping the different types of loading units. The task is closed by a description of the regulatory framework and processes required for bringing new loading units and transhipment technologies to market.

The loading units and technologies to be investigated in the following steps were identified in the first stage of compiling these lists. The indicative list of transhipment technologies provided by the European Commission in the ToR proved to be a qualified starting point, from which an investigation was conducted to identify missing intermodal loading units and transhipment technologies. To validate the listed elements and identify missing elements, information from previous studies, press releases, website information, and contacts from the intermodal industry and partner consulting firms were used. Two lists, one for loading units and one for transhipment technologies were thus created to be further investigated in this study.

3.1 Identify a detailed list of all different types of loading units in intermodal transport

This task focuses on the identification and description of standardized intermodal loading units. Transhipment technology specific loading units are not considered here but are described in chapter 3.2 in the framework of the description of transhipment technologies.

For freight-transport in (standard) intermodal loading units the study basically distinguishes containers, swap bodies, semi-trailers as well as road vehicles l (vehicle combinations (road trains, articulated vehicles) and single road vehicles[7]).

3.1.1 Container

Freight containers come along in the form of ISO-containers (sea containers) and non ISO-containers (inland containers).

ISO-containers

ISO-containers, intended for intercontinental traffic, are designed according to ISO 668[8] with standardised dimensions, for example, in terms of size, weight, door opening size, corner fittings. The ISO 668, defined by the International Maritime Organization (IMO), thereby regulates not only the external, but also the internal (minimum) dimensions of containers. Besides the external length of 20’, 30’, 40’ and 45’, there were also shorter containers with a length of 5’, 6-1/2’ and 10’ defined in former ISO 668 editions, but only the 10’ is still included in the current edition.

As can be seen in Table 1, not every dimension in length and height is foreseen as a combination.

[7] See Article 2 of Directive 96/53/EC amended by Directive 2002/7/EC and Directive (EU) 2015/719.
[8] Current version: ISO 668:2020-01, Series 1 freight containers — Classification, dimensions and ratings.

Table 1: Selected nominal external length and height of freight containers according to ISO 668 and their ISO code

Freight container designation		Nominal length (ft)			
		20’	30’	40’	45’
Nominal height (mm)	2 438 mm	1 C	1 B	1 A	-
	2 591 mm	1 CC	1 BB	1 AA	1 EE
	2 896 mm	-	1 BBB	1 AAA	1 EEE

Source: ISO 668, KombiConsult analysis

Besides the nominal heights presented in Table 1, reduced heights are permissible for certain types of containers, such as tank, open top, bulk, platform and platform-based:

- hard top - container consists of a removable metal roof;
- open top - container consists of a tarpaulin roof, thus this container cannot be stacked;
- open side containers: as the name says, it can be open also from the side;
- flat - container: platform-based containers with no side walls and no roof, but with two either permanently installed or foldable end walls; primarily suitable for very heavy and bulk goods;
- plat – container: consists of a simple base plate with no roof and no side and end walls; also, primarily suitable for very heavy and bulk goods;
- conditioned containers for the transport of temperature-controlled cargoes;
- bulk containers: consists of filling openings on the roof for bulk material;
- tank containers: consists of a round inner shape for the transport of liquids and gases.

Inland container

Sea containers have a standard external width of 8’ (= 2.438 mm). In Europe, the Euro-pallet is the standard for transporting goods. Its external dimension are 800 x 1 200 mm. To reach a better capacity utilisation of the loading units, and thus to reduce costs and to be more efficient, the dimensions of so-called inland containers, also called pallet-wide containers, are geared to the European pallet dimensions and consequently wider with an external width of 2 550 for normal or 2 600 mm for insulated containers. Thus, with an internal width of at least 2.440 mm, these containers are able to load either two or three European pallets side by side. Inland containers are used almost exclusively in the European transport market and are even accepted by sea shipping companies, in particular on Short Sea Shipping within Europe and from and to North Africa. Like sea containers, inland containers can be transhipped and locked by corner fittings according to ISO 1161 in order to fit the spreader and to the container spaces in ships.

Most common type of containers in terms of length used in container transport are 20’ and 40’ containers, and with a standard external height of 8’ 6’’ (2 591 mm) or 9’ 6’’ (2 896 mm, so-called high cube container). The predominant container is the 40’ container, but the still high share of 20’ containers shows that the advantage of economies of scale is sometimes limited. Due to their static and high load capacity in terms of tonnes equal to the 40’ container, 20’ containers are more suitable for heavier goods and smaller charges. Besides the 20’ and 40’ containers, 45’ pallet-wide containers are more and more in use, espcecially in European short sea traffic[9]. It can load 33 Euro-pallets, thus, 32% more than a 40’ standard container with 25 Euro-pallets. The manufacturer Unit45 even offers a 45’ pallet-wide container that can load 34 Euro-pallets. At the beginning the 45’ container was not well received. It did not fit in between the 20’ and 40’ containers on the ships, it led to problems in road transport, and for the transport on rail two 45’ containers did not fit on many

[9] https://unit45.com/de/aktuelle/45-ft-container-hat-aufwind-bekommen-59/.

intermodal wagons in use like two 40' containers. The first two problems were first solved by rounding the corners, also adjusting the size for wider containers and to comply with road transportation regulations[10], and later by amending the Regulation[11]. The amended regulation allows the maximum length of vehicle combinations transporting 45' containers or 45' swap bodies, empty or loaded, to be exceeded by 15 cm, provided that the road transport of the container or swap body in question is part of an intermodal transport operation. The third problem with the wagons could be solved by the increased number of longer (articulated) wagons that could carrry two 45' containers.

Tank Container

Tank containers, which are widely used in intermodal transport, were made especially for the transport of hazardous or non-hazardous liquids, powdered goods or gases for intra-European traffic. The vessels are surrounded by a frame which fits to the ISO container standard for the use in intermodal transport to be loaded and unloaded from the top and the bottom. Tank containers must be at least 80% full, to prevent dangerous surging movements during transport.

3.1.2 Swap bodies

Swap bodies are standardised in the norm EN 284 for class C ("short" swap bodies of 7.15m, 7.45m and 7.82m external length, though C715 are no longer included in the edition of the standard DIN EN 284: 2007-01), and EN 452 for class A ("long" swap bodies with length between 12.5m and 13.6m). There are two main types of swap bodies: bodies with a hard surface, which may be stackable up to three layers, and bodies with curtains and tarpaulins.

For rail transport they have to be fitted with equipment that allows transhipment according to UIC IRS 50592, but they can have several pick-up points to be handled not only by crane or reach stacker, but also by a forklift. However, all are equipped with lower "corner" fittings positioned in ISO 668 dimensions for 20' or 40' ISO-containers respectively, while for transhipment purposes they have grappler pockets in the standard distance of 4 876 mm. Some types of bulk containers even have both: a frame with lower and upper corner castings making them top-lift and stackable as well as grappler pockets allowing a heavier weight when lifting. Except for the longer 13.60 m swap bodies, most swap bodies have four supporting legs so they can easily be switched between road vehicles and switched off for intermediate storage. The width on the outside is 2.50 meters for regular and 2.60 meters for refrigerated swab bodies respectively, and 2.44 meters on the inside. Thus, like inland containers, the dimensions of swap bodies are adapted to Euro-pallets to be used mainly for continental transport. For freight forwarders and carriers, swap bodies are frequently used due to the fact that they can be handled quickly and switched without further technical equipment between road vehicles. The short swap bodies offer space for 17 (7.15m), 18 (7.45m) or 19 (7.82m) Euro pallets.

Their payload is up to 16 tons, so that a truck with a trailer can transport two swap bodies at once. The 13.60 m long swap body offers space for 33 Euro-pallets, equal to a 45' inland container and only one less than a semi-trailer. That being said, today there are even swap bodies that can carry 34 Euro-pallets, making them comparable to semi-trailers.

[10] Directive 96/53/EC of July 1996 laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic.

[11] Directive (EU) 2015/719 of the European Parliament and of the Council of 29 April 2015 amending Council Directive 96/53/EC laying down for certain road vehicles circulating within the Community the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic.

3.1.3 Semi-trailers

Semi-trailers are trailers with one or more own axles on the rear end, carried by a tractor unit to which they are connected via a kingpin on the semi-trailer and a coupling device called “fifth wheel” on the towing vehicle. Normally they are equipped with two legs that can be lowered to stand on its own when uncoupled. Motor vehicles and vehicle combinations or the type road trains (motor vehicle coupled to a trailer) or articulated vehicle (motor vehicle coupled to a semi-trailer) are designed according to different norms. Directive (EU) 2015/719, which amends Directive 95/53/EC, sets maximum dimensions and weights for international road traffic, also ensuring that Member States cannot restrict the circulation of vehicles which comply with these limits from performing international transport operations within their territories. In the European Union the maximum permitted length of the semi-trailer is 13.62 m.

Semi-trailers for vertical lifting are standardised in EN 16973 which includes general requirements like swept envelope, dimensions and positioning of the grappler pockets and other things. Relevant technical and operational data for semi-trailers can be found in Table 2 and Table 3.

Mega Trailer

The word “Mega Trailer” is widely used for a semi-trailer of 13.62 m length and an external height of 4 m and an internal loading height of 3 m allowing three box pallets (according to automotive industry standard) to be stacked on each other. These trailers have smaller but wider tires to compensate the load. They can also be built in the form of craneable semi-trailers for intermodal transport.

Euro Trailer

Since a high share of long-distance transports are said to be limited by the freight volume, but not by their weight, certain vehicle concepts for enhancing the maximum permitted length of trucks were developed. One of these concepts is the “Euro Trailer” (formerly known as “Big Maxx”), which is produced by the vehicle manufacturers Kögel and Fliegl. The length of the trailer is 14.92 m, which is 1.3 m longer than for other trailers. The extended semi-trailer was first used in 2006 in Germany as part of a nationwide test, and since the end of the tests in 2017 the Euro Trailer has been allowed in almost all German federal states, with the initial exception of Berlin until the end of 2023. For intermodal transport, the Euro Trailer does not play a big role, as cross border transports are not generally possible[12] due to different national regulations and from a technical perspective only fits on some pocket wagons with sufficient space such as the T3000e. Even more, the transhipment of the “Euro Trailer” from road to rail and v.v. is quite difficult due to small room for manoeuvring. According to available information, the “Euro Trailer Mega Rail” version with an interior height of 3 m might even not be accepted by intermodal operators, as the necessary clearance in the rear area cannot be achieved. As it stands, the future of the “Euro Trailer” in intermodal transport is uncertain, however in road-only, especially national, transport it is gaining further attention and momentum. This needs to be observed carefully, since the overall length is a sensitive figure for the compatibility of semi-trailers and rail wagon (see standard EN 16973). In practical application in particular if longer than 13.62 m trailers come

[12] Exemptions exist between Belgium and The Netherlands as well as between Scandinavian countries according to bilateral State Treaties. The recent Treaty between The Netherlands and Germany on the mutual acceptance of longer vehicle combination in cross border transport between .the two countries includes different type of vehicle combinations but not the truck and longer trailer combination (“Type 1“) (https://www.eurotransport.de/artikel/abkommen-mit-den-niederlanden-lang-lkw-auch-grenzueberschreitend-11189859.html).

together with 3 m internal height design ("Mega Trailer") and rear underrun protection devices which fulfil the standard ECE R 58.

3.1.4 Full road vehicles

Contrary to the containers, swap bodies and semi-trailers described before, road vehicles include a motor vehicle and thus are self-propelled vehicles which can be transported on specialized means of transport (for example "Rollende Landstraße"). Road vehicles can be distinguished into the two groups of single vehicles and vehicle combinations.

A lorry, which is neither a road train nor an articulated vehicle, is still included in the current Directive 92/106/EC as an eligible loading unit for the definition of combined transport, but not covered anymore by this language. It is a synonym used for "truck" and means a motor vehicle for the transport of cargo.

Vehicle combinations, as set in Directive 96/53/EC, hereby can be either road trains or articulated vehicles:

- a road train consists of a motor vehicle coupled to a trailer;
- an articulated vehicle consists of a motor vehicle coupled to a semi-trailer. "Articulated" hereby means that the coupling between the motor vehicle and semi-trailer is by a permanent or semi-permanent pivot joint.

There exist a variety of full road vehicles geared to specific customer's requirements. technical parameters are nevertheless displayed in the next chapter exemplary.

3.1.5 Technical comparison of loading units

The technical parameters of different types of loading units are shown in Table 2 and Table 3, which we derived from regulations, norms and other sources. As some technical parameters are fixed according to regulations (e.g. external dimensions), the loading capacity in terms of volume and weight may vary for each single loading unit as a result of different internal dimensions and weights. This is because, among other things:

- different manufacturers;
- different interiors materials (e.g. wood floor, steel floor, etc.);
- different uses (dry units, reefer, bulk, etc.);
- different age: use of more modern techniques and lighter materials but reaching the same strength. Some old units can exceed the stated weights below while newer containers are often slightly lighter.

As an example: for containers, the exact tare weight for an individual unit should be displayed on the container door. Typically, a standard 20' container weighs about 2.2 tonnes. But there are also 20' containers with 2.1 tonnes or 2.4 tonnes. High cube containers at those sizes have about 150 kg more weight: more height = more metal, but despite the higher weight they have a much better ratio in terms of volume per tonne. The opposite concerns for example reefer containers, which have not only about more weight to carry due to the cooling or heating unit and the insulation, but also less volume, which is also due to the unit and the insulation. To compensate for the additional weight of the cooling or heating system, at least partially, walls are often made of aluminium or composite material.

Table 2: Technical comparison of selected loading units (exemplary external and internal dimension)

Category	Type	External dimensions				Internal dimensions*			Area (m²)	Volume (m³)	Euro-pallets (n°)
		Length (ft)	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)			
ISO container	Standard	20'	6.06	2.44	2.59	5.87	2.33	2.35	13.7	32.1	11
	Reefer				2.59	5.45	2.29	2.27	12.5	28.2	10
	Open Top				2.59	5.90	2.33	2.34	13.7	32.2	11
	Hard Top				2.59	5.90	2.33	2.30	13.7	31.6	11
	Flat Rack				2.59	5.6	2.23	2.22	12.5	27.7	n.a.
	Bulk				2.70	5.90	2.34	2.50	13.8	34.5	n.a.
	HC				2.90	5.87	2.33	2.66	13.7	36.4	11
	HC Reefer				2.90	5.46	2.29	2.26	12.5	28.3	10
	HC	30'	9.13		2.90	8.93	2.33	2.66	20.8	55.3	18
	Standard	40'	12.19		2.59	12.00	2.33	2.35	28.0	65.7	25
	HC				2.90	12.00	2.33	2.66	28.0	74.4	25
	HC Reefer				2.90	11.57	2.29	2.49	26.4	65.9	23
	HC Open Top				2.90	12.02	2.33	2.65	28.0	74.2	25
	HC Hard Top				2.90	12.02	2.33	2.62	28.0	73.4	25
	Reefer				2.59	11.58	2.29	2.18	26.5	57.7	23
	Open Top				2.59	12.03	2.33	2.34	28.0	65.6	25
	Hard Top				2.59	12.02	2.33	2.30	28.0	64.4	25
	HC	45'	13.72		2.90	13.54	2.33	2.66	31.5	83.9	27
Inland container	PW	40'	12.19	2.55	2.59	12.00	2.44	2.35	29.3	68.8	30
	PW HC				2.90	12.00	2.44	2.70	29.3	79.1	30
	PW	45'	13.72		2.59	13.56	2.44	2.39	33.1	79.1	33
	PW HC				2.90	13.56	2.44	2.70	33.1	89.3	33
	PW HC (34 EUR)				2.90	13.62	2.44	2.72	33.2	90.4	34
	PW HC Reefer				2.90	13.32	2.44	2.57	32.5	83.5	33

Category	Type	External dimensions				Internal dimensions*			Area (m²)	Volume (m³)	Euro-pallets (n°)
		Length (ft)	Length (m)	Width (m)	Height (m)	Length (m)	Width (m)	Height (m)			
Tank container	20'	20'	6.06	2.44	2.44	n.a.	n.a.	n.a.	n.a.	20-26	n.a.
	20'				2.59	n.a.	n.a.	n.a.	n.a.	20-26	n.a.
	30'	30'	9.06		2.59	n.a.	n.a.	n.a.	n.a.	36.5	n.a.
	40'	40'	12.19		2.59	n.a.	n.a.	n.a.	n.a.	46.0	n.a.
	45'	45'	13.70		2.59	n.a.	n.a.	n.a.	n.a.	63.0	n.a.
	52'	52'	15.80		2.59	n.a.	n.a.	n.a.	n.a.	73.5	n.a.
Swap body	7.15 m	24'	7.15	2.55	2.67	7.05	2.44	2.40	17.2	41.3	17
	7.45 m	25'	7.45	2.55	2.67	7.36	2.44	2.40	18.0	43.1	18
	7.45 m Jumbo			2.55	2.98	7.28	2.44	2.71	17.8	48.1	18
	7.82 m	26'	7.82	2.55	2.67	7.76	2.44	2.40	18.9	45.4	19
	7.82 m Jumbo	26'		2.55	3.18	7.71	2.48	2.82	19.1	53.9	19
	13.60 m	45'	13.60	2.55	2.67	13.45	2.44	2.40	32.8	78.8	33
	13.715 m	45‘	13.72	2.55	2.95	13.61	2.48	2.55	33.8	86.1	34
Semi-trailer	13.6 m	45'	13.68	2.55	4.00	13.62	2.48	2.93	33.8	99.0	34
	13.6 m Mega	45'				13.62	2.48	3.00	33.8	101.3	34
	13.6 m Coil	45'				13.62	2.48	2.65	33.8	89.5	34
	13.6 m n.c.	45'				13.62	2.48	2.70	33.8	91.2	34
	13.6 m Mega n.c.	45'				13.62	2.48	3.00	33.8	101.3	34
« Euro Trailer »	14.9 m Rail	50'	15.25			14.92	2.48	2.70	37.0	99.9	34
	14.9 m Mega	50'				14.92	2.48	3.00	37.0	111.0	34
	14.9 m non n.c.	50'				15.00	2.48	2.70	37.2	100.4	34
	14.9 m Mega n.c.	50'				15.00	2.48	3.00	37.2	111.6	34
Vehicle Combination	Truck/semi-trailer	n.a.	16.50	2.55/2.60	4.00	13.60	2.45	3.00	n.a.	Various	34
	Road train	n.a.	18.75	2.55/2.60	4.00	Various	2.45	3.00	n.a.	Various	36

Table 3: Technical comparison of selected loading units (exemplary external dimension, weight, craneability, transhipment, stackable)

Category	Type	Length (ft)	Weight* Gross weight (t)	Tare (t)	Max. payload (t)	Craneable	Trans-shipment	Stackable Yes / NO	Up to
ISO container	Standard	20'	30.5	2.2	28.3	Yes	Spreader	Yes	9
	Reefer		30.5	2.9	27.5	Yes	Spreader	Yes	9
	Open Top		30.5	2.3	28.2	Yes	Spreader	Yes	9
	Hard Top		30.5	2.7	27.8	Yes	Spreader	Yes	9
	Flat Rack		30.5	2.7	31.3	Yes	Spreader	Yes	9
	Bulk		30.5	2.7	32.3	Yes	Spreader	Yes	9
	HC		30.5	2.4	28.1	Yes	Spreader	Yes	9
	HC Reefer		30.5	3.1	27.4	Yes	Spreader	Yes	9
	HC	30'	30.5	2.9	27.6	Yes	Spreader	Yes	9
	Standard	40'	30.5	3.8	26.7	Yes	Spreader	Yes	9
	HC		30.5	3.9	26.5	Yes	Spreader	Yes	9
	HC Reefer		30.5	4.5	26.0	Yes	Spreader	Yes	9
	HC Open Top		30.5	4.3	26.2	Yes	Spreader	Yes	9
	HC Hard Top		30.5	4.9	25.6	Yes	Spreader	Yes	9
	Reefer		30.5	4.5	26.0	Yes	Spreader	Yes	9
	Open Top		30.5	3.7	26.7	Yes	Spreader	Yes	9
	Hard Top		30.5	4.7	25.8	Yes	Spreader	Yes	9
	HC	45'	30.5	4.8	25.7	Yes	Spreader	Yes	9
Inland container	PW	40'	34.0	4.1	29.9	Yes	Spreader	Yes	6
	PW HC		34.0	4.6	29.4	Yes	Spreader	Yes	6
	PW	45'	34.0	4.8	29.2	Yes	Spreader	Yes	6
	PW HC		34.0	4.6	29.4	Yes	Spreader	Yes	6
	PW HC (34 EUR)		34.0	4.4	29.6	Yes	Spreader	Yes	6
	PW HC Reefer		34.0	6.1	27.9	Yes	Spreader	Yes	6

Category	Type		Weight*			Craneable	Trans-shipment	Stackable	
		Length (ft)	Gross weight (t)	Tare (t)	Max. payload (t)			Yes / NO	Up to
Tank container	20'	20'	36.0	3.8	32.2	Yes	Spreader	Yes	5
	20'		36.0	4.5	31.5	Yes	Spreader	Yes	5
	30'	30'	30.5	5.4	25.1	Yes	Spreader	Yes	5
	40'	40'	75.0	8.8	66.2	Yes	Spreader	Yes	5
	45'	45'	75.0	8.2	66.8	Yes	Spreader	Yes	5
	52'	52'	16.0	3.0	13.0	Yes	Spreader	Yes	5
Swap body	7.15 m	24'	16.0	2.3	13.7	Yes	Grappler arm	No/Yes	n.a.
	7.45 m	25'	16.0	3.0	13.0	Yes	Grappler arm	No/Yes	n.a.
	7.45 m Jumbo		16.0	3.0	13.0	Yes	Grappler arm	No/Yes	n.a.
	7.82 m	26'	16.0	3.0	13.0	Yes	Grappler arm	No/Yes	n.a.
	7.82 m Jumbo	26'	16.0	3.0	13.0	Yes	Grappler arm	No/Yes	n.a.
	13.60 m	45'	34.0	4.6	29.4	Yes	Grappler arm	No/Yes	n.a.
	13.715 m	45'	34.0	3.9	30.1	Yes	Grappler arm	No/Yes	n.a.
Semi-trailer	13.6 m	45'	39.0	7.2	31.8	Yes	Grappler arm	No	n.a.
	13.6 m Mega	45'	36.0	7.2	28.8	Yes	Grappler arm	No	n.a.
	13.6 m Coil	45'	36.0	7.8	28.2	Yes	Grappler arm	No	n.a.
	13.6 m n.c.	45'	39.0	6.6	32.4	No	n.a.	No	n.a.
	13.6 m Mega n.c.	45'	39.0	6.4	32.6	No	n.a.	No	n.a.
« Euro Trailer »	14.9 m Rail	50'	42.0	7.4	34.6	Yes	Grappler arm	No	n.a.
	14.9 m Mega	50'	39.0	7.7	31.3	Yes	Grappler arm	No	n.a.
	14.9 m non n.c.	50'	39.0	6.8	32.2	No	n.a.	No	n.a.
	14.9 m Mega n.c.	50'	39.0	6.9	32.1	No	n.a.	No	n.a.
Vehicle Combination	Truck/semi-trailer	n.a.	40/44.0	14.1	25.9/29.9	No	n.a.	No	n.a.
	Road train	n.a.	40/44.0	16.0	24/28	No	n.a.	No	n.a.

3.1.6 Share of intermodal loading units in Europe

Container

About 38 million TEU of standard containers are estimated to be currently in circulation around the world[13]. To avoid misunderstanding, this is the number of containers that are currently in use or in service, not the number of transport operations with containers that is recorded in transport statistics, where a single container can be counted more than once during a year while others disappeared in the “after market”. Estimations are that dry containers make up about 93% of this number, the rest is reefer containers with about 6 % and tank containers with about 1%[14]. That being said, 1% share for tank containers would mean about 380 000 units, but the International Tank Container Organisation (ITCO) estimates a tank container fleet of about 600 000 units. Thus, such numbers have to be treated with caution.

Nevertheless, as concerns the number of transported containers, about 152.5 million TEU were transported to and from European ports via ship in 2019[15]. According to the “2020 Report on Combined Transport in Europe”[16], which focuses on intermodal transport by rail, in the same year about 7.81 million TEU were transported on rail in domestic maritime intermodal transport and about 4.19 million TEU on rail in international maritime intermodal transport in Europe[17]. This sums up to about 12 million TEU for maritime intermodal transport or container hinterland transport on rail[18]: this is a share of almost 8% of the global sea container transport, which were transported on rail from the European seaports to the European hinterland and vice versa.

The “2020 Report on Combined Transport in Europe” also states that a total of about 24.8 million TEU were transported on rail in Europe (including continental intermodal transport). Thus, maritime intermodal transport accounts for about 48% of all transported goods in intermodal transport on rail.

The conversion factor between average loading units and TEU often varies between about 1.5 TEU per LU and about 1.7 TEU per LU, with a tendency towards 1.7 LU per TEU. On the basis of 1.7 TEU per LU, it would mean that a volume of 12 million TEU for maritime transport is equal to about 7.1 million containers, of which about 2.1 million LU would be 20’ container and about 4.9 million would be 40’ containers, assuming that other sizes are of a lesser share and are often not counted at all. Thus, 40’ containers account for 70% of all maritime containers transported by rail, and 20’ containers for about 30%.

[13] http://www.hamburg-container.com/en/container.html.
[14] Drewry Maritime Research.
[15] Destatis.de.
[16] 2020 Report on Combined Transport in Europe, November 2020. The Report aims to provide an assessment of the entire European combined transport market (https://uic.org/spip.php?action=telecharger&arg=3200); Although the Report is titled “Combined Transport” it does not only count “combined transport” but rather intermodal transport according to an explanation of the UIRR provided to DG MOVE.
[17] In the 2020 Report maritime combined transport means the movement of goods (mainly in containers with origin and/or destination overseas) between European seaports and European inland destinations by rail.
[18] In the 2017 Updating Study for the Commission the terms “Maritime Combined Transport” and “Container Hinterland CT” are defined as a combined transport operation, mostly of containers, that feeds to or delivers from maritime transport (short sea or ocean going) and they are used simultaneous.

Table 4: Volume of global sea shipping and European maritime CT by rail, 2019

European shipping volumes	European container hinterland transport by rail			
Total	Total		20'	40'
m. TEU	m. TEU	m. LU	m. LU	m. LU
152.5	12	7.1	2.1	4.9

Source: destatis.de, UIC/UIRR 2020 Report, KombiConsult analysis

As concerns EU inland waterway shipping, about 6.7 million TEU of containers were transported on inland waterways in 2019[19]. Eurostat thereby calculates the share of the different container sizes on basis of TEU-km. Assuming a similar share for TEU, we estimated about 4.2 million containers that were transported on inland waterways in Europe in 2019.

Table 5: Volume of European maritime intermodal transport by inland waterway shipping, 2019

European container hinterland transport by IWW					unit
Total	20'	>20' - <40'	40'	45'	
100%	26%	1%	72%	1%	%
6.7	1.7	0.07	4.8	0.07	TEU
	1.0	1.5	2.0	2.3	TEU/LU
4.2	1.7	0.04	2.4	0.03	LU

Source: Eurostat, KombiConsult analysis

Summarising rail and inland waterways, in total about 18.7 million TEU or 11.3 million containers respectively were transported in Europe in 2019. 20' container account for about 3.9 million containers, and 40' containers for about 7.4 million, considering that from the statistical side other sizes are of a lesser share. Nevertheless, it is worth to mention that other sizes are often not explicitly shown by the statistics. For the statistics on inland waterways, for instance, only Germany reported larger containers than 40'. Thus, this is only an assumption and especially the volume of larger sizes, such as 45' containers, may be higher.

Table 6: Volume of European maritime intermodal/container hinterland transport, 2019

	European container hinterland transport			
	m. TEU	m. LU	m. LU 20'	m. LU 40'
Rail	12.0	7.1	2.1	4.9
Inland waterways	6.7	4.2	1.7	2.4
Total	**18.7**	**11.3**	**3.9**	**7.4**

Source: UIC/UIRR 2020 Report, Eurostat, KombiConsult analysis

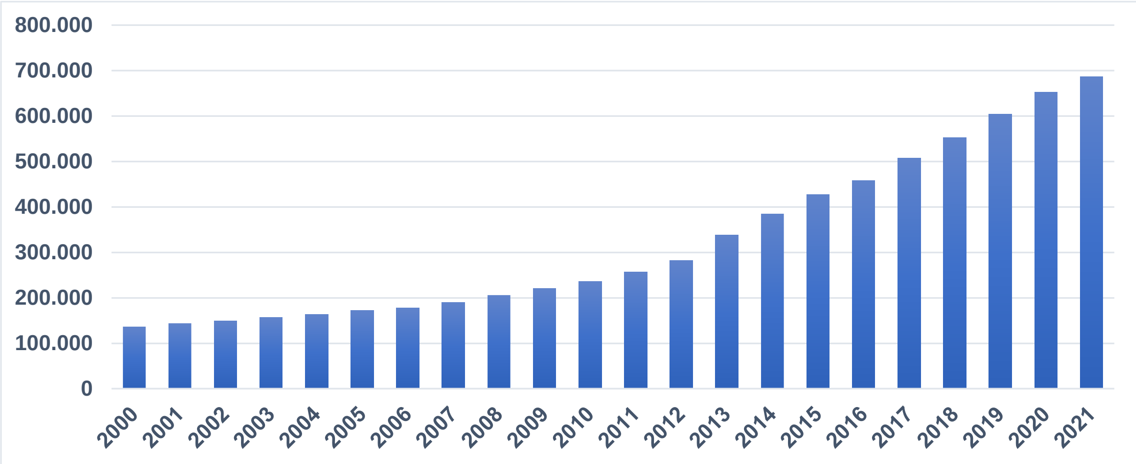
The aforementioned statistics and reports – despite their naming - focus mainly on intermodal transport which is also the scope of the present study and not on the combined transport only as defined in Directive 92/106/EEC. The statistical evidence of the difference between combined transport and intermodal transport is however not easily available.

[19] Eurostat.eu.

Tank containers

As concerns tank containers, the International Tank Container Organisation (ITCO) estimates that at beginning of 2021 the global tank container fleet stood at 686 650 units worldwide (2020: 652 350)[20].

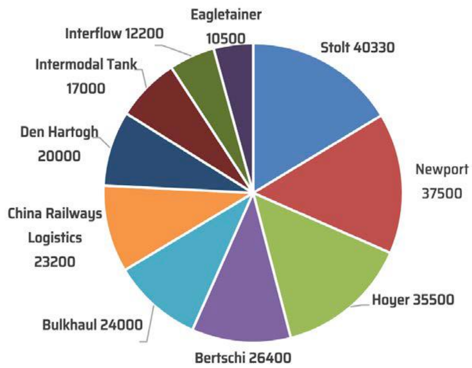
Figure 1: Tank Container World Fleet (2000-2021)



Source: ITCO, 2021 Global Fleed Report

The tank container market is thereby dominated by a relatively small number of players (tank container operators and leasing companies).

Figure 2: Top Ten Tank Container Operators (1 January 2021)



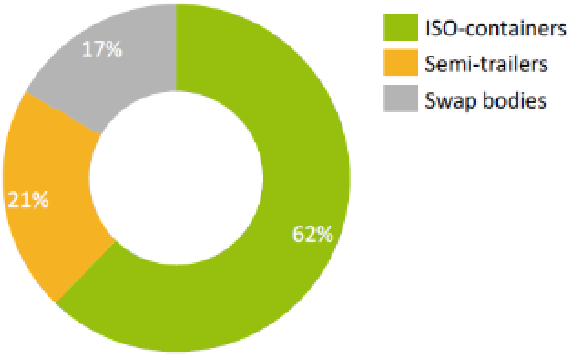
Source: ITCO, 2021 Global Fleet Report

Swap bodies and semi-trailers

The UIC/UIRR 2020 Report states that containers are the most used accounted loading units with almost a two third of the rail intermodal rail (62%). Swap bodies have a share of 17%, and semi-trailers about 21%.

[20] https://www.international-tank-container.org.

Figure 3: Distribution of loading units in intermodal transport



Source: 2020 Report on Combined Transport in Europe

As concerns the number of swap bodies, there are several estimations of about 300 000 to 400 000 units in Europe, although no reliable statistical information is available.

According to Eurostat, there were 2.8 million semi-trailers registered in the EU and 17 800 semi-trailers in Switzerland in 2019[21], but a large majority of them is never used in intermodal transport. There is no information available regarding the number of existing craneable and non-craneable semi-trailers in circulation.

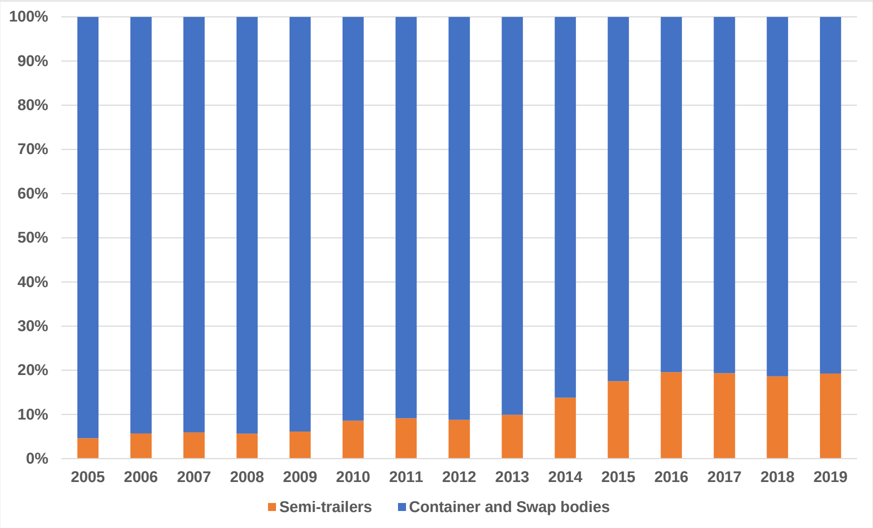
In any case, the share of transhipped and transported semi-trailers in intermodal transport have increased significantly over recent years. This was shown for example in an analysis of the German unaccompanied intermodal rail transport market between 2005 and 2019. Within this timeframe the share increased from about 5% (152 000 transported semi-trailers) to almost 20% (942 600 transported semi-trailers) in 2016, where it could remain at this level over the past years. In 2019, over one million transports of semi-trailers in unaccompanied intermodal transport were conducted in Germany alone.

An exact amount of the number of semi-trailers (box trailers) suitable for direct vertical transhipment in intermodal transport (craneable) in Europe cannot be determined, as there are no statistics on how many of the manufactured semi-trailers are craneable or not. There are certain estimations that between 90% and 95% of the total European semi-trailer fleet might be non-craneable (including all different types of semi-trailers). In Germany for example, the transport of non-craneable semi-trailers has not played a big role so far in intermodal rail transport and the share of non-craneable semi-trailers is likely in the single digit percentages. Assuming 1 million transports of craneable semitrailers in Germany and 2 transhipments per transport, the total number of transhipments of craneable semitrailers is 2 million per year in Germany.

In comparison, the total number of annual transhipments involving all technologies enabling the transhipment of non-craneable semitrailers onto rail in the whole of Europe (CargoBeamer, Modalohr, Nikrasa, ISU and r2l) adds up to less than half a million (determined in chapter 4.3). As some of these technologies are also used for the transhipment and transport of craneable semi-trailers (e.g. Modalohr), the actual number of transhipped non-craneable semitrailers is even lower.

21 https://ec.europa.eu/eurostat/databrowser/view/road_eqs_semit/default/table?lang=en, semi-trailers with a permissible maximum gross weight of over 30 tonnes

Figure 4: Development of share of semitrailers in unaccompanied intermodal rail transport in Germany 2005-2019



Source: Destatis, KombiConsult analysis

For the purpose of this study, we reduced the number of loading units used for the further analysis in our model environment to a small selection of typical loading units. The selected loading units are suitable to facilitate the comparison between different transhipment technologies and for different modes of transport. The selected loading units can be seen in Table 7 below. A simple 20’ ISO Box container has the lowest tare weight, while the non-craneable semi-trailer has the highest payload. However, it is only 600 kg higher than the payload of a craneable semi-trailer.

Table 7: Intermodal loading units and their technical dimensions selected for the further purpose of this study

Group	Type	External length (m)	Max gross weight (t)	Tare (t)	Payload (t)
ISO-Container	20’	6.09	30.5	2.2	28.3
	40’	12.19	30.5	3.8	26.7
Semi-trailer	Craneable	13.68	39	7.2	31.8
	Non craneable	13.68	39	6.8	32.4
Complete road vehicle	Truck with semi-trailer	16.50	44	14.1	29.9

Source: KombiConsult analysis;

3.2 Detailed list of all different types of transhipment technologies in intermodal transport; establishing the costs and investments needed associated with different transhipment technologies

This chapter concerns the ToR tasks 1.2 and 2 including all subtasks. Data gathering for these tasks has taken place together. When contacting manufacturers/providers or users of transhipment technologies, questions about the costs and investments associated with the technologies were included with the operational data to avoid a second round of inquiries. The results for tasks 1.2 and 2 are displayed in the fact sheets shown in Annex 1.

The list of transhipment technologies to be examined in this study was compiled starting from the indicative list of transhipment technologies provided by DG MOVE in the ToR. With the help of the sources mentioned in the text an investigation was conducted regarding the technologies on the indicative list as well as to look for further technologies that had not been considered so far. However, the indicative list proved to be comprehensive and no other technologies were identified.

This resulted in the compiled list of transhipment technologies to be further investigated shown in Table 8. The list provides the name and a short description of the technologies.

Table 8: List of transhipment technologies to be evaluated in the study

	Transhipment Technology	Short description
1	Gantry Crane	A crane for handling intermodal loading units which is built on a gantry, which spans over the workspace beneath and can usually move along rails (Rail Mounted Gantry Crane / RMG) or tracks (Rubber Tyred Gantry Crane / RTG). The working area can be extended via cantilevers to the left and right of the gantry. A spreader is required for transhipment of the loading units.
2	Reach Stacker	A rubber tyred vehicle used for the handling of intermodal loading units. The required spreader for the transhipment of intermodal loading units is attached in front of the vehicle at the end of a lifting arm.
3	Hydraulic Material Handling Crane	A mobile crane which is capable of rotating on its base and which uses a hydraulic lifting arm for lifting loading units or other objects. For intermodal transhipment, this requires a spreader for intermodal loading units.
4	Mobile Harbour Crane	A mobile crane which is capable of rotating on its base and which uses hoist ropes, wire ropes or chains and sheaves for the lifting of loading units or other objects. For intermodal transhipment, this requires a spreader for intermodal loading units.
5	Crane Ship	A ship with deck cranes for the autonomous loading/unloading without the necessity for further terminal handling equipment. For intermodal transhipment, this requires a spreader for intermodal loading units.
6	Furmia RTS 500	A horizontal transfer machine which was originally (1999/2000) built by Neuweiler AG, Switzerland. Development was continued eventually by Bosch Rexroth Hungary in the framework of the European InHoTra project between 2000 and 2004.
7	RoRo Ramp to/from Ship	A ship with built-in ramps over which wheeled cargo can be loaded or unloaded. RoRo stands for roll-on/roll-off. There are variants within the technology where land-based ramps, pontoon bridges and/or other additional equipment is utilized depending on local and operational circumstances and which are agreed upon bilaterally between the shipping lines and the ports.
8	RoRo double stacking cassettes	A cassette (platform) which can be used to transport two stacked containers on RoRo-ships with sufficient deck height. The cassette is hauled by a terminal truck with a translifter. This specific technology is distinguished from the common practice since a second container can be stacked and fixed on the first layer for loading/transporting/unloading the vessel.
9	Metrocargo	Horizontal loading technology capable of loading containers and swap bodies on trains working under the catenary (prototype developed 2011-2013).

	Transhipment Technology	Short description
10	N.E.H.T.S. (Neuweiler)	Horizontal Transfer Machine originally (1999/2000) built by Neuweiler AG, Switzerland which was part of the European InHoTra project between 2000 and 2004. The technology reached the demonstrator stage of the InHoTra project and a prototype was built in Zurich.
11	IUT (ÖBB Rail Cargo Austria)	Innovativer Umschlagterminal / IUT (Innovative transhipment terminal). Rack structure for the stacking of non-stackable loading units, random access to these units and for the vertical handling of containers and swap-bodies in rail-road transhipments developed to a demonstrator until 2010.
12	CarConTrain	Horizontal loading technology capable of loading containers and swap bodies on trains working under the catenary. The technology was part of the European InHoTra project between 2000 and 2004.
13	Sidelifter	A device, usually mounted on a chassis used for the direct transhipment of loading units between the chassis and the ground, rail wagons or another chassis.
14	BOXMover	A brand and specific type of a sidelifter with some technical differences developed by the company BOXmover. (www.boxmover.gmbh)
15	Mobiler (Rail Cargo Austria)	A horizontal loading technology for specifically designed loading units and brand of Rail Cargo Austria (www.railcargo.at).
16	Container Mover 3020 (Innovatrain)	A horizontal loading technology for swap-bodies and containers and brand of the company Innovatrain (www.innovatrain.ch).
17	Cargo Beamer 1st generation (Cargobeamer AG)	Horizontal transhipment system for "non craneable" semi-trailers with terminal installations and specifically designed rail wagon. Product and brand of the company CargoBeamer (www.cargobeamer.com).
18	Cargo Beamer next generation (Cargobeamer AG)	Horizontal transhipment system for "non-craneable" semi-trailers with terminal installation and specifically designed wagon, which can also be loaded "vertically", if semi-trailers are craneable. Product and brand of the company CargoBeamer (www.cargobeamer.com).
19	Modalohr 1st generation (AFA)	Horizontal transhipment system for semi-trailers and tractor units with terminal installations and specific wagons, which require adaptations in the lower UIC loading gauge on the rail tracks with regard to dwarf signals. The first generation, still in operation between Aiton and Orbassano, targeted at accompanied non-craneable semi-trailer transports. Product and brand of the company LOHR (www.lohr.fr).
20	Modalohr 2nd generation « N/A » (Lohr Industrie)	Horizontal transhipment system for semi-trailers and tractor units with terminal installations and specific wagons, which require adaptations in the lower UIC loading gauge on the rail tracks with regard to dwarf signals. The second generation, still in operation on certain lines, targeted at « non-accompanied » (« N/A ») transport of « non-craneable » semi-trailers. Product and brand of the company LOHR (www.lohr.fr).
21	Modalohr UIC (Lohr Industrie, VIA)	Horizontal transhipment system for semi-trailers with terminal installations and specific wagons, which, due to its adaptability, respects the UIC loading gauge. Present product and brand of the company LOHR (www.lohr.fr).

	Transhipment Technology	Short description
22	Helrom	Special rail wagon which turns out for loading/unloading semi-trailers promoted and used by company Helrom (www.helrom.com).
23	Nikrasa	A transport plate form for craning "non-craneable" semi-trailers in pocket wagons (promoted and used by TX Logistik). A corresponding terminal platform is required. All other technologies necessary for the transhipment and transport of the loading unit, such as crane, spreader, semi-trailer and wagon, do not have to be modified.
24	ISU (ÖBB Rail Cargo Austria)	Innovativer Sattelanhänger Umschlag / ISU (Innovative Semi-Trailer transhipment) consists of a ramp in terminals and beams attached to ropes to load "non-craneable" semi-trailers into pocket wagon (promoted and used by Rail Cargo Austria).
25	Megaswing	A special rail wagon which turns out for loading/unloading semi-trailers which was developped by Kockums Industrier in Sweden. The Megaswing technology has been taken over and is marketed by Helrom. It is included in this study under the new name (see technology 22 in this list) and will not be mentioned separately from here on.
26	Cargospeed	A special rail wagon which turns out for loading/unloading semi-trailers with the help of a pop-up mechanism located between the rails in the terminal which is used to lift or drop the wagon floor for the unloading/loading process.
27	Rail Runner (Europe)	The Rail Runner technology consists of a specially designed semi-trailer with in-build rail components which can be placed on two boogies for rail transport.
28	RoLa Ramp	RoLa (Rollende Landstraße or Rolling Highway) is a technology for the transport of full vehicles on specially designed rail wagons. With the help of a ramp, the truck can drive onto the train itself.
29	Eurotunnel Le Shuttle freight	The Eurotunnel Le Shuttle freight system is a localized technology for the transport of full vehicles on specially designed rail wagons through the Eurotunnel.
30	Flexiwaggon	The Flexiwaggon is a special type of rail wagon which turns out for the loading/unloading of full vehicles. Product and brand of the company Flexiwaggon (www.flexiwaggon.se).
31	r2l 2.0 road rail link (VEGA)	Road Rail Link is made of a ramp in terminals and basket type of tray to load all types of vehicles into pocket wagon (promoted and used by VEGA Trans, VTG and TX Logistik).

Source: KombiConsult analysis

This provides a consolidated and comprehensive base for further investigation of transhipment technologies for intermodal transport chains involving road to rail, inland waterway or short sea transhipments in the EU. The connected modes of transport also enable a distinction of the various technologies. Whereas some technologies were specifically designed to be used for transhipments between specific modes of transport, others can be used in combination with different modes of transport, but possibly changing the operational characteristics and performance indicators according to the involved modes. A further distinction can be made between the “transhipable” loading units. For the study this effectively implies that the technologies might have to be evaluated in multiple different settings depending on the involved modes of transport and the transhipped loading units. It is important to note that the technologies are not all mutually exclusive. Cranes and reach stackers, for example, can also be used jointly or in combination with a technology that allows the handling of loading units that it was not previously capable of.

Further classifications of the transhipment technologies can be made according to the type of intermodal service, i.e. accompanied or unaccompanied transport, and the type of transhipment, i.e. vertical or horizontal transhipment.

3.2.1 Description of the guidelines and assumptions for setting up the model

To have comparable framework conditions for the different technologies and thereby enable the comparative evaluation, all technologies were analysed in a dedicated model environment. This means that the terminal setting and transport chain are created and described for the exclusive use of an individual transhipment technology with one mode of transport for the main leg and an individual type of loading unit. All transport chains consist of the main leg via. rail, IWW or SSS, one transhipment conducted in a terminal dedicated to the transhipment technology at each end of the main leg as well as pre and post carriage of the LU via road leg to or from the terminal. Multi-purpose facilities, mixed load transports and transhipments between more than two different modes of transport are therefore purposefully excluded from this analysis. Furthermore, unplanned waiting times, delays and other technology independent events are not incorporated as they would affect absolute values for every technology but not change the results of the comparison. For this reason, certain assumptions about the terminal setup, terminal processes and the transport are made in a generalized manner for all technologies. Terminal check-in for example is handled differently in different terminals and depending on the type of loading unit, however there is no reason why certain automation principles could not be adopted by other terminals (and transhipment technologies) as well.

Although the goal is to enable a realistic comparison between the different transhipment technologies, the logistics reality is far more complex than can be shown here. Some simplifications made to allow comparison in this study may overlay or hide certain situation-dependent principles and considerations for choosing a certain technology or might cause certain values to differ from the real operating conditions. However, the approach is well suited to achieve the main objective of this study, which is to establish a comparative evaluation between different transhipment technologies and to provide information on their individual strengths and weaknesses.

When creating the model environment, the following basic guidelines and assumptions were applied in the terminal design:

- the terminals need to be able to handle trains, barges or ships, used on the main leg, according to the following specifications as specified DG MOVE:
  - trains with a max. length of 740m and a max. weight of 2 000t.
  - Barges with a length of 110m, a width of 11.4m and a height of 3.5m as well as a capacity of 2 800t or 200 TEU.
  - Short Sea Ships with a capacity of 1 000 TEU or 2 500 lane meters. An exemplary 1 000 TEU short sea container ship can have a length of 150m and a width of 22.5m. For the RoRo-Ship with 2 500 lane meters a length of 180m and a width of 25m can be assumed.
- The terminal layout will include a gate area, an intermediate buffer area, a transhipment area and driving or loading lanes as standard elements as well as technology specific elements. Other general supporting elements, which are not directly linked to the transhipment process, are excluded.
- The non-technology specific terminal operations are assumed to be the same for all technologies. This especially concerns the check-in and check-out processes as

well as most preparation and security processes for the full train, barge or ship. For the terminal check-in rail-road a differentiation is made based on the type of loading unit transhipped. Containers, swap bodies and craneable semi-trailers take less time during the technical check-in than non-craneable semi-trailers. For the later the technical check-in takes a little longer and has a different focus due to the necessity to check the suitability of the specific loading unit for rail transport. This does however not prolong the total check-in time as the technical check-in takes place in parallel to other check-in processes. It does however increase the working time per LU of the checker conducting the technical check-in. This assumption has been coordinated with technology providers and terminal operators[22] accepting different types of loading units.

- For certain necessary security processes during the transhipment of a single loading unit and caused by the type of loading unit being transhipped, additional personal is shown supporting the transhipment. For example, in the vertical transhipment of semitrailers onto rail waggons, an additional groundsman is included who checks the correct placement and securing of the semitrailer on the rail waggon.
- The terminal was designed in a compact way to reduce in terminal driving times. For all driving times an average based on the expected distance distribution was assumed which is already included in the shown process times if applicable.
- Extra movements of the train, barge or ship or the terminal equipment for the transhipment in the terminal are avoided unless they are explicitly required by the technology. For example, rearrangements of buffered loading units are not included whereas relocating the mobile harbour crane is required multiple times during the loading/unloading of a full train as the length of the train exceeds the range of the crane hoist many times over. After entering the terminal trains, barges or ships are not moved for any technology included until the unloading and loading process is finished.
- An indirect terminal operation organisation is assumed for all technologies to provide a common basis. In indirect terminal operations, the loading unit is not transhipped directly onto the truck or the train, barge or ship, but is first deposited in an intermediate buffer area, thereby decoupling the linked modes of transport. The time spent in the buffer area will not be included in the process times. This also means, that each transhipment in the model consists of two loading unit handlings in the terminal, either by the same or different equipment. This approach has been discussed with all consulted technology providers and users and is considered to accurately reflect the common practice.
- The intermediate buffer area is spaced to accommodate loading units up to roughly 50% of the daily handling capacity.
- Shunting of trains is not considered for all technologies. To this end for vertical transhipment technologies for rail/road terminals we are assuming the catenary to extend over the ends of the transhipment tracks pointing towards the main line. With this solution the wagon sets can be placed on and picked up from the transhipment tracks by the electric main line locomotive without requiring additional shunting equipment.

For the transport chain, the following basic guidelines and assumptions were applied in the model design:

- the total transport distance of 600 km and 1 000 km is split between the main leg and the road legs. An initial approach aimed to differentiate the road leg and main leg lengths depending on the mode of transport of the main leg. The study “Updating EU combined transport data” concluded, that the average and median main leg and road leg distances in intermodal transport chains in Europe differ based on the

[22] E.g. Terminali Italia in Verona, where a multitude of different loading units is transhipped using different technologies, amongst others NIKRASA for the transhipment of non-craneable semi-trailers.

chosen mode of transport.[23] However the study data does not allow for a clear conclusion of a positive correlation between the average or median length of the road legs and the length of the main leg. Therefore, scaling up the proportions between road leg and main leg distance to the 600 km and 1 000 km total transport chains analysed in this study was not feasible. Furthermore, using the absolute average or median road leg distances from the study would lead to implausible distances for these transport chains as well. Table 9 below shows an example of the resulting distances when using the absolute median road leg distances from the study and only scaling the main leg per mode of transport.

Table 9: Variation of road leg distance per mode of transport

	600km		1 000km
	Main leg	Road legs	Main Leg
Rail/Road	440km	2*80km	840km
Barge/Road	560km	2*20km	960km
ShortSea/Road	340km	2*130km	740km

Source: KombiConsult analysis

As can be seen, the resulting distances would not have allowed for a meaningful comparison between transhipment technologies used for different modes of transport. For this reason it was finally decided, to assume an equal distance of 75 km for each road leg and each mode of transport, thereby enabling a fair comparison of transhipment technologies for the 600km and 1 000 km transport chains.
This assumption leads to the distances shown in Table 10 below which will be used for this study.

Table 10: Uniform road leg distance per mode of transport

	600km		1 000km
	Main leg	Road legs	Main Leg
Rail/Road	450km	2*75km	850km
Barge/Road	450km	2*75km	850km
ShortSea/Road	450km	2*75km	850km

Source: KombiConsult analysis

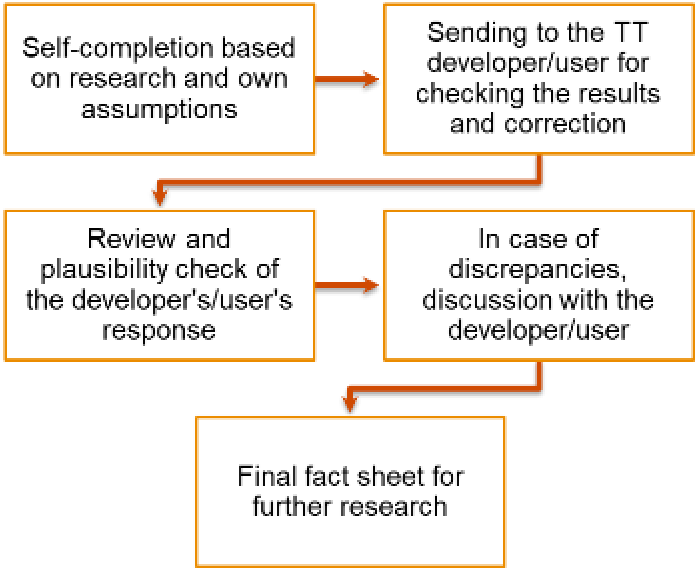
- The start point and the end point of the transport chain lay at a distance of 600 km or 1 000 km as the crow flies. It is therefore further assumed, that a transport between these two points is always conducted on the same straight connecting line, regardless of the mode of transport.
- For all technology and loading unit combinations a load weight of 20 tons is assumed, unless the technology is technically incapable of this weight. If this is the case, the load weight is lowered to the possible max. load weight. Other characteristics of the loaded goods, which influence the choice of the optimal loading unit, like the type, density/ volume and grouping of the cargo are purposefully not considered for this study and no other assumptions about the loaded cargo are made.
- After the train, barge or ship has left the terminal, no planned stops will be listed until it enters the terminal at the destination. This explicitly excludes border and customs controls, material and personnel changes as well as any other disruptions. Accordingly, a constant average speed is applied for the entire transport between the two linked terminals:
  - the average speed for the road leg is assumed to be 60 km/h based on evaluations conducted for other assignments.

[23] Study “Updating EU combined transport data“.

– The average speed for rail transport is set at 40 km/h. The average speed of flexible point-to-point rail freight transport in Germany is 50 km/h[24], however this average value is not achievable on all lines in all European countries. We therefore lower the average speed of the train to account for regional differences. As the max. speed of freight trains on properly developed main lines usually is between 90 and 120 km/h, this average speed value already includes implicit assumptions about operational stops.
– The average speed for Short Sea ships is set to be at 17 knots or 31.5 km/h on average.
– The average speed for Inland Waterway is set to be at 8 knots or 15 km/h on average.

3.2.2 Description of the data collection and validation

Figure 5 : Data collection for the transhipment technology fact sheets



Source: KombiConsult analysis

For the transhipment technologies (TT) to be evaluated in the study, detailed technological and operational data was collected in fact sheets for each transhipment technology based on the model environment. The approach to data collection and validation is shown in Figure 5. A preliminary knowledge base on the basic parameters, modes of operation and areas of application was built up in desk research. This involved, among others, data from the following types of sources which was gathered in draft self-completed fact sheets:

- sources provided by the European Commission in the ToR. The provided documents include a number of studies, which previously examined the technical and, to a lesser extent, financial properties of various intermodal transhipment technologies;
- information material made publicly available from manufacturers and providers of the transhipment technologies;
- information from logistics industry-specific sources such as journals and blogs, which published pieces about certain technologies;
- further identified relevant studies like the In HoTra study of the year 2001-2003 on horizontal transhipment technologies or the Austrian Federal Ministry of Transport Study on RoLa Services;

[24] Netzwerk Europäischer Eisenbahnen, Studie 35 – Güterverkehrsverlagerung aus Betreibersicht.

- information from professional experience and previous assignments was used to complement and validate the above-mentioned sources of information.

Based on this preliminary research and the draft fact sheets, manufacturers, promoters and users of the technologies were contacted. The outreach followed two objectives. On the one hand, the data that had been collected was to be validated by these stakeholders. On the other hand, additional data was collected to fill data gaps for which no information was previously available. All the data collected was subjected to a plausibility check and if reasonable was incorporated in the fact sheet. If further discussions were necessary, especially for discrepancies in the information provided by different stakeholders for the same transhipment technology, the stakeholders were contacted again to clarify these issues and open points. From the collected data certain other values were calculated to finalize the fact sheets for further use. The content of the fact sheets and how it was compiled is described in the following chapter.

3.2.3 Description of the fact sheet elements

The fact sheets created in task 1 and task 2 provide detailed technical, operational and financial information about the different transhipment technologies. While some information and values were collected directly in the research or from stakeholders, other values had to be calculated therefrom taking into account the framework of our model environment. The various items contained in the fact sheets and the way in which this information was assembled are explained below.

All costs shown in the fact sheets are part of the total system costs for the various technologies as defined for this study. These total system costs consist of different cost elements which are incurred either on the transport legs or during transhipment. The main goal of the analysis of system costs as conducted in this study is to enable and to optimize the comparative evaluation between the different transhipment technologies. The focus is therefore on cost elements which are closely linked to the deployment of the technologies and cost elements which differ for the various technologies and for which the differences are triggered by the choice of technology. Cost elements, like overhead, insurances, interest or information and communication technology costs, are not considered because they are not directly influenced by the choice for a specific technology and are assumed to be identical for the different technologies when deployed under similar conditions. It is therefore important to note that the total system costs shown here, and parts of them, deviate from the costs to be expected in operational practice. Costs in operational practice are expected to be higher than those shown here as not all cost elements are taken into account and the operational practice is in fact too complex to be adequately modelled within the scope and limitations of this study.

Picture of the technology

A display of the technology is included to provide a visual reference and aid on the functionalities and applications.

Description of the transhipment technology and transhipment process (referring to ToR item 1.2, 1.2.8, 1.2.9, 1.2.10)

This element provides a qualitative description of the technologies, their elements, necessary support equipment and possible variants and configurations of the technology as well as how a transhipment process from the road to the main leg is technically/operationally carried out. Furthermore, the common use cases for the technology are explained while also describing factual limitations and restrictions for the technology or by the technology on elements of the transportation chain. The content provided herein has been coordinated and verified with the technology manufacturers/providers and users.

Classification

In this item the technologies are classified into horizontal or vertical transhipments and whether they facilitate accompanied or unaccompanied transportation services or both. These are standard classifications in intermodal transport chains.

Horizontal transhipment describes a transhipment process during which the transhipped loading unit is not lifted or is lifted only a small amount to release it from the transport locks. Horizontal transhipment technologies can usually be used under the overhead line (catenary).

Vertical transhipment on the other hand describes a transhipment process during which the loading unit is subject to a high vertical lift to be moved between the different modes of transport. These technologies cannot be used under the overhead line (catenary).

Accompanied intermodal transport describes a form of transport where the loading unit is transported by rail, inland waterway or sea and is accompanied by the tractor unit and the road vehicle driver.

Unaccompanied intermodal transport describes the transport of loading units on rail, inland waterway or sea without the accompanying driver and usually also without the tractor unit.

Connected modes of transport

This element shows with which modes of transport the technology can be used for the transhipment of intermodal loading units. For this study only transhipments between road and one other mode of transport are included. This results in the following relevant combinations to be further investigated:

- rail/road intermodal transport;
- inland waterway/road intermodal transport;
- short sea/road intermodal transport.

A technology might be suitable for one or more of these combinations. If it is suitable for more than one combination, the following sections of the fact sheet are done separately for each combination, as the technologies' characteristics can vary highly between the different modes of transport and showing them in the same place is not feasible.

Technology readiness level and prevalence of the technology

Due to the large variety of technologies investigated this element provides an indication towards the technical readiness and market prevalence of the technology.

This assessment was made based on the desk research and interview results.

The technical readiness assessment is performed based on the European Technology Readiness Levels (TRL), which were established for the use in EU-funded research and development projects and first introduced in the HORIZON 2020 program with respect to transport technologies. The technologies are rated on a scale ranging from 1 to 9, with 1 representing the lowest and 9 the highest TRL. This standardized system enables a common understanding of the status of a particular technology. The levels are described in Table 11[25].

[25] https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2016-2017/annexes/h2020-wp1617-annex-ga_en.pdf.

Table 11: European Technology Readiness Levels

Technology Readiness Level	Description
TRL 1	Basic principles observed.
TRL 2	Technology concept formulated.
TRL 3	Experimental proof of concept.
TRL 4	Technology validated in lab.
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies).
TRL 7	System prototype demonstration in operational environment.
TRL 8	System complete and qualified.
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space).

Source: HORIZON 2020 – WORK PROGRAMME 2014-2015 General Annexes

The prevalence of the technology was assessed based on identified use cases. This assessment considered two aspects: the total number of use cases and the geographical spread of these use cases across Europe. Arguments for the degree of prevalence of a specific technology were provided, considering the identified factors such as the degree of specialization, ease and flexibility of use, and barriers to deployment.

Based on the TRL and the prevalence of a particular technology, it was decided whether further technology assessment should be conducted as part of this study. Regarding their TRL, the main decision factor was, whether the transhipment technologies were successfully developed and are actively used or at least being promoted on the European intermodal market. Technologies that never achieved a high TRL or have since been pulled from the market were excluded from this study. Furthermore, with respect to prevalence, the main decision factor was whether a technology is technically and operationally suitable to be deployed outside of its current area of application. If a technology is either too specialized, faces major barriers to wider deployment or has been identified as being in decline due to specific technical and competitive disadvantages they were also excluded from the further analysis in this study.

Indicative qualitative assessment – Strengths and Weaknesses/Limitations

A list will be provided in this element showing an indicative list of strengths and weaknesses of the technology. The list focuses on strengths and weaknesses directly identified in the research or mentioned in the interviews, which were not based on further evaluation and therefore do not prejudge the outcome of the study. The strengths and weaknesses listed here are qualitative in nature, and do not serve to directly compare the different technologies. The purpose of this list is to give a better impression of the suitable, or unsuitable, areas of application of the technology.

Transhipable loading units (LU)

This item provides information on which types of loading units the transhipment technology is technically capable of transhipping. Furthermore, relevant exceptions and limitations are listed, for example regarding the outer dimensions or weight of the loading units and whether these exceptions and limitations are strict or if there are ways to overcome them. Later parts of the fact sheet might focus only on one type of loading unit or even only one size of a LU-type and will be repeated accordingly per analysed type and/or size of LU. Not all technically transhipable loading units will be analysed per transhipment technology, for an easier comparison the focus will be on ISO-containers as well as semi-trailers and truck and semi-trailer combinations (full vehicles).

Transhipable max. weight

The transhipable max. weight is the max. weight which the transhipment technology is technically able to handle during standard operations. In practice however, there can be other factors limiting the max. weight of the loading unit. These are, for example, regulations limiting the max. weight of road vehicles or the max. weight to be transported on the main leg. As these limitations are not specific to the technology and are influenced by the choice of transport equipment, they are not provided here. They are however considered in the calculations for the transport chain in the model environment according to the equipment chosen for the model environment to ensure the validity of the results.

Description of the model terminal

This element provides the layout of a basic model terminal for the transhipment technology and a particular modes of transport combination. The model terminal is based on the general guidelines and assumptions described in 3.2.1 as well as the technologies individual characteristics and focuses on the terminal elements which are involved in the transhipment process, the gate area, the intermediate buffer area and the transhipment area. The goal is to create a favourable model environment for each technology; however, this does not mean that the specific terminal design is the optimum for the specific technology. To enable the main goal of the comparison between the different technologies some generalisations regarding the terminal layout had to be made which can be improved upon when the goal is shifted to designing an optimal terminal for a specific transhipment technology. The model terminal does however not include elements which are common for all types of technologies and which are depending on the operational process of the mode of transport e.g. to park rail wagon, and/or logistics considerations, e.g. to store loading units for a longer time.

Necessary road leg equipment

This element lists the equipment necessary for the road leg in conjunction with a specific technology. This equipment was either described in detail in the transhipment technology description for technology specific equipment or in 3.2.1 for standardized equipment like a truck or chassis. The listing here functions as a reference to these more detailed descriptions.

Necessary main leg equipment

This element has the same function as the “Necessary road leg equipment element” in the way, that it also only provides references to main leg equipment, that was either described in the technology description for technology specific equipment or in 3.2.1 for standardized equipment used for multiple technologies. However, this element is different in so far, as it provides references for the necessary main leg equipment to be used in conjunction with the particular transhipment technology for a specific mode of transport whereas the road leg equipment is the same for all connected modes of transport.

Max. number of units on full trains/barges/ships

For the comparative evaluation of the different transhipment technologies, the max. number of loading units that can be transported on a full train, barge or ship on the main leg is an important performance indicator as well as a basis for later cost calculations. The calculation procedure for this result differs depending on the mode of transport.

For the short sea transport using container ships, the max. capacity is, as per the definition of the standard ship for the purpose of this study, 1 000 TEU. According to our research a plausible max. load weight for container ships this size is 13 000 t.

For the short sea transport using RoRo ships we are assuming a usable capacity of 2 500 lane meters. This is a simplification to make the comparison possible. In practice, RoRo ships are oftentimes designed and built to maximize capacity for a specific transport profile whereby the usable lane length and loading unit capacity of a 2 500 lane meter ship depends on the exact ship and loading unit combination as well as the specifications for lashing. Each loading unit requires at least its own length in loading meters, however typically additional loading length is required per loading unit. The space requirement is entirely dependent on the shipping companies' specifications for the loading scheme and the lashing (securing) of the cargo. Based on our interviews the additionally required "loading length" typically lies between one to one and a half meters per loading unit. We will therefore assume a required length of 15 meters for semitrailers, and 13.5 meters for 40' cassettes and roll trailers. To reach the max. capacity in terms of loading unit spots the 2 500 lane meters are then divided by the required length for the respective loading units' "loading length". The max. load weight for the RoRo ship is assumed to be 12 000 t.

For the barge in inland waterway transport, the max. capacity is, as per the definition of the standard barge for this study, 200 TEU, with the added restriction of a max. load weight of 2 800 t or 14 t per TEU on average.

For all ships it was first checked, how many loading units can be transported with the max. load weight restriction. For this the weights of the loaded goods, the loading unit and, if applicable, the additional equipment per loading unit spot were added up and the max. load weight for the ship was then divided by this total weight per loading unit spot. For the average load weight per loading unit 20 t are assumed which is a weight also used in previous studies analysing intermodal transhipment technologies.[26] The loading unit weight is taken from task 1.1 and the additional equipment weight depends on the specific transhipment technology. If the result of the division is lower than the max. number of LU spots, the limiting factor is weight. If the result is higher the number of loading unit spots is the limiting factor.

The calculation was more complex for the full train with a total max. weight of 2 000 t and a max. length of 740 m as different wagon parameters had to be taken into account. The model assumes that one locomotive with a weight of 90 t and a length of 20 m is sufficient to pull the train. The loaded wagon sets can therefore have a max. weight of 1.910 t and a max. length of 720 m. Depending on the type of loading units, a fitting standard wagon from the list shown in Table 12 was chosen. If the technology requires a special type of rail wagon listed in the second part of the table this was of course used instead.

[26] https://www.alpine-space.eu/projects/alpinnoct/outputs/deliverable-d.t1.2.1.pdf ; 17.06.2021.

Table 12: List of standard rail wagons

Standard Rail wagons for the main leg							
Name of wagon	*6-axle Megatrailer Pocket Wagon*	*4-axle Container wagon*	*6-axle articulated Container wagon*	*6-axle articulated swap body wagon*	*8-axle low bed container wagon*	*6-axle container wagon*	*6-axle double pocket wagon*
Type	*Sdggmrss "TWIN"*	*Sgnss 60'*	*Sggrss 80'*	*Sggmrss 104'*	*Sffggmrrss "Megafret"*	*Sggmrss 90'*	*T3000e*
Length over buffers [mm]	*34 030*	*19 640*	*26 700*	*33 480*	*36 440*	*29.590*	*34 200*
Loading length [mm]	*4 x 7 820; 2 x 15 761*	*18 400 (60')*	*2 x 12 370 (40')*	*2 x 15 765; 4 x 7 820*	*2 x 16 105*	*2 x 13.820(45')*	*4 x 7.820; 2 x 15.761*
Maximum loading weight [t]	100	70	107	105	89	106	100.9
Loading height [mm]	1 155 (270)	1 155	1 155	1 155	825	1 155	1 155 (270)
Tare Weight [t]	35	20	28	30	39	29	34.1
Total max. mass [t]	*135*	*90*	*135*	*135*	*128*	*135*	*135*

Special Rail wagons for the main leg				
Name of wagon	*Flexiwagon*	*Low floor RoLa-wagon*	*CargoBeamer wagon*	*Modalohr UIC*
Type	*Flexiwagon SW*	*Saadkms*	*Sdkmss with „CargoBeamer JetModule"*	*UIC 2*
Length over buffers [mm]	*26 610*	*19 090*	*19 330*	*32 940*
Loading length [mm]	*17 300*	*n/a*	*n/a*	*n/a*
Maximum loading weight [t]	45	44	37	76.3
Loading height [mm]	230	410	240 (210-230)	213
Tare Weight [t]	45	18.5	29	40.7
Total max. mass [t]	*90*	*62.5*	*66*	*117*

Source: KombiConsult knowledge base and technology providers

In addition to the wagon data and the loading unit data from task 1.1 assumptions about the load weight were necessary to conduct the capacity calculation. The average weight of the loaded goods is assumed to be 20 t as for the other modes of transport. For some technologies where 20t is above the max. weight limitation the transhipped and transported weight per loading unit is reduced to the possible max. weight.

The capacity calculation was then carried out in three steps as shown in the example in Table 13. In the final step the lower of the two calculated numbers was chosen which represents the overall number of max. wagons per train considering both the max. train weight of 2 000 t and the max. train length of 740 m. To then receive the max. number of loading units this number was multiplied with the number of LU spots on one wagon.

Table 13: Exemplary calculation of max loading units per train

Calculation of max. wagons per train considering weight (2000t; loco ~ 90t)									
For 20' containers on Sggrss 80' wagons with no further special equipment									
Loading unit			Wagon		Equipment		Full wagon weight	Max. train weight	Wagons per train
Payload	Tare	Total	Tare	LU-spots	Tare	On wagon			
20t	2.23t	22.23t	28t	4	-	-	116.92	1910t	16
Calculation of max. wagons per train considering length (740m; loco ~ 20m)									
Wagons per train	Wagon length over buffer		Train length		Max. train length	Wagons to be reduced		Wagons per train (final)	
16	26.7m		427.2m		720m	-		16	
Max. units per full trains (740 m, 2000 t)						64 20' containers			

Source: KombiConsult analysis

First, the maximum number of loading units per wagon set depending on the max. number of loaded wagons in compliance with the made assumptions, especially the max. weight, was calculated. The total loading unit weight was multiplied with the number of loading unit spots on one wagon and the wagons own weight was added to calculate the total weight of one loaded wagon. The max. weight for the total wagon set of 1 910 t was then divided by the weight of one (loaded) wagon and the result rounded down to receive the permissible total number of wagons per train by weight. In the second step, the max. wagon set length of 720 m was divided by the length of one wagon and the result rounded down to calculate the permissible total number of wagons per train by length. In the final step the lower of the two calculated numbers was chosen which represents the overall number of max. wagons per train considering both the assumed max. train weight of 2 000 t and the assumed max. train length of 740 m. To then receive the max. number of loading units this number was multiplied with the number of LU spots on one wagon. For different train parameters, like shorter max. trains, the result of the loading unit capacity calculation might vary.

This calculation was done for the different sizes and variants within one class of LUs where applicable.

For the further model calculations within this study the assumption was made, that on average only 85% of the max. available capacity for loading units will be utilized per transport. Therefore, based on the possible max. number of loading units, also the number of loading units on a train, barge or ship assuming only 85% capacity utilization is provided here which will be used for the further transport chain analysis.

The results of the max. wagons per train by length and by weight under our model assumptions as well as the resulting max. LU capacity and the LUs at 85% utilization are shown in Table 14 below. The table also provides information on the considered wagon type as well as any peculiarities of the technology and loading unit combination like additional necessary equipment or technology limitations which influence the calculation of the wagon capacity. Details about the peculiarities can be found in the respective technology fact sheet in Annex 1.

Table 14: Model train capacity per technology and loading unit combination

Tranship-ment Technology	Loading unit	Wagon type	Peculiarities	Capacity wagons		Capacity LUs	
				By total length	By total weight	Max. capacity	85% utilization
Gantry Crane	20' Ct	Sggrss 80'	-	26	16	64	54
	40' Ct	Sggrss 80'	-	26	25	50	43
	St (craneable)	T3000e	-	21	21	42	36
BOXmover	40' Ct	Sggrss 80'	-	26	25	50	43
Flexiwaggon	St with truck	Flexiwaggon SW	Club car	26	23	23	20
Reach stacker	20' Ct	Sggrss 80'	-	26	16	64	54
	40' Ct	Sggrss 80'	-	26	25	50	43
	St (craneable)	T3000e	-	21	21	42	36
RoLa	St with truck	Low floor wagon (Saadkms)	Club car	36	35	35	30
CargoBeamer	St (non-craneable)	"Sdkmss" with „CargoBeamer JetModule"	-	37	34	34	29
Sidelifter	40' Ct	Sggrss 80'	-	26	25	50	43
Modalohr	St (non-craneable)	UIC 2	-	21	20	40	34
r2l 2.0 trailer-use	St (non-craneable)	T3000e	Transport platform	21	19	38	32
Mobile harbour crane	20' Ct	Sggrss 80'	-	26	16	64	54
	40' Ct	Sggrss 80'	-	26	25	50	43
NiKRASA - crane	St (non-craneable)	T3000e	Transport platform	21	20	40	34
Hydraulic crane	20' Container	Sggrss 80'	Lower goods weight	26	16	64	54
	40' Ct	Sggrss 80'	Lower goods weight	26	26	52	44
Container-Mover	20' Ct	Sggrss 80'	Lower goods weight; adapter weight	26	20	80	68
	40' Ct	Sggrss 80'	Lower goods weight; adapter weight	26	31	52	44
ISU	St (non-craneable)	T3000e	Additional equipment	21	21	42	36
Mobiler	30' Ct	Sggmrrss-y 2 x 60'	-	18	14	56	48

Detailed description of the transhipment process (referring to ToR items 1.2.1 and 1.2.2)

In this element the transhipment process for one loading unit, from entering the terminal (by road) to leaving the terminal (by the main leg mode), and vice versa, was described in detail. The description focusses on the path of the loading unit. The analysis focused on the operational process steps, administrative process steps not directly linked to the loading unit and its transhipment were not considered since they occur independently from the transhipment technology and mode combination. Furthermore, storage and waiting times are excluded from the analysis if they are not relevant for the transhipment technology or the terminal operations.

Table 15: List of terminal and transport personnel functions

Terminal and other involved personnel	
Name	**Function description**
Direct terminal personnel	
Checker	Person performing the Technical Check-in
Gate Agent	Person carrying out the Administrative Check-in
Handling Equipment Driver	Driver of crane, reach stacker etc.
Terminal Truck Driver	Driver of internal terminal trucks
Instructor “groundsman”	Person supporting the Handling Equipment Driver from the ground, if needed, and assuring that the loading units are safely fixed on vehicles
Terminal dispatcher	Person overseeing the entire terminal processes
Road leg personnel	
Truck driver	Driver of truck
Truck dispatcher	Person scheduling several trucks and organises transports
Main leg personnel-rail	
Visitor/Wagon Inspector	Person responsible for checking the train before leaving (function of the railway undertakings)
Train dispatcher	Person overseeing the main leg transport
Train driver	Driver of the train
Attendant	Attendant for the passengers in the club car in accompanied intermodal rail transport
Main leg personnel-Inland water way	
Captain	Person navigating the ship, planning the loading and unloading of the ship and organising the transport
Helmsman	Person supporting the captain
Sailor	Further vessel crew
Main leg personnel-short sea	
Captain	Person navigating the ship, planning the loading and unloading of the ship and organising the transport
Helmsman	Person supporting the captain
Sailor	Further vessel crew

Source: KombiConsult knowledge base

Each individual process step includes descriptive information about the necessary equipment and involved personnel as well as the time per personnel and the total process step duration. The description is provided for both the loading and the unloading process of the train, barge or ship. Furthermore, it mentions when process steps vary for the transhipment of different types of loading units. For better understanding, Table 15 shows a list of standard personnel with a short description of their function. The personnel for the different transport legs are shown in the table as well as they are relevant for later analyses.

Table 16: List of standard transhipment process steps

Transhipment process steps	
Process steps	**Description**
Loading main leg	
Technical check-in	The loading units are checked by the terminal for their compatibility with the transhipment and transport process as well as for existing damages
Administrative check-in	The truck drivers check in to the terminal for LU drop-off and pick-up
Drive to drop-off/parking	The truck drivers drive to the dedicated drop-off/parking spot
Handover of loading unit	The loading units are handed over to the terminal and are placed in the intermediate buffer area, either by being dropped off on their own or being lifted off with terminal equipment
Movement of loading unit	The loading units are moved from the intermediate buffer area to the transhipment area using terminal equipment
Preparing transhipment	If required by the technology, further process steps for the preparation of the transhipments are conducted
Transhipment of loading unit	The loading units are transhipped onto the main leg
Terminal check-out	The transhipped loading units are prepared and checked for departure
Further procedures for departure	The main leg equipment is prepared and checked for departure
Departure	The main leg equipment departs from the terminal
Unloading main leg	
Arrival	The main leg equipment arrives at the terminal
Further arrival procedures	If required, further process steps for the arrival procedure are conducted
Terminal check-in	The loading units are checked into the terminal and are examined for damages
Transhipment	The loading units are transhipped from the main leg
Preparing transhipment	If required by the technology, further process steps for the transhipment or the further handling are conducted. Depending on the technology, these might be conducted earlier or later than implied by the order of process steps listed here
Movement of loading unit	The loading units are placed in the intermediate buffer area
Handover of loading unit to truck	The loading units are picked up by the trucks either on their own or with the help of terminal equipment
Administrative check-out	The truck drivers check out of the terminal. In our model process the check-out is included in the check-in because the same truck driver is dropping off as well as picking up a loading unit. Therefore, this process step is not shown in the fact sheets
Drive from drop-off/parking	The trucks depart from the terminal

Source: KombiConsult knowledge base

The total process step duration is not necessarily equal to the sum of the individual times per personnel as they might work in parallel and not sequential. Information about both the total duration as well as the individual times allows for conclusions about whether the work is done consecutively or in parallel as well as the total working time per process step. The general process steps for the loading and unloading process are shown in Table 16 above.

The upstream and downstream processes of the actual transhipment are typically not technology-specific and were therefore described as uniformly as feasible for the different transhipment technologies. The further from the transhipment they are, the more uniformly they become. This means that, for example, the technical and administrative check-in processes are assumed to be similar for all technologies, as the reasons for efficiency gains currently achieved in one terminal, for example due to the terminal layout or the use of camera/OCR gates, could be adopted in all other terminals as well, regardless of the transhipment technology.

One exception to this is the process step “further procedures for departure” for the main leg on rail. The length of the wagon technical inspection depends on the number of loaded rail wagons and the overall number of axles on the full wagon set. From our consultation with wagon inspectors and rail freight operators a duration of 0.6 minutes per axle and an additional 0.4 minutes per loaded wagon was gathered. The duration for the process step therefore depends on the number and type of wagons, the load factor, and thereby indirectly on the assumptions made for the specific technology. The duration of the wagon technical inspection, included in the further procedures for departure, was calculated for each technology using the mentioned inputs.

The upstream and downstream processes in the loading process, for which uniform assumptions were made for all technologies, are the technical check-in, the administrative check-in, the drive to drop-off/parking, the terminal check-out and the departure. For the unloading process these are the arrival, the terminal check-in and the drive from drop-off/parking. Detailed information about these processes was available from previous assignments and was validated for this study by consulting with terminal operators.

For the gathering and determination of the necessary information for the other process steps, first a general understanding of the technology specific transhipment process was built up in the consultation with the technology providers and/or users. This process was then adopted to our model environment, especially taking into consideration the terminal layout as well as the available equipment. The detailed description of the transhipment process was then verified and validated by the technology providers and users as far as possible.

Total time for the transhipment of one loading unit (referring to ToR item 1.2.1)

The time for the transhipment of one loading unit was directly derived from the detailed description of the indirect transhipment process. Two values are provided here: the first is the total duration of the terminal processes for one LU (i.e. how long is the loading unit in the terminal without storage time) before it is placed and secured on the main leg equipment. This is calculated by adding up the times provided for “Total LU” in the description of the transhipment process up to the check-out. The second is based on the time the actual transhipment technology or equipment, as the likely bottleneck, is involved in the transhipment of one loading unit. This is calculated by adding up the times for which the handling equipment driver (or truck driver or terminal truck driver for some technologies where no handling equipment is used) is involved in the process steps described for the transhipment process and only concerns the processes which take place in between the intermediate buffer area and the main leg transhipment. Both values are provided for the loading as well as the unloading from the main leg. For unloading the time for all process steps includes all time provided for “Total LU” starting after the terminal arrival.

Time spent in Terminal for the road haulage operator (referring to ToR item 1.2.6)

The time spent in the terminal was again directly derived from the detailed description of the transhipment process by adding up the times during which the truck driver is involved in the transhipment. One value is provided for the loading and one for the unloading process steps. For the model it is assumed, that the truck is dropping off as well as picking up one loading unit during its time in the terminal, thereby the total time spent by the road haulage operator in the terminal is the sum of the loading and unloading times provided in this item. The one exception to this is accompanied intermodal transport where the truck driver stays with the LU for the main leg.

Total time for loading/unloading one train/barge/ship (excl. headway) (referring to ToR item 1.2.4)

The total time for loading or unloading one train, barge or ship (excluding headway) includes the total time from the first LU being loaded up to the time the train, barge or ship is fully loaded (loading) or the total time between the first LU being unloaded to the time the train, barge or ship is fully unloaded (unloading). For train/barge/ship it does not include the "headway" time which is the time the main leg means of transport spent in the terminal prior to the unlading and after the loading. To determine the total time for the loading and unloading of one train, barge or ship, the time for the loading or unloading of one loading unit based on the transhipment technologies involvement is multiplied with the number of loading units per train, barge or ship considering the assumed capacity utilization of 85%. The result is then divided by the number of involved equipment which were assumed to work in parallel and which were described in the basic terminal description. The formula below shows the calculation for the total loading time of a train, barge or ship.

$$t_{le} = \frac{t_{te} * X_{LU}}{X_E}$$

With:
$\mathrm{t_{le}}$ = Total time for loading one train, barge or ship (excl. headway)
$\mathrm{t_{te}}$ = Time for the transhipment of one LU (based on terminal equipment driver)
$\mathrm{X_{LU}}$ = number of LUs on the train, barge or ship
$\mathrm{X_E}$ = Number of involved terminal handling equipment

If applicable, a differentiation was made for different loading unit sizes and variants due to a different total number of loading units on a train, barge or ship. For terminals with multiple transhipment tracks or berths the total terminal handling capacity is determined by the handling equipment time per transhipment excluding headway, as the handling equipment can continue transhipping on another track or berth. This is true assuming the headway is less than X_I times the total time for unloading plus loading a full train, barge or ship with X_I being the number of tracks or berths.

Total time for loading/unloading one train/barge/ship (incl. headway) (referring to ToR item 1.2.4)

The total time for loading or unloading one train, barge or ship (including headway) is based on the loading/unloading time calculated without headway and then adding the arrival, further arrival procedures and terminal check-in times for the unloading process or the terminal check-out, further procedures for departure and departure times for the loading process. Including the headway is important for terminals only having one transhipment track or berth. The additional time spent in the terminal by the train, barge or ship limits the total handling capacity of the terminal because the next train, barge of ship can only be unloaded and loaded after the previous one has left the terminal.

Trains/barges/ships that can be handled in an 8-hour shift (referring to ToR item 1.2.5)

This fact sheet element provides the total number of trains, barges or ships that can be handled in an 8-hour shift. The calculation was based on the process times already assessed in the detailed description of the transhipment process. Specifically, the total loading and unloading times for one train, barge or ship were taken into account.

Furthermore, the terminal layout, especially the number of tracks or berths for transhipment influences the calculation. For a single track or berth terminal the total time incl. headway must be taken because the track or berth is not available for other trains, barges or ships during the headway times. For a multiple track or berth terminal another train, barge or ship can be loaded or unloaded in the terminal during the headway time of another train, barge or ship, therefore the total time for loading or unloading one train, barge or ship excluding headway times is used in the calculation for these terminals.

In either terminal, 7 hours of productive working time for one 8-hour shift are assumed. The other hour is assumed to be lost due to inefficiencies and disturbances. For the calculation these 7 hours, or 420 minutes, were divided by the sum of the total times for unloading and loading one train, barge or ship, either incl. or excl. headway depending on the terminal layout. If applicable for the technology, this calculation was carried out per different type of main loading units.

Description of a full 600 and 1 000 km transport chain (referring to ToR item 1.2.3)

This element describes a full 600 and 1 000 km door-to-door transport within our model environment including two transhipments using the specific transhipment technology in the model environment as previously described in detail. Furthermore, the transport chain consists of the initial and the final road leg as well as the main leg via rail, inland waterway or sea. For all five elements information about the involved personnel and their working times as well as the total duration is provided. Because the transhipments have already been described in detail, their description here was kept short. The distances for the transport legs also provided here are as described in chapter 3.2.1, Table 9. The initial road leg begins after the road vehicle has been loaded at the ramp of the shipper, this initial loading procedure is not included in our transport chain analysis. This loading procedure may include loading the goods into the loading unit or “just” picking up the loading unit with the road leg means of transport. It is however worth to mention that some transhipment technologies require specific means of transport for the road leg which provide specific loading options at the shippers’ ramp . Accordingly, the final road leg ends with the arrival of the road vehicle at the destination without incorporating the unloading into this analysis. The total duration of the road legs and the main legs was calculated using the assumed average speeds of travel as described in chapter 3.2.1.

The description focusses on one type of LU, albeit a differentiation for different LU sizes might be included where applicable.

The information about the involved personnel and working times for the transhipments was taken from the previous elements. For the description of the road legs and the main leg initial assumptions were developed and then discussed with relevant practitioners to determine their validity and plausibility. The personnel include the operational personnel as well as personnel in production back office that is directly involved with the transport like dispatchers. Personnel in the administrative back office was excluded as this was assumed to be the same for all technologies.

For the road legs it is assumed, that one road dispatcher is necessary per 12 trucks, therefore its working time is 1/12th of the road leg duration.

For the main leg rail, the working time of the production back office was set to be 1/5th of the main leg rail duration based on inquiries to rail freight operators.

For inland waterway and short sea main legs, the functions captain, helmsman and sailor are summarized in one item, the ship’s crew, for all required main leg personnel. The input for this item has been gathered from other studies and from industry experts.

For inland waterways, when determining the working hours for the main leg duration, 3 crew members are assumed to be working at each point of the journey.

A study by Deloitte indicates a crew size between 15 and 26 crew per European ship, with smaller ships being on the lower end.[27] The study did not distinguish between short sea shipping and deep-sea shipping. For short sea shipping the crew is assumed to be at the lower end of the range, therefore assuming 16 personnel in various functions for this study. Of these crew members 8, or half of the total number, are assumed to be working at each point of the journey for determining the total working hours.

In accompanied intermodal transport, the main leg duration can, at least partly, be used for mandatory rest periods of the truck drivers, though to which extent this is possible or feasible depends on the circumstances and characteristics of the accompanying road legs. The distances in the model environment with relatively short road legs and long main legs are not representative for most practical implementations of accompanied intermodal transport. Having long rest periods above 8 hours after short driving times on the road is neither optimal nor economically feasible from the freight forwarders point of view. To accommodate this aspect the decision was made to not count the main leg duration as working time of the truck drivers in accompanied intermodal transport. However, when looking at personnel costs later on, a per diem for the truck driver for the time spent on the main leg is assumed.

For the road legs the working time was determined based on transporting one LU per truck, regardless of the type or size of the LU. For the transhipments and the main leg the working time was determined for a full train, barge or ship.

After the description of the individual elements of the transport chains, the sums for the total duration and the total working hours are shown for both the 1 000 km and the 600 km transport chain. The total duration is calculated by adding up the individual durations of the transhipments and the transport legs.

For the total working hours, the shown labour for the transhipments and the main leg can be summed up as well, although the working time for the road legs only shows the transport of one LU. Therefore, the working time for one LU as shown is multiplied by the number of transported LUs on the transport chain to calculate the total working hours for the road legs. The result is then added to the working hours of the transhipments and the main leg to get the total working hours for the transport chain.

Finally, the working hours are also provided on a per LU basis for the technology for the 1 000 km and 600 km transport chains to enable a better comparison with regard to personnel efficiency.

Terminal infrastructure

A detailed list of the terminal infrastructure in the model terminal for the technology and the connected modes of transport is provided here. The listed terminal infrastructure relates to the pathway of the loading unit in the model terminal; other infrastructure elements which might reasonably be part of an existing terminal but do not interact with the loading unit and are not relevant to the technology, like offices or social rooms, are not included in this analysis.

For the chosen elements, information is provided on their dimensions, the number of units and unit costs as well as the total area and total costs for the terminal infrastructure element. The dimensions, number of units and unit costs are input parameters which are used to calculate the total area (dimensions multiplied with number of units) and the total costs (number of units multiplied with unit costs). Some unit costs are expressed as costs per

[27] https://www2.deloitte.com/content/dam/Deloitte/global/Documents/dttl-er-challengeindustry-08072013.pdf; 17.08.2021.

area or costs per length, in these cases the unit costs are multiplied with the corresponding value, either total area or length dimension, to calculate the total costs.

The shown terminal infrastructure elements and their unit costs are used uniformly for all transhipment technologies. Table 17 below provides the description of these standard terminal elements and their unit costs. Technology specific infrastructure elements are closely linked to the technology specific equipment and are listed and described there.

The dimensions and number of units of the general elements per model terminal were based on experiences from previously conducted terminal projects as well as further research and were then discussed with the technology providers and users for validation. The corresponding unit costs were gathered through inquiries to engineering firms in the relevant field known to us from previous assignments. The general terminal infrastructure is scaled to accommodate a full train (740 m, 2 000 t), barge (110 m, 200 TEU) or ship (1 000 TEU, 2 500 loading meters) regardless of the number of loading units transported and transhipped in our model environment per train, barge or ship.

Table 17: List of standard terminal infrastructure elements and their unit costs

Terminal infrastructure elements		
Element	**Description**	**Unit costs**
Gate area	Fortified area for terminal check-in and administrative processing	80- €/m²
Driving lane	Lane for trucks and terminal trucks inside the terminal to reach the loading/unloading place. Normally there are 2 lanes per terminal (inbound and outbound)	80- €/m²
Loading lane	Transfer lane for parking the truck and loading unit and wait for transhipment	80- €/m²
Turning area	Area for changing between the two lanes (inbound lane and outbound lane) at the end of the terminal	80- €/m²
Intermediate buffer area (stackable)	Area for the storage of stackable LU. Stacking height is 4 LU on top of each other	90- €/m²
Switch from main line	Connecting switch between main line and terminal connection	62 500- €/unit
Line connection	Rail connection between main line and terminal	1 000- €/m
Transhipment track	Track for transhipment in the terminal	1 000- €/m
Terminal switch	Switch to connect line connection with the individual transhipment tracks	62 500- €/unit
Buffer stop	A device to prevent railway vehicles from going past the end of a transhipment track	12 000- €/unit
Driving range reach stacker/mobile harbour crane/HMHC	A specially fortified area for heavy transhipment equipment	90- €/m²
Sea port quay per metre	Berth for ships in a seaport	75 000 €/m
Inland port quay per metre	Berth for ships in an inland port	45 000 €/m
Crane tracks (two tracks) per metre	Tracks used by gantry cranes	2 500 €/m

Source: KombiConsult knowledge base

After describing and calculating the terminal infrastructure elements' area and cost, the sum for the total terminal area is provided. Based on the area, additional costs of 50€ per square metre for general structural engineering (e.g. lighting, fencing,) and 100 € per square metre for general earthworks and civil engineering are assumed and calculated. The total terminal building costs are provided by adding up the values for the individual elements as well as costs for structural engineering and earthworks and civil engineering.

Planning costs of 20% of the building costs are then calculated and added to derive the total terminal building costs. The value of 20% is derived from previously conducted terminal assignments.

Terminal building cost range

For the terminal building cost range cost factors based on the European construction cost price index were used.[28] From the website construction cost factors have been gathered for the European average as well as the individual countries. The costs presented so far are consistent with the European average. The list of cost factors is shown in Table 18 below. By multiplying the total terminal building costs with the shown factors, the indicative construction costs per terminal per country can be calculated. In the fact sheets only the calculated maximum value as well as the minimum value will be shown for the respective transhipment technology and loading unit combination.

Table 18: European construction costs price indices

Construction cost factors Europe	
Country	**Factor compared to European average**
EU 27	**100.00%**
Denmark	145.38%
Sweden	134.18%
Finland	114.04%
France	103.87%
Austria	100.67%
Luxembourg	98.21%
Germany	96.62%
Italy	93.63%
Belgium	89.29%
Netherlands	82.00%
Slovenia	80.00%
Malta	79.58%
Ireland	79.18%
Spain	70.52%
Poland	65.61%
Greece	63.46%
Czechia	61.11%
Cyprus	60.29%
Estonia	59.33%
Lithuania	58.72%
Latvia	57.90%
Croatia	55.00%
Hungary	53.24%
Slovakia	51.68%
Portugal	50.33%
Bulgaria	48.69%
Romania	46.40%

[28] http://constructioncosts.eu/cost-index/; 20.08.2021.

Depreciation time terminal

The depreciation time for the terminal infrastructure is assumed to be 25 years for all following calculations. This timeframe also coincides with the assumed service life and payback period of the terminal infrastructure. The implication for our model calculation is that the terminal will only be fully paid off at the end of the service life, which is typically not the case in practice, however this approach is suited to enable a fair comparison between the different technologies. If the payback period were defined differently, e.g. in the sense of the period required to operate the terminal and order to earn the operational costs and investment costs certain assumptions on the development of the revenues from sales would have to be made. These would depend on an estimate how fast the number of handlings per year can reach the maximum operational capacity and the development of the price per handling over time. For the comparison of transhipment technologies this information is not necessary so that we focused on the cost side and the depreciation time.

Terminal building costs per year

Here the terminal building costs per year are calculated. With regard to the financing an interest rate of 5% and constant yearly repayments is assumed. The financing period corresponds to the depreciation period.

Terminal equipment

The equipment used in the model terminal operations is described here. The information provided per equipment covers the unit costs, the number of units in operation in the terminal, the total costs per equipment and the depreciation time of the equipment. The unit costs, number of units and the depreciation time are input parameters which were collected and validated in desk research and from the producers of the equipment. From these parameters the total costs are calculated multiplying the unit costs with the number of units.

The depreciation time in years, as for the infrastructure, also represent the service life and payback period of the equipment. An aftermarket for used and depreciated equipment was not considered as it was deemed highly circumstantial and dependent on external changing factors which cannot be analysed within the scope of this study.

The total costs for all equipment are then summed up to provide a value for the total costs of the terminal equipment.

Planning costs of 20% of the investment are again assumed, which are added to the total equipment costs. Furthermore, as for infrastructure a constant yearly repayment considering 5% interest is assumed for the calculation of the total terminal equipment investment costs per year.

Total terminal investments (infrastructure and equipment)

For infrastructure and equipment, the total investments including planning costs are summed-up to provide the initial necessary investment for starting up the terminal. In the same way the infrastructure and equipment investments including planning costs per year are summed up to provide the total investment costs per year for a complete terminal for the respective transhipment technology.

Total terminal handling capacity

The total terminal handling capacity in loading units handled per year of the previously described and analysed model terminal is described here.

To determine the total handling capacity of the model terminal it is important to know whether the tracks/berths or the handling equipment are the limiting factor: two calculations are therefore conducted per technology and LU combination to determine the handling capacity limitation.

For the yearly operating time of the terminal 250 operating days per year with 2 shifts of 7 productive working hours each per day are assumed.

The handling capacity per year of the tracks or berths is calculated with the following formula:

$$C_1 = X_I * \frac{t_{OT}}{t_H} * 2C_{TBS}$$

$With$:
$C_1 = Handling\ capacity\ by\ tracks\ or\ berths$
$X_I = Number\ of\ transhipment\ infrastructure\ (tracks\ or\ berths)$
$t_{OT} = Operating\ time\ of\ the\ terminal\ per\ year\ (minutes)$
$t_H = Handling\ time\ for\ one\ train, barge\ or\ ship\ incl.\ headway$ (minutes)
$C_{TBS} = Loading\ units\ on\ one\ train, barge\ or\ ship$

The handling capacity per year of the handling equipment is calculated with the following formula:

$$C_2 = X_E * \frac{t_{OT}}{t_T}$$

$With$:
$C_2 = Handling\ capacity\ by\ terminal\ equipment$
$X_E = Number\ of\ terminal\ handling\ equipment$
$t_{OT} = Operating\ time\ of\ the\ terminal\ per\ year\ (minutes)$
$t_T = Average\ time\ for\ the\ transhipment\ of\ one\ LU\ with\ one\ handling\ equipment\ unit$

From the two calculated values the lower one is the resulting total terminal handling capacity per year shown here.

Terminal maintenance costs

The costs incurred for the repairs and maintenance of the terminal infrastructure and equipment are calculated using a percentage rate of the investments. For the infrastructure a fixed rate of 5% per year on the total infrastructure investments (excluding planning costs) is assumed. This percentage covers all maintenance work on fortified areas, traffic lanes, tracks, supply and disposal systems. The value is based on our previous experience and has been verified with terminal operators contacted for this study.

For the equipment the percentage has been gathered from the equipment manufacturers or users for the individual pieces of equipment and might therefore be different from the 5%. The percentage rate is applied to the total equipment investments (excluding planning costs) to calculate the yearly equipment maintenance costs as for the infrastructure.

With the yearly percentages on the investment costs the costs per year are calculated for the infrastructure and all equipment and the results are then summed up to derive the total terminal maintenance costs per year.

Terminal energy consumption

In addition to the energy required for handling, which is technology-dependent, energy costs for the infrastructure are also included under this item. Based on the area of the terminal, the same value of 1.1 kWh per square metre and year is applied for all terminals regardless of the technology. This value has been gathered from terminal operators and includes the energy costs for lighting, switch heating, etc., which are not directly caused by the transhipment technology.

The energy required for handling is consumed by the terminal equipment. All energy consuming equipment is listed here with the type of energy source it uses and the consumption per transhipment which has been gathered from the technology providers and users. The energy consumption per year for the equipment is then calculated using the terminal handling capacity per year. Using the corresponding costs for the type of energy, the annual energy costs are calculated for the infrastructure and the equipment.

For electricity costs, the average European energy cost per kWh for non-household consumers of 0.125 €/kWh (incl. non-recoverable taxes) is applied.[29]

For diesel costs, the average European diesel cost per litre of 1.12 €/l (incl. non-recoverable taxes) is applied.[30]

Summing up the partial costs per energy consumer gives the overall value for the total terminal energy costs per year.

Terminal energy cost range

The terminal energy cost range in Europe was determined by taking into account the electricity as well as diesel cost range across Europe. The electricity costs per country as well as the EU27 average were gathered from the Eurostat database and the cost factors per country calculated using the EU27 average as the 100% baseline.[31] The resulting electricity cost factors are shown in Table 19 below.

[29] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics#Electricity_prices_for_non-household_consumers; June 2021.
[30] https://ec.europa.eu/energy/data-analysis/weekly-oil-bulletin_en ; June 2021.
[31] https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205/default/table?lang=de ; August 2021.

Table 19: Electricity cost range Europe (Index EU27 = 100)

Electricity cost factors Europe	
Country	**Factor compared to European average**
EU27	**100.00%**
Germany	144.98%
Italy	120.73%
Ireland	118.50%
Cyprus	108.77%
Malta	107.42%
Slovakia	104.94%
Belgium	94.50%
Austria	94.42%
Spain	93.70%
Portugal	88.84%
Poland	85.89%
Greece	84.45%
Latvia	84.13%
Netherlands	82.54%
Lithuania	81.82%
Croatia	81.58%
Romania	81.26%
Slovenia	77.83%
France	76.08%
Hungary	74.96%
Luxembourg	74.80%
Estonia	69.62%
Bulgaria	67.22%
Czechia	67.15%
Finland	60.53%
Denmark	54.70%
Sweden	46.89%

For the diesel cost range the diesel costs per country as well as the European average were gathered from the European weekly oil bulletin.[32] The bulletin only provides information about the diesel costs either completely including or excluding taxes and levies. To enable a better comparison, the Value Added Tax (VAT) has been deducted from the costs per country including all taxes and levies. With these new values excluding VAT the cost factors are calculated as for the electricity cost range. The resulting diesel cost factors are shown in Table 20 below.

[32] https://ec.europa.eu/energy/data-analysis/weekly-oil-bulletin_en ; August 2021 for the week of August 16th.

Table 20: Diesel cost range Europe (Index EU27 = 100)

Diesel cost factors Europe	
Country	**Factor compared to European average**
EU27	**100.00%**
Sweden	122.20%
Belgium	110.27%
Italy	110.09%
Finland	108.91%
Netherlands	107.34%
France	106.41%
Portugal	104.43%
Germany	104.20%
Ireland	103.46%
Denmark	100.62%
Greece	100.21%
Croatia	98.39%
Cyprus	98.15%
Slovenia	95.95%
Slovakia	93.46%
Spain	93.21%
Luxembourg	92.96%
Austria	92.64%
Czechia	91.59%
Malta	91.34%
Latvia	90.81%
Estonia	90.64%
Hungary	88.57%
Romania	87.09%
Lithuania	87.09%
Poland	86.33%
Bulgaria	82.37%

With each cost ranges the resulting values for the minimum and maximum electricity and diesel costs per technology and loading unit combination are calculated. Furthermore, the total minimum and maximum energy costs per technology and loading unit combination are calculated by adding up the minimum electricity and diesel costs as well as the maximum electricity and diesel costs based on the technology's specific energy consumption. It is important to note, that the resulting total minimum and maximum values are calculated theoretical values and not concrete values from any of the European countries. As can be seen in the tables above the order of countries is different between both types of energy and the minimum or maximum values per type of energy occur in different countries and not in the same one, as is assumed for the calculation of the provided minimum and maximum values.

Terminal personnel

The table provides the relevant terminal personnel functions and information about their necessary numbers per shift and per year as well as the resulting personnel costs per year.

The necessary personnel per function and per shift in FTE (full time equivalent) is calculated from the number of handling equipment and accordingly the necessary number of handling equipment drivers which are assumed to be set and provide the starting point for the calculation. Based on the time each function is involved in the loading and unloading of one loading unit the ratio compared to the handling equipment drivers can be determined per function. As an example, if one handling equipment driver takes 10 minutes to load and unload one loading unit and there are two FTE in handling equipment drivers, then another function that is only involved in the process for 5 minutes must be filled with one FTE to keep the process and handling equipment running.

As this calculation oftentimes provides uneven results, the necessary personnel per shift was rounded-up to half FTE, providing a more realistic and feasible assumption for the number of required personnel.

To calculate the number of necessary personnel per year the necessary personnel per shift was multiplied by two to account for the two shifts per day and a factor of 1.635 to account for absences due to public holidays (~10 days), vacation days (~30 days) illness (~5 days) and other reasons (~3 days) as well as a 25% productivity factor subtracted from the remaining working hours to account for time spent by the personnel on other tasks not directly included to the transhipment process.[33]

The personnel costs per year per employee for a specific function are shown in Table 21 below. Yearly personnel costs were gathered in consultation with different terminal operators and then standardized to correspond to the European average personnel costs using the data provided by Eurostat about the ratios between the average European labour costs and the labour cost level per country the gathered information applied to.[34]

Table 21: Terminal personnel costs

Terminal personnel costs	
Function	**Yearly personnel costs**
Checker	26 500 €
Gate Agent	33 000 €
Handling Equipment Driver	35 000 €
Terminal Truck Driver	32 000 €
Instructor “groundsman”	31 000 €
Terminal dispatcher	37 000 €

Source: KombiConsult analysis

The overall personnel costs per function are calculated by multiplying the general yearly personnel costs as shown above with the technology specific necessary personnel per year for each function.

The sum of the personnel costs for all functions then provides the total terminal personnel costs per year.

[33] https://www.billomat.com/magazin/jahresarbeitszeit-berechnen/; June 2021
[34] https://ec.europa.eu/eurostat/databrowser/view/lc_lci_lev/default/table

Terminal personnel cost range

As for the other cost ranges, a minimum and a maximum value for the terminal personnel costs is provided. These values were determined from the European average labour costs per country for the group of industry, construction and service workers which includes the logistics sector.[35] Based on the provided labour costs the cost factors per country compared to the EU27 average were determined.

Table 22 below shows the resulting cost factors per country.

Table 22: Personnel cost range Europe (Index EU27 = 100)

Personnel cost factors Europe	
Country	**Factor compared to European average**
EU27	**100.00%**
Denmark	161.37%
Luxembourg	150.18%
Belgium	146.21%
France	132.13%
Netherlands	131.41%
Sweden	131.05%
Germany	128.52%
Austria	125.27%
Finland	122.74%
Ireland	119.86%
Italy	103.97%
Spain	78.70%
Slovenia	68.59%
Cyprus	62.82%
Greece	59.21%
Malta	54.15%
Portugal	52.71%
Czechia	48.74%
Estonia	48.38%
Slovakia	45.13%
Croatia	40.07%
Poland	38.63%
Hungary	35.74%
Latvia	35.74%
Lithuania	33.94%
Romania	27.80%
Bulgaria	21.66%

[35] https://ec.europa.eu/eurostat/databrowser/view/LC_LCI_LEV/default/table ; August 2021.

Total ground costs per year

The total ground costs for the terminal are calculated under the assumption of 5 € per m² per year. As ground costs in the EU and Switzerland vary greatly and depend on local conditions the flat rate of 5 € per m² per year was agreed with DG MOVE beforehand to have some simplified way of including them.

With this final cost element included for the analysis in this study, the total terminal costs per year are also provided.

Furthermore, a variation of the ground costs with costs per square metre of zero (0 €) and 10 € per m² and year is shown.

Total costs per year

The sum of the terminal building costs and terminal equipment investments costs per year (both including planning costs) as well as the yearly ground costs is shown here.

Costs per transhipment

Based on the previously calculated terminal costs per year as well as the total terminal handling capacity per year the different cost elements per transhipment are calculated. These are yearly values for the total terminal investment costs (building and equipment incl. planning), maintenance costs, energy costs, personnel costs as well as ground costs per transhipment. The maintenance, energy and personnel costs per transhipment summed up provide the value for the total operational costs per transhipment.

Cost range per transhipment in EU

The overall cost range for the transhipment, based on the cost ranges previously determined for the construction, energy, personnel and ground costs, is shown here. The minimum and the maximum value are calculated using the individual cost ranges for the different cost elements. Therefore, as has previously been explained for the energy costs and for the same reasons specified there, the resulting total minimum and maximum values are calculated theoretical values and not concrete values from any of the European countries.

Loading unit investments and costs

This element provides information about the LU investments and costs for further consideration in the following analysis of the transport chain. The LU specifications do not change for different technologies, only the chosen LU or LUs might vary. Table 23 below provides information about unit costs, depreciation time and maintenance costs per year for different LU types. The information has been gathered from producers and users of the mentioned LUs and from previous assignments. From the gathered values for investments and maintenance the total costs per operating hour have been calculated under the assumptions of 5% interest and constant repayments over the depreciation time as well as 300 operating days per year with 16 operating hours each.

For technology-specific loading units or loading unit adapters the relevant investment costs were obtained directly from the supplier and are described in the respective fact sheets.

Table 23: Standard loading units and their costs

LU type	LU	Unit costs (€)	Depreciation time (years)	Maintenance per year (€)	Costs per operating hour (€)
ISO-Container	20'	3 000	12	90.00	0.06 €
	40'	4 200	12	126.00	0.09 €
	40' HC	4 900	12	147.00	0.11 €
Mobiler Container	30'	20 000	12	300.00	0.38 €
Swap bodies	7 m	9 500	12	285.00	0.20 €
	13.6 m	17 000	12	510.00	0.37 €
Semi-trailer	Craneable	27 000	11	810.00	0.61 €
	Non craneable	26 000	11	780.00	0.59 €
Complete road vehicle	Truck with semi-trailer	126 000	10	10 780.00	4.24 €

Source: KombiConsult analysis

Main leg investments

The necessary costs for main leg equipment are shown here. The values for unit costs, number of units and depreciation time are input parameters. The information was gathered from equipment providers and from equipment users. The total costs per main leg equipment are calculated multiplying the unit costs with the number of units. To calculate the total costs per operating hour first the yearly investment costs, assuming 5% interest and constant repayments over the depreciation time, are calculated and the result is then divided by the operating hours per year. For main leg equipment 300 operating days per year with 16 operating hours a day are assumed.

Then the sums of the total costs and the total costs per operating hour are calculated for all listed equipment.

Main leg equipment maintenance costs

The main leg equipment maintenance costs were gathered as a yearly percentage of the total investment costs. With this percentage, the total maintenance costs per year were calculated which were then broken down further to maintenance costs per operating hour using the previously mentioned assumption of 300 operating days per year with 16 operating hours a day.

The total maintenance costs per operating hour for all listed equipment were then summed up.

Main leg energy consumption

This element lists the main leg equipment which consumes energy. For each listed equipment the type of consumed energy and the consumption were gathered in desk research and from industry practitioners.

For the main leg rail an electric locomotive is assumed, and the consumption is expressed in consumption per ton-kilometre (tkm).

For the calculation of the rail tkm the calculated weight per train from the calculation of the number of loading units, assuming an 85% load factor, is used.

Results from a 2018 study, which analysed the energy consumption for electricity powered freight trains travelling between Germany and the Netherlands[36], are used for estimating the energy consumption. The locomotive observed in this study, a Siemens ES64F4, is a common locomotive used in rail freight and assumed to be comparable in energy consumption to our model locomotive. The study results show a typical energy consumption of 0.02 kWh/tkm with the achievable optimum being at 0.01 kWh/tkm. Different total train weights and lengths were looked at in this study, with higher weight and lower length moving the consumption closer to the optimum. The trains calculated for the technologies have a high weight but are also relatively long with over 600 m. We therefore assume the typical energy consumption observed of 0.02 kWh/tkm for our transport model. This consumption value has been confirmed to be plausible by rail freight practitioners.

For IWW and SSS the consumption of gasoil (diesel for ships) is assumed.

The energy consumption for IWW is assumed to be 0.004 l/tkm. This value falls within the consumption range determined in a study commissioned by the German Federal Waterways and Shipping Administration.[37]

For SSS the energy consumption is assumed to be 0.003 l/tkm based on a report by the international energy agency[38] and in line with other sources found during the research for this study.

From the consumption per distance described above the consumption per hour was derived using the average speed per mode of transport as mentioned in chapter 2.2.1.

The consumption per hour was then multiplied with the cost factor per consumed energy to calculate the energy costs per operating hour for the equipment.

The full cost of electricity per kWh for the consumer is assumed to be 0.125 €. This value includes applicable and non-recoverable taxes and levies. The value is the European average cost of electricity for non-household consumers[39].

For diesel used in IWW and SSS operations the costs are assumed to be 0.72 €/l. This includes the bunker costs and has been coordinated with shipping operators.

Other operational costs main leg

In addition to maintenance and energy costs there are other costs incurred during main leg transport. For all modes of transport personnel costs fall under this category. These are calculated using the total working time determined for the main leg and the hourly costs per each main leg personnel function as shown in Table 24. These have been determined in the same manner described already for the terminal personnel costs but were then broken down to personnel costs per working hour instead of personnel costs per year assuming the same personnel efficiency factor of 1.635 described for the terminal personnel.

For accompanied rail intermodal transport, in addition to the train driver, the attendant and the train dispatcher, a per diem for the truck drivers is added as a flat value of 20 € per truck driver per transport in the personnel costs.

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[36] TNO 2018, Insight into the energy consumption, CO2 emissions and NOx emissions of rail freight transport; https://publications.tno.nl/publication/34626344/HT13Na/TNO-2017-R11679.pdf; 11.06.2021.
[37] Verkehrswirtschaftlicher und ökologischer Vergleich der Verkehrsträger Straße, Schiene und Wasserstraße; https://www.bafg.de/DE/08_Ref/U1/02_Projekte/05_Verkehrstraeger/verkehrstraeger_lang.pdf?__blob=publicationFile; 18.08.2021.
[38] https://www.iea.org/reports/international-shipping.
[39]https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205/default/table?lang=en;11.06.2021.
https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205/default/table?lang=en; 11.06.2021.

For IWW and SSS the personnel costs per hour are provided for the entire ship's crew as one item. The crew item considers the respective crew sizes per mode of transport as described under working hours.

Table 24: Main leg personnel costs

Main leg personnel costs	
Personnel function	**Personnel costs per hour (€)**
Train driver	35.38 €
Train dispatcher	32.43 €
Wagon inspector	35.38 €
Attendant	30.96 €
Ship crew IWW	60.40 €
Ship crew SSS	285.76 €

Source: KombiConsult analysis

For rail transports additional track access charges are incurred. According to a study conducted by PWC in 2018, the average track access charge for rail freight in Europe was 2.98 € per track kilometre in the year 2017[40]: track access charges of 3 € per track kilometre will thus be assumed for this study.

For SSS an additional port fee of 1 494 € per transport will be assumed based on the study "The COMPetitiveness of EuropeAn Short-sea freight Shipping compared with road and rail transport (COMPASS)" commissioned by DG Environment.[41]

Road leg investments

This element shows the necessary investments into road leg equipment for the technology. In most cases the listed equipment is less dependent on the technology but rather on the transhipped loading units. Semitrailers and full vehicles used as loading units and described and considered under loading unit investments will not be included as road leg equipment again.

Similarly, to what has been done with the main leg equipment, the unit costs and the depreciation time were gathered as input parameters from previous assignments and validated with freight forwarders. As each listed equipment is only used once, there is no necessity to show number of units and total costs. With the unit costs and depreciation time the total costs per operating hour are calculated under the assumption of 5% interest and constant yearly repayments as for all other investments as well as 250 operating days per year and 14 operating hours per day as for terminal equipment.

The total road leg investment costs and the total road leg investment costs per operating hour are summed up for all listed equipment.

Reasonable fleet size (truck/semi-trailer ratio)

For intermodal transport with the loading unit semi-trailer (non-craneable and craneable) an estimate is provided for a reasonable fleet size depending on the main leg distance, e.g., how many semi-trailers should be used per truck to achieve a good utilization of both equipment types.

[40] PWC, Studie zur Gestaltung der Eisenbahninfrastrukturpreise in Europa, https://www.pwc.de/de/offentliche-unternehmen/eisenbahninfrastrukturpreise_012018.pdf; 11.06.2021.
[41] https://www.tmleuven.be/en/project/europeanshortseashipping; August 2021.

To calculate this ratio, first the time one representative truck is involved in the transport chain for both road legs is estimated. This time includes the time spent in the terminal by the road haulage operator during loading and unloading, two times the road leg duration as well as an assumed time of 60 minutes for breaks and an assumed time of 240 minutes spent at the start/end point of the road leg.

Second, the time of one semi-trailer transport on the entire 600 km or 1 000 km transport chain was calculated. For the calculation it was assumed, that the transport time of one semi-trailer is equal to the involvement time of the truck plus the main leg duration and the total terminal time for loading and unloading one full train or ship.

By then dividing the transport duration of the semi-trailer by the time the truck is involved, a ratio between the two times is calculated which also represents an adequate ratio between trucks and semi-trailers.

Road leg equipment maintenance costs

The road leg equipment maintenance costs were gathered as a yearly percentage of the unit costs from which the total maintenance costs per year and equipment can easily be derived. Based on the assumption of 250 operating days per year and 14 operating hours per day the costs per operating hour are then calculated, again also providing a sum for the total maintenance costs per operating hour for the road leg.

Road leg energy consumption

In this item information is provided about the road-leg energy consumption and type of energy consumed per 100 km. For all technologies the type will be diesel and the consumption of the truck is assumed to be 33 l/100 km on average. Using the assumed average speed of 60 km/h the consumption per operating hour is calculated to be 19.8 l for the described standard truck. The consumption is then multiplied with the costs per unit of energy to calculate the energy costs per operating hour for the road leg.

For the road-only transport the fuel consumption is assumed to be 30l /100 km due to better fuel efficiency on longer distances.

The cost of diesel is assumed to be 1.12 € based on the European average costs for diesel fuel. This value includes the cost of the diesel fuel and the various non-recoverable taxes.[42]

The costs per operating hour for all energy consumers on the road leg are summed up to calculate the total energy costs per operating hour for the road leg.

Personnel costs road leg

To calculate the personnel costs for the road-leg, personnel costs per hour for the truck driver and the dispatcher are provided here. The personnel costs per hour are assumed to be 22.11 € for the truck driver and 24.32 € for the dispatcher. These values already include the personnel efficiency factor of 1 635 described for the terminal personnel.

Other operational costs road leg

For the road legs, we assume that 80% of the transport distance takes place on toll roads. An average cost of 0.187 € per km driven on toll roads in Europe is assumed for this study based on data found in desk research.[43]

[42] https://ec.europa.eu/energy/data-analysis/weekly-oil-bulletin_en; June 2021.
[43] https://impargo.de/en/blog/truck-toll-europe.

Total costs 600 km/1 000 km transport

To determine the total costs of the transport chain, first the total costs for the road legs, for the main legs with 600 and 1 000 km lengths, for the transhipments and the LU costs are individually determined and then added together for the grand total. The costs are provided for both the transport of all loading units on the train, barge or ship as well as for a single LU.

The total costs for the first road leg are first determined for one LU using the following formula:

$$RL_1 = (I_r + M_r + E_r + W_{td}) * (t_{rl} + t_{tl}) + W_{rd} * t_{rd}$$

$With$:
$RL_1 = Total\ costs\ first\ road\ leg$
$I_r = Total\ investment\ costs\ road\ leg\ per\ operating\ hour\ (€/hour)$
$M_r = Total\ maintenance\ costs\ road\ leg\ per\ operating\ hour\ (€/hour)$
$E_r = Total\ energy\ costs\ road\ leg\ per\ operating\ hour\ (€/hour)$
$W_{td} = Personnel\ costs\ truck\ driver\ per\ operating\ hour\ (€/hour)$
$t_{rl} = Duration\ of\ the\ road\ leg\ (hours)$
$t_{tl} = Time\ spent\ in\ Terminal\ for\ the\ road\ haulage\ operator\ loading\ (\text{hours})$
$W_{rd} = Personnel\ costs\ road\ dispatcher\ per\ operating\ hour\ (€/hour)$
$t_{rd} = Working\ time\ road\ dispatcher\ per\ road\ leg\ (hours)$

The investments and operational costs for the road leg equipment as well as the costs for the truck driver per hour are multiplied with the sum of time spent on the road leg and the time spent in the terminal for the road haulage operator during loading. Then the costs for the road dispatcher are added based on the working time determined per road leg.

For the second road leg the calculation is mostly the same, only the 'Time spent in Terminal for the road haulage operator loading' is changed to the 'Time spent in Terminal for the road haulage operator unloading'.

As these are the costs for the transport of one loading unit on the road leg, they are multiplied with the number of loading units transported on the main leg for the technology to receive the total costs per road leg.

The costs for the transhipment of one loading unit have already been calculated and can be taken directly from the element 'Total costs for one transhipment'. These costs are used both for the first and for the second transhipment of one LU.

As for the road leg they are multiplied with the number of loading units transported on the main leg to receive the total costs for the first and the second transhipment in the transport chain.

For the main leg rail of 450km length (and similarly for the main leg of 850 km length) the total costs are calculated for all loading units on the full train with the following formula:

$$ML_r = (I_{mr} + M_{mr} + E_{mr} + O_{mr} + W_{tp}) * (t_{450mr} + t_a + t_d) + (I_{wmr} + M_{wmr}) * (t_{li} + t_{ui} - t_a - t_d) + W_{td} * t_{td450} + W_{wi} * t_{wi} + W_{pd}$$

$With$:
$ML_r = Total\ costs\ main\ leg\ rail$
$I_{mr} = Total\ investment\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$M_{mr} = \ Total\ maintenance\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$E_{mr} = \ Total\ energy\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$O_{mr} = \ Other\ operational\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$W_{tp} = \ Personnel\ costs\ train\ personnel\ per\ operating\ hour\ (\frac{€}{hour})$

$t_{450mr} = Duration\ of\ the\ 450\ km\ main\ leg\ (hours)$

t_{ta} = Time of train personnel for arrival of train in terminal

t_{td} = Time of train personnel for departure of train from terminal

$I_{wmr} = \ Total\ investment\ costs\ wagons\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$M_{wmr} = \ Total\ maintenance\ costs\ wagons\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$t_{li} = Total\ time\ for\ loading\ one\ train\ incl.headway\ (hours)$

$t_{ui} = Total\ time\ for\ unloading\ one\ train\ incl.headway\ (hours)$

$W_{td} = \ Personnel\ costs\ train\ dispatcher\ per\ operating\ hour\ (\frac{€}{hour})$

$t_{td450} = Working\ time\ train\ dispatcher\ for\ 450\ km\ main\ leg\ (hours)$

$W_{wi} = \ Personnel\ costs\ wagon\ inspector\ per\ operating\ hour\ (\frac{€}{hour})$

$t_{wi} = Working\ time\ wagon\ inspector\ per\ train\ (hours)$

W_{pd} = Costs for the per diems of truck drivers (only in accompanied intermodal transport)

The investments and operational costs for the main equipment as well as the costs for the train personnel per hour are multiplied with the duration of the main leg and the time of the train driver in the terminal during arrival and departure. The train personnel include only one[44] train driver for unaccompanied transport and one train driver and one attendant for accompanied transport. Then the investments and operational costs for the wagon set multiplied with the total time they spend in the terminal, minus the time they spend in the terminal with the train driver, are added. Then, the personnel costs for the train dispatcher and the wagon inspector are added based on their individual working times on the full train. For unaccompanied intermodal transport the calculation is done, however for accompanied intermodal transport finally the per diem for each truck driver is added.

If additional main leg equipment besides the loco and the wagon set is used, it will be treated like the wagon set and its costs per hour will also be added for the standing time in the terminal.

This is the calculation for the train, therefore, to get the costs per LU the result is divided by the number of loading units on the train.

The calculation for the 850 km rail main leg follows the same formula, only changing the duration of the main leg and the working time of the dispatcher from the 450 km to the 850 km values.

For IWW and SSS the calculation follows a similar approach with the differences as shown below.

[44] It is known that in some regions in Italy a second person is required in the cabin of a locomotive, but this is neglected in the calculation since it is not determined by the transhipment technology.

$$ML_w = (I_{mr} + M_{mr} + E_{mr} + W_{tp}) * (t_{450mr} + t_a + t_d) + (I_{wmr} + M_{wmr}) * (t_{li} + t_{ui} - t_a - t_d) + W_{td} * t_{td450} + W_{wi} * t_{wi} + W_{pd}$$

$With$:

$ML_{mw} = Total\ costs\ main\ leg\ IWW/SSS$

$I_{mw} = Total\ investment\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$M_{mw} = Total\ maintenance\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$E_{mw} = Total\ energy\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$W_{cw} = Personnel\ costs\ Crew\ per\ operating\ hour\ (\frac{€}{hour})$

$t_{450mw} = Duration\ of\ the\ 450\ km\ main\ leg\ (hours)$

t_{ta} = Time of crew for arrival of barge/ship in terminal

t_{td} = Time of crew for departure of barge/ship from terminal

$I_{mw} = Total\ investment\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$M_{mw} = Total\ maintenance\ costs\ main\ leg\ per\ operating\ hour\ (\frac{€}{hour})$

$t_{li} = Total\ time\ for\ loading\ one\ barge/ship\ incl.\ headway\ (hours)$

$t_{ui} = Total\ time\ for\ unloading\ one\ barge/ship\ incl.\ headway\ (hours)$

$O_{mw} = Other\ operational\ costs\ main\ leg$

For one, all investment and maintenance costs are also applied to the entire transhipment duration because the main leg equipment cannot be split like for rail. Furthermore, no additional personal costs other than the ship's crew are assumed. Additionally flat other operational costs, for example port fees, are added per main leg.

Also, for IWW and SSS the 850 km main leg is calculated in the same way, only changing the main leg duration.

For the grand total costs of the 600 km and 1 000 km transport chains the costs for the loading unit are left to be determined. These will be calculated by multiplying the costs per operating hour for the LU and the total duration of the transport chain of 600k km or 1 000 km length.

In order to take into account the additional organizational costs that are necessary to plan and carry out an intermodal transport chain, a surcharge of 25% on the previous total costs will be added in agreement with the DG MOVE.[45]

All the described costs for the 600 km and 1 000 km transport chains can now be summed up to calculate the grand total costs for both distances.

[45] See also the variety of assumptions in TRT/MDS Transmodal, Gathering additional data on EU combined transport, Final Report, 2017. The study determines the total additional costs for organizing intermodal transports to be 40%, as also summarized in the 2017 COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT (DG MOVE). These total additional costs of 40% include cost factors which are incorporated in this study in other cost elements, for example for longer transport durations, which we will not be considering again at this point.

Cost range 600 km/1 000 km transport in EU

The cost range provided for the 600 km and 1 000 km transport chain takes into account the minimum and maximum transhipments costs previously determined and applies these values to both transhipments in the transport chain.

External costs

External costs (social, environmental and economic costs) are those costs that are not borne by the entities or people causing them but are imposed on society or third parties. Freight transport produces exhaust gases and noise. In addition, fuel and infrastructure must be provided. All these points have a direct and indirect impact on third parties. The amount of negative externalities inflicted upon others depends on the involved modes of transport, with road transport causing higher external costs per transported ton than rail, IWW or SSS. This chapter aims to present the external costs between the different transhipment technologies and modes of transport and to compare them with road-only transport.

In this study external costs are composed of the costs of accidents, air pollution, climate change, noise, congestion, well-to-tank emissions (WTT), habitat damage and other external cost categories (e.g., soil and water pollution) as specified in the Handbook on the external costs of transport.[46] The values for the average external costs of the EU states in tonne-kilometres (tkm) for freight transport of the individual modes of transport HGV (heavy goods vehicle), rail and inland waterways can be seen in the Handbook Table 73 on page 172. The external costs include CO2 emissions as climate change costs.

For the external costs of rail freight, the values shown here assume a share of 25% of diesel and only 75% electricity in the fuel consumption. In our model environment we are assuming all electric traction for the rail main leg, therefore the excel sheet provided with the handbook was used to calculate the external costs for this case. For electric traction only, the external costs for rail freight are calculated to be 1.1 €-cent/tkm instead of the 1.3 €-cent/km shown as the overall average including the diesel-traction share. For HGV and IWW transports the external costs are applied as shown in table 73 of the handbook.

The values for the external costs are then determined for the tkm of the 600 and 1 000 km transport chains including the rail and inland waterway main legs as specified for the individual transhipment technology and LU combinations. For short sea shipping, the Handbook has little data. Primarily, external costs for ferries with a focus on passenger transport are given in €-cents per passenger-kilometre. For this reason, the values for maritime transport are used as the basis for external costs for short-sea shipping. For short-sea transport, Figure 16 on page 159 in the handbook and the Excel-table “Complete overview of country data for Handbook” are used, which takes into account air pollution, climate change and WTT costs as external costs for maritime transport.

Following the premises stated above, the Handbook provides the following external costs for the individual modes of transport:

HGV (Road): 3.4 €-cent/tkm

Rail: 1.1 €-cent/tkm

Inland waterways: 1.9 €-cent/tkm

Short sea shipping (maritime transport): 0.7 €-cent/tkm

[46] Handbook on the external costs of transport (2019).

The Handbook does not show separate data on external costs for the transhipment terminals. To obtain a comparison of the individual transhipment technologies in the context of their environmental friendliness, the energy consumption and thus the CO2 emissions per transhipment are assessed. Technologies in which the truck driver loads the loading units with his own truck are assessed in this context like a terminal tractor were used. The energy consumption per transhipment of each technology have previously been determined. The CO2 equivalent emissions per consumed unit of fuel have been determined to be 255 g CO2e per kWh for electricity[47] and 2 700 g CO2e per l for diesel[48].

Based on the values provided in the Handbook external costs on p. 65 f. of 100 € per ton of CO2e are assumed and applied to the CO2e emissions per transhipment for the technologies.

To determine the external costs, the transport performance of the individual transport legs along the transport chain is the basis. This is then multiplied by the average external costs. To make the results of the different technologies comparable, the external costs determined are calculated in terms of net tonnes transported. This gives a better representation of the relationship between different payloads and deadweight. For example, technologies with a lot of additional necessary material will have the same transport performance as ones using less material, but the external costs will be greater per net tonnes transported than for technologies with less deadweight.

For the two road legs before and after the main leg in the example transport chains, the distances listed in Table 10: Road leg distance per mode of transport for the individual modes of transport are used. These are multiplied by the weights of the truck, loading unit and loaded goods. If a loading unit is not self-driving, the weight of the chassis is added. For technologies that require additional equipment for road transport, this is also added. The resulting transport performance added up for both road legs is multiplied by the external costs for road transport. Due to the different loading units, the performance of the transhipment technologies and the additional equipment required in some cases, there are different external costs for road transport.

For the main leg, the total train weight determined for each transhipment technology is multiplied by the distances listed in Table 10: Road leg distance per mode of transport for the individual modes of transport and by the factor for rail from the Handbook. The resulting external costs are then divided by the number of loading units transported. The result is added to the external costs determined for the road leg. Due to the different transport distance, modes of transport, loading units, performance of the handling technologies and the additional equipment required in some cases, there are different external costs for the main leg.

To enable the comparison with road-only transport, it is assumed that a truck pulls a semi-trailer loaded with 20 t of goods. The calculated transport performance results in external costs of € 695.64 for the 600 km and € 1 159.40 for the 1 000 km road-only transport. These costs are the same for all transhipment technologies in intermodal transport, because from today's point of view the described combination of truck and semi-trailer is the most common in long-distance road transport.

The difference between the intermodal transport chain and road-only transport is the external costs saved or the economic benefit of choosing one transport chain over the other. These are shown in the fact sheet for each transhipment technology.

[47] https://www.eea.europa.eu/data-and-maps/daviz/co2-emission-intensity-8/#tab-googlechartid_googlechartid_chart_111_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_date%22%3A%5B2019%5D%7D%7D ; August 2021

[48] https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4306.pdf ; August 2021

3.2.4 Technology fact sheets

Based on the process for data collection described in chapter 3.2.1 the fact sheets for the transhipment technologies listed in Table 8 were created. Their layout follows the elements described in chapter 3.2.3. All technology fact sheets can be found in Annex 1.

Within the scope of the technology fact sheets, certain technologies are excluded from further analysis in this study as explained in the description of the “Technology readiness level and prevalence” element in chapter 3.2.3. The fact sheets for technologies which were excluded stop after this element and an explanation of the application of the described exclusion criteria for the specific technology is provided.

The status of all transhipment technologies is shown in Table 25 below providing an overview of which technologies are included in or excluded from the further evaluation in this study.

Table 25: Status of the transhipment technology analysis per technology

	Transhipment Technology	Included/ excluded in further evaluation
1	Gantry Crane	Included
2	Reach Stacker	Included
3	Hydraulic Material Handling Crane	Included
4	Mobile Harbour Crane	Included
5	Crane Ship	Excluded
6	Furmia RTS 500	Excluded
7	RoRo Ramp to/from Ship	Included
8	RoRo double stacking cassettes	Included in RoRo
9	Metrocargo	Excluded
10	N.E.H.T.S. (Neuweiler)	Excluded
11	IUT (ÖBB Rail Cargo Austria)	Excluded
12	CarConTrain	Excluded
13	Sidelifter	Included
14	BOXMover	Included
15	Mobiler (Rail Cargo Austria)	Included
16	Container Mover 3020 (Innovatrain)	Included
17	Cargo Beamer 1st generation (Cargobeamer AG)	Excluded
18	Cargo Beamer next generation (Cargobeamer AG)	Included
19	Modalohr 1st generation (AFA)	Excluded
20	Modalohr 2nd generation « N/A » (Lohr Industrie)	Excluded
21	Modalohr UIC (Lohr Industrie, VIA)	Included
22	Helrom	Excluded
23	Nikrasa	Included
24	ISU (ÖBB Rail Cargo Austria)	Included
25	Megaswing	Renamed to Helrom
26	Cargospeed	Excluded
27	Rail Runner (Europe)	Excluded
28	RoLa Ramp	Included
29	Eurotunnel Le Shuttle freight	Excluded
30	Flexiwaggon	Included

	Transhipment Technology	Included/ excluded in further evaluation
31	r2l 2.0 road rail link (VEGA)	Included

Source: KombiConsult analysis

As shown 13 of the initial 31 technologies are to be excluded from further evaluation for the reasons provided in their technology fact sheets. One of the technologies has been renamed and will only be looked at under its new name and one of the technologies will be included as subset of another technology. Both are marked accordingly. This results in 16 distinct technologies to be included in the further evaluation conducted within this study. A special case is the Modalohr technology, or better the three Modalohr technologies of which the 1st and 2nd generation are excluded from further analysis due to them being gradually replaced and only Modalohr UIC will be included for the comparative evaluation. For technical and financial aspects this statement is fully correct. However, as the earlier generations are still in use and it will take some time before they are fully replaced, when analysing the EU and Switzerland intermodal network data in task 3, data for these earlier generations will be included in Modalohr UIC for tasks 3.1 to 3.4.

Table 26 below shows the possible transhipment technology and LU combinations. A "x" means the technology is technically capable and commonly used for the transhipment of the respective loading unit whereas a "(x)" means that the technology is technically capable of transhipping the loading unit however due to operational reasons this is not commonly done. If there is no marking, then the technology is technically not capable of transhipping the loading unit.

Table 26: Technology and Loading Unit Compatibility Matrix

	Transhipment Technology	Type of Loading Unit			
		Containers	Swap Bodies	Semi-Trailers	Full vehicles
1	Gantry Crane	x	x	x	
2	Reach Stacker	x	x	x	
3	Hydraulic Material Handling Crane	x	(x)	(x)	
4	Mobile Harbour Crane	x	(x)	(x)	
5	RoRo Ramp to/from Ship	x	x	x	x
6	Sidelifter	x	(x)		
7	BOXMover	x	(x)		
8	Mobiler (Rail Cargo Austria)	x			
9	Container Mover 3020	x	x		
10	Cargo Beamer next generation			x	
11	Modalohr UIC			x	
12	Nikrasa			x	
13	ISU			x	
14	RoLa Ramp				x
15	Flexiwaggon				x
16	r2l 2.0 road rail link			x	

Source: KombiConsult analysis; * "Full Vehicle" means a motor vehicle or a vehicle combination (road trains and/or articulated vehicle); "x" means technical capable and commonly used, "(x)" means technically possible but not operationally meaningful

One of the main results of the technology analysis are the total costs for the 600 km and 1 000 km transport chain per technology and loading unit combination on different modes of transport. An overview of the transport costs is provided in Figure 6 for the 600 km transport chain and in Figure 7 for the 1 000 km transport chain as explained in the description of the fact sheet elements.

Figure 6: Total transport costs for the 600 km model transport chain per LU

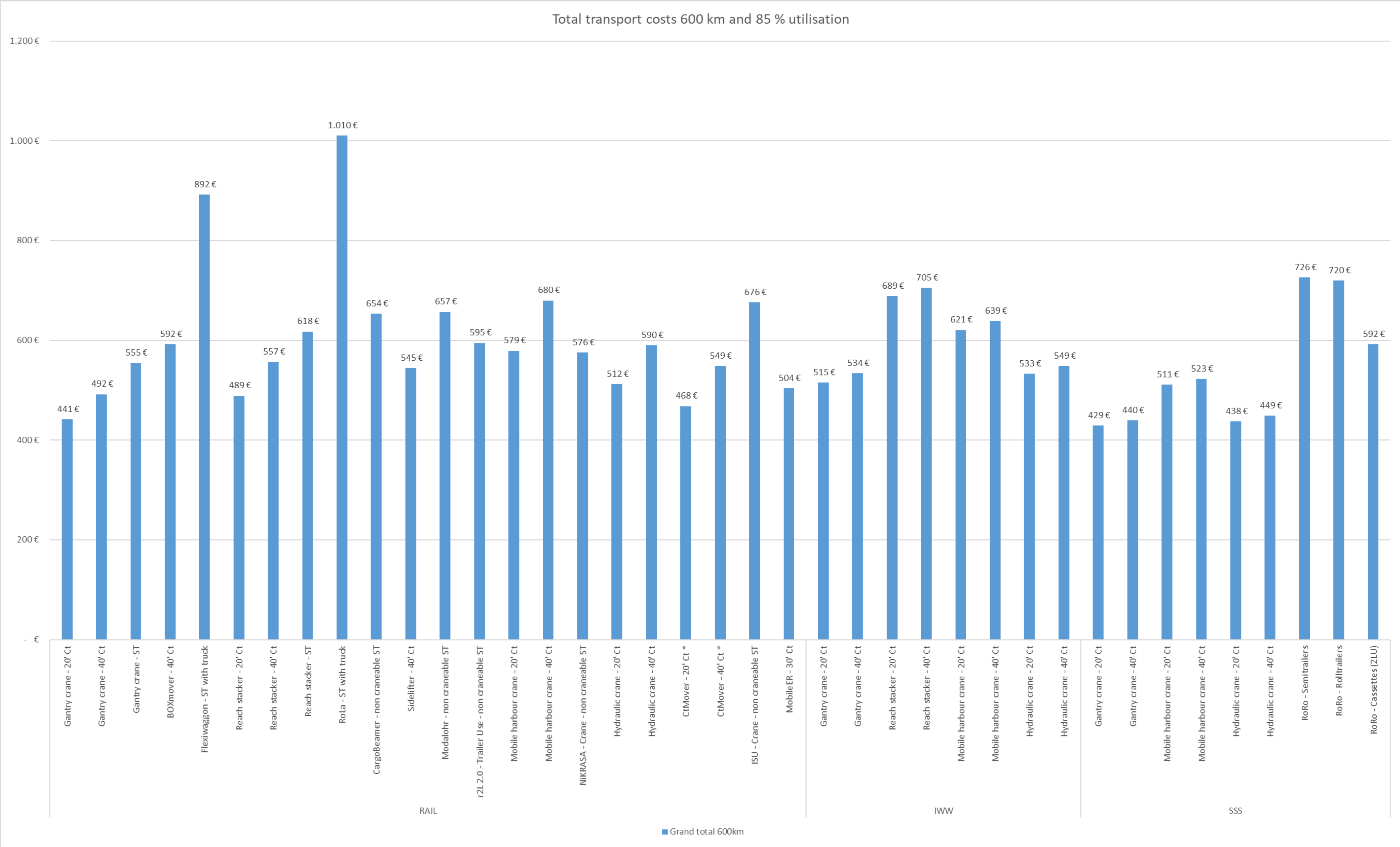
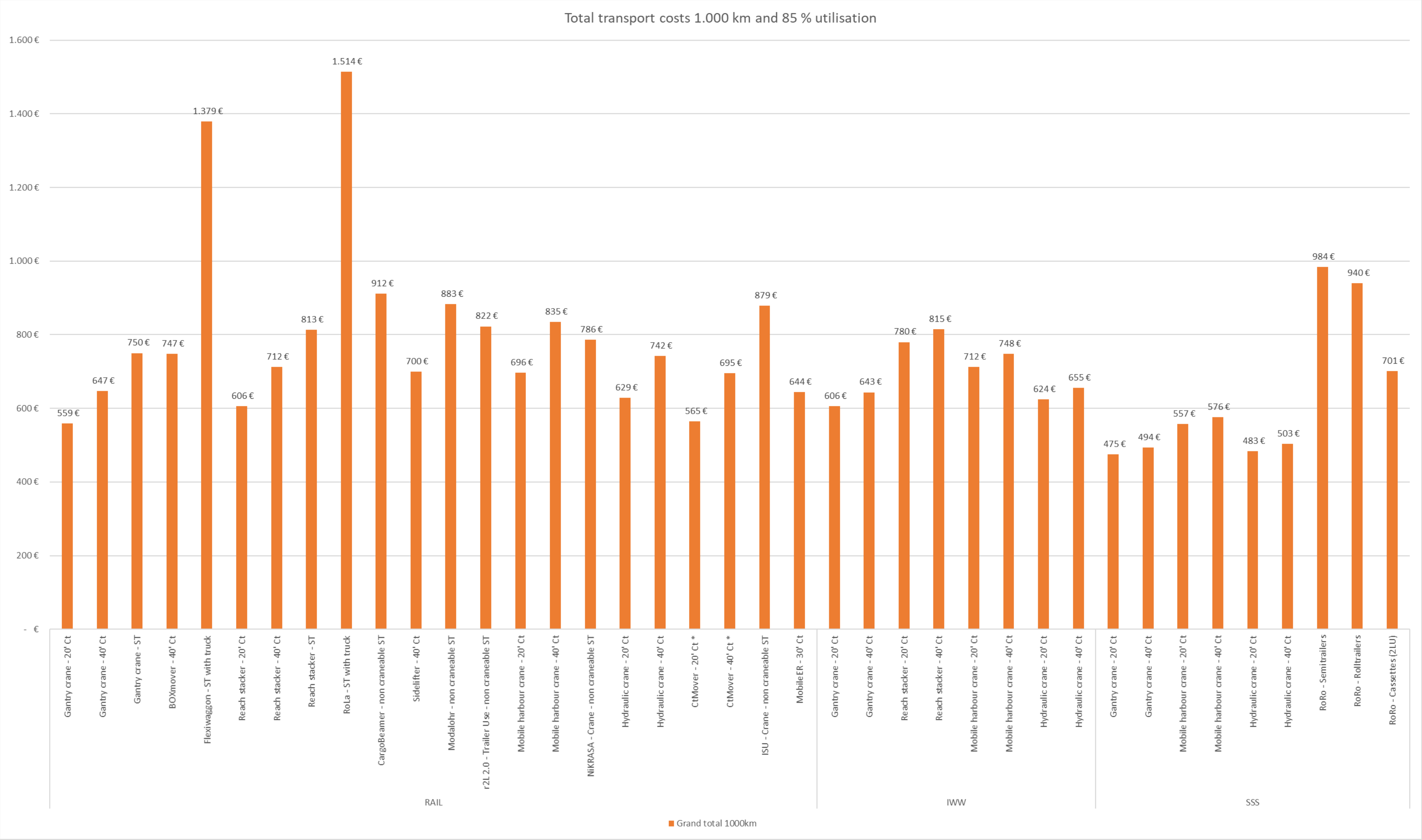


Figure 7: Total transport costs for the 600 km model transport chain per LU

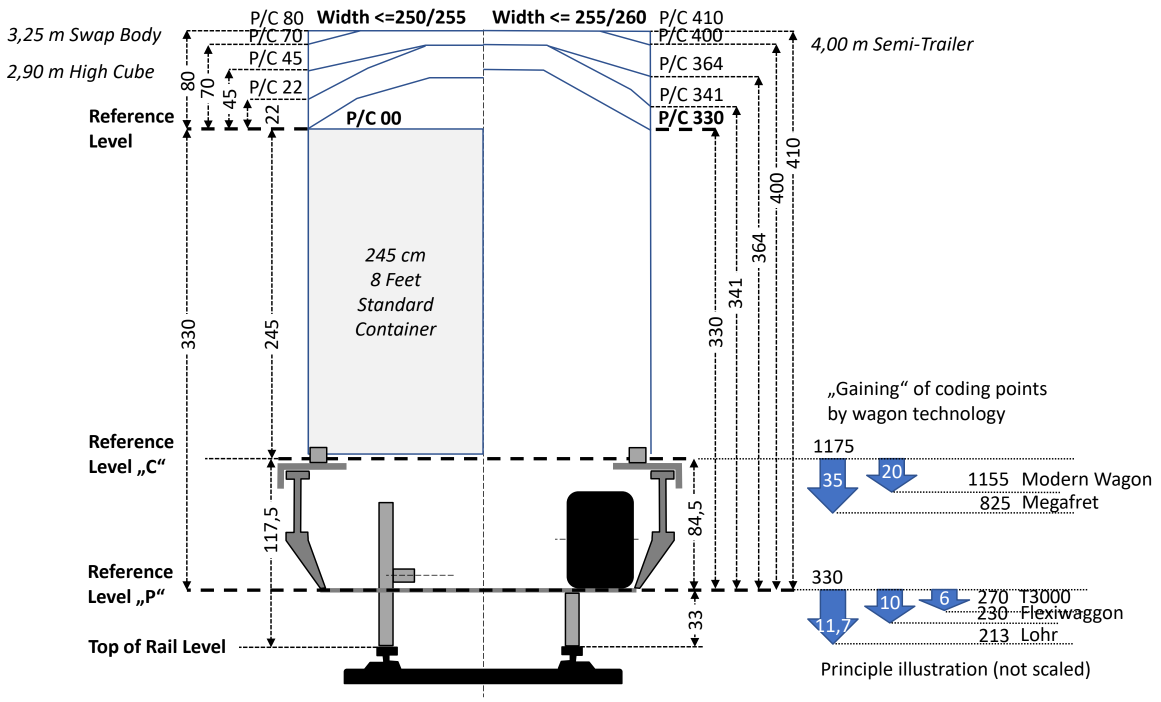


3.2.5 Necessary loading gauge per technology and loading unit combination (rail)

To allow a relatively easy checking if a loading unit / wagon combination is suitable for rail transport on certain rail lines a codification system was agreed upon in the Interunit committee between railways and intermodal operators and documented in UIC leaflets (among others the IRS 50596-6).

The following illustration visualizes the principle of the system which distinguishes between pocket wagon (coded "P") and flat wagon for swap bodies and containers (coded "C") as well as between semi-trailers with an outer width of < 2 500 mm and containers and swap bodies with an outer width of 2 550 mm for which a two-digit coding is used and semi-trailers of > 2 550 mm and containers/swap bodies of 2 600 mm for which a three-digit code is used.

Figure 8: Loading gauge for rail freight



Loading Profiles for different Loading Unit/Wagon Combinations © KombiConsult GmbH

The coding of a loading unit is depending on its relation to the reference profile of coding according to IRS 50596-6.

At the time of invention of the coding system the reference level for semi-trailers was 330 cm above the stand-up position of the pocket which itself was 33 cm above top of rail level, while the reference level for containers and swap bodies was 245 cm above the stand-up position on the flat wagon which itself was 1 175 mm (rounded 118 cm) above top of rail, and 845 mm (rounded 85 cm) above pocket level. These profiles were called P/C 00 and P/C 330 respectively. The C 00 coding allowed to transport standard 8 feet ISO containers (8 feet rounded 245 cm) on standard wagon and the P00 coding the transport of semi-trailers with 330 cm (corner) height. For higher swap bodies and containers, one had to add the two-digit coding value to the 245 and for semi-trailers to 330 to calculate their maximal height.

For the wider units the three-digit code was relevant which is equal to the maximal (corner) height of semi-trailers while for containers and swap bodies one had to subtract 85 cm (the initial distance between the "P" and the "C" Reference Levels) from the three-digit code.

Example 1: 260 cm wide semi-trailer coded P400 = total height for rail transport 400 cm plus 33 height of the base level above top of rail results to 433 corner height above top of rail when loaded on standard pocket wagon.

Example 2: 255 cm wide swap body of 325 cm height plus height of the reference loading level (1 175 mm, rounded 118 cm) minus height of the base level above top of rail (33 cm) equals to a coding of C410.

Modernized flat and special wagon (see Table 12) brought into the market made it possible to "gain" coding points since their loading platform for semi-trailers or the carriage level for containers and swap bodies was lower than the respective reference lines. In these cases the wagon got markings which indicated the difference, e.g. "6" for the pocket wagon "T3000".

From Figure 8 above it gets clear that the critical units are basically wide semi-trailers and high cube containers as well as wide and high swap bodies. It is also evident that the "P400" profile is the standard requested by the market parties for rail lines relevant for intermodal transport since it will allow the transport of the highest semi-trailers allowed for cross border transport in Europe (4 m total height when driving on road).

Thirdly the illustration indicates why on certain lines it may be suitable to use "lower wagon" rather than enlarging the infrastructure gauge. Those issues are dealt with in chapter 4 - Establish EU and Switzerland intermodal network data.

Table 27: Minimum necessary loading gauge on route per rail wagon and loading unit combination (2550 wide boxes/2500 mm wide Semi-Trailers)

N°	Rail wagon type	Loading height (mm)	Wagon Compati-bility Code*	Type of loading unit, their height (mm) and Compatibility Code						
				ISO-Container	HC-Container	Swap Body			Semi-Trailer	Full vehicle
				2450	2900	2670	3000	3150	4000	4000
				C 00	C 45	C 22	C 55	C 70	P 70	n/a
1	Sdggmrss "TWIN"	1155	C +20	**C 00**	**C 25**	**C 02**	**C 35**	**C 50**	n/a	n/a
		270	P +6	n/a	n/a	n/a	n/a	n/a	**P 64**	n/a
2	Sgnss 60'	1155	C +20	**C 00**	**C 25**	n/a	n/a	n/a	n/a	n/a
3	Sggmrrss-y 2 x 60'	1155	C +20	**C 00**	**C 25**	n/a	n/a	n/a	n/a	n/a
4	Sggrss 80'	1155	C +20	**C 00**	**C 25**	n/a	n/a	n/a	n/a	n/a
5	Sggmrss 104'	1155	C +20	**C 00**	**C 25**	**C 02**	**C 35**	**C 50**	n/a	n/a
6	Sffggmrrss "Megafret"	825	C +35	**C 00**	**C 10**	**C 00**	**C 20**	**C 35**	n/a	n/a
7	Sggmrss 90'	1155	C +20	**C 00**	**C 25**	**C 02**	**C 35**	**C 50**	n/a	n/a
8	T3000e	1155	C +20	**C 00**	**C 25**	**C 02**	**C 35**	**C 50**	n/a	n/a
		270	P +6	n/a	n/a	n/a	n/a	n/a	**P 64**	n/a
9	Flexiwagon SW	230 (180 when loaded)	P +10 tbc	n/a	n/a	n/a	n/a	n/a	n/a	**P 390**

N°	Rail wagon type	Loading height (mm)	Wagon Compati-bility Code*	Type of loading unit, their height (mm) and Compatibility Code						
				ISO-Container	HC-Container	Swap Body			Semi-Trailer	Full vehicle
				2450	2900	2670	3000	3150	4000	4000
				C 00	C 45	C 22	C 55	C 70	P 70	n/a
10	Low floor wagon (Saadkms)	410	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**route specific**
11	Sdkmss „CargoBeamer JetModule“	210 (when loaded)	n/a *****	n/a	n/a	n/a	n/a	n/a	**P 54****	n/a
12	Lohr "UIC 2"	213	P +12 tbc	n/a	n/a	n/a	n/a	n/a	**P 58**	n/a

Source: KombiConsult knowledgebase based on IRS 50596-6 and manufacturers data;
* subject to country specific adjustment; tbc = to be confirmed, n/a = not applicable
** due to Wagon Adapter Unit placed between wagon and loading unit during rail transport; semi-trailer generally not possible
*** due to specifically designed platform placed between wagon and loading unit during rail transport; container or swap body generally not possible
**** Limitation calculation according UIC leaflet 502 with measuring exact corner height and loading height prior to each train departure allows to transport "4-m semi-trailer" on routes coded "P384" (equivalent P54 for narrow semi-trailers) such as the Gotthard-Route in Switzerland according to CargoBeamer.

Table 28: Minimum necessary loading gauge on route per rail wagon and loading unit combination (2550 wide boxes/2600 mm wide Semi-Trailers)

N°	Rail wagon type	Loading height (mm)	Wagon Compati-bility Code*	Type of loading unit, their height (mm) and Compatibility Code						
				ISO-Container	HC-Container	Swap Body			Semi-Trailer	Full vehicle
				2450	2900	2670	3000	3150	4000	4000
				C 00	C 45	C 22	C 55	C 70	P 70	n/a
1	Sdggmrss “TWIN”	1155	C +20	**P 330**	**P 355**	**P 332**	**P 365**	**P 380**	n/a	n/a
		270	P +6	n/a	n/a	n/a	n/a	n/a	**P 394**	**n/a**
2	Sgnss 60'	1155	C +20	**P 330**	**P 355**	n/a	n/a	n/a	n/a	n/a
3	Sggmrrss-y 2 x 60'	1155	C +20	**P 330**	**P 355**	n/a	n/a	n/a	n/a	n/a
4	Sggrss 80’	1155	C +20	**P 330**	**P 355**	n/a	n/a	n/a	n/a	n/a
5	Sggmrss 104’	1155	C +20	**P 330**	**P 355**	**P 332**	**P 365**	**P 380**	n/a	n/a
6	Sffggmrrss "Megafret"	825	C +35	**P 330**	**P 340**	**P 330**	**P 350**	**P 365**	n/a	n/a
7	Sggmrss 90’	1155	C +20	**P 330**	**P 355**	**P 332**	**P 365**	**P 380**	n/a	n/a
8	T3000e	1155	C +20	**P 330**	**P 355**	**P 332**	**P 365**	**P 380**	**n/a**	**n/a**
		270	P +6	n/a	n/a	n/a	n/a	n/a	**P 394**	**n/a**
9	Flexiwagon SW	230 (180 when loaded)	P +10 tbc	n/a	n/a	n/a	n/a	n/a	n/a	**P 390**

N°	Rail wagon type	Loading height (mm)	Wagon Compati-bility Code*	Type of loading unit, their height (mm) and Compatibility Code						
				ISO-Container	**HC-Container**	**Swap Body**			**Semi-Trailer**	**Full vehicle**
				2450	2900	2670	3000	3150	4000	4000
				C 00	C 45	C 22	C 55	C 70	P 70	n/a
10	Low floor wagon (Saadkms)	410	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**route specific**
11	Sdkmss „CargoBeamer JetModule“	210 when loaded	n/a ****	n/a	n/a	n/a	n/a	n/a	**P 384** ****	n/a
12	Lohr "UIC 2"	213	P +12 tbc	n/a	n/a	n/a	n/a	n/a	**P 388**	n/a

Source: KombiConsult knowledgebase based on IRS 50596-6 and manufacturers data;
* subject to country specific adjustment; tbc = to be confirmed, n/a = not applicable
** due to Wagon Adapter Unit placed between wagon and loading unit during rail transport; semi-trailer generally not possible
*** due to specifically designed platform placed between wagon and loading unit during rail transport; container or swap body generally not possible
**** Limitation calculation according UIC leaflet 502 with measuring exact corner height and loading height prior to each train departure allows to transport "4-m semi-trailer" on routes coded "P384" such as the Gotthard-Route in Switzerland according to CargoBeamer.

As explained above the coding system was designed for easy guidance in daily operations. It considered that the built infrastructure may differ from the planned, that building margins are also relevant for wagon and loading units, that wear and tear, and tolerances are impacting the figures. In particular the system is static, that means it captures a light, empty semi-trailer on a new built pocket wagon with the same value as a fully loaded one on a wagon with almost worn wheel diameter and suspension. The first needs a top clearance while the latter “sits almost on the rails”. A weighing of the loading units before loading is thus not needed and the maximum height above rail surface can be measured with a simple meter measure stick without a detailed limitation calculation for each loading unit and wagon combination.

However, CargoBeamer explained that they are making the limitation calculation according to the UIC leaflet 502-1 which requires to measure the exact corner height of the semi-trailer and the loading platform height prior to each train departure. With that it was possible to transport semi-trailers with a total height of “4-m” when driving on road within the limits of a “P 384” loading profile on the Gotthard Route through Switzerland. We have therefore used their value rather than the figure of P 388 or P391 calculated according to IRS 50596-6.

When looking at specific transhipment technologies which use additional equipment on the wagon the minimum necessary loading gauge might be impacted.

For the ContainerMover, the wagon adapter unit placed between wagon and loading unit during rail transport has a height of 15 cm and thus reduces the wagon compatibility code points by 15.

In a similar way the r2L 2.0 technology used for semitrailers reduces the wagon compatibility code points by 5-6 points due to the specifically designed platform placed between wagon and loading unit during rail transport which has a height of 5.4 cm.

Table 29: Minimum necessary loading gauge on route per rail wagon and relevant transhipment technology combination

N°	Rail wagon type	Impact of transhipment technologies	
		ContainerMover	r2L 2.0 - Semi-Trailer
1	Sdggmrss “TWIN”	**-15 code points****	n/a
		n/a	**- 5-6 code points*****
2	Sgnss 60'	n/a	n/a
3	Sggmrrss-y 2 x 60'	n/a	n/a
4	Sggrss 80’	n/a	n/a
5	Sggmrss 104’	**-15 code points****	n/a
6	Sffggmrrss "Megafret"	n/a	n/a
7	Sggmrss 90’	**-15 code points****	n/a
8	T3000e	**-15 code points****	n/a
		n/a	**- 5-6 code points*****
9	Flexiwagon SW	n/a	n/a
10	Low floor wagon (Saadkms)	n/a	n/a
11	Sdkmss „CargoBeamer JetModule“	n/a	n/a
12	Lohr "UIC 2"	n/a	n/a

Source: KombiConsult knowledgebase based on IRS 50596-6 and manufacturers data;
* subject to country specific adjustment; tbc = to be confirmed, n/a = not applicable
** due to Wagon Adapter Unit placed between wagon and loading unit during rail transport; semi-trailer generally not possible
*** due to specifically designed platform placed between wagon and loading unit during rail transport; container or swap body generally not possible

3.3 Regulatory framework/procedures for introducing a new Loading Unit/Transhipment Technology

3.3.1 Procedure and regulatory framework for Loading Units

Every LU that is put on the market needs to comply with relevant regulation, specific standards where they exist and pass quality assurance tests (certification). In order to acquire a better understanding of the process to be followed to put newly constructed LUs on the EU market, we have been able to get in contact with a representative of Bureau Veritas. LU used in rail have to be further codified and most LU in rail and all LU in maritime transport have to be identified. In order to acquire additional information on the codification and identification of LUs, we have conducted a dedicated interview with a codification agency (ANSFISA[49]).

Certification

There are several certification agencies operating in the European Union territory, whose work is to check newly created LUs before they can be legally marketed – that is that they fulfil all existing regulatory requirements and mandatory standards. Some examples of such agencies are, among others, Bureau Veritas, RINA and Certifer: the first two mainly operate in the maritime sector and thus certify newly constructed containers, while the latter is rail oriented. Certification of loading units is a paid service from certification agencies upon request of the manufacturer.

Rules for safety structural build of Loading Units

This section is linked to task 1.1 and is meant to give more detail concerning the set of standards regulating the constructions of LUs.

Containers

The main standard for intermodal transport containers is the ISO 668. This document establishes a classification of series 1 freight containers based on external dimensions, specifies the associated ratings and, where appropriate, the minimum internal and door opening dimensions for certain types of containers.

ISO 668 also specifies the respective associated gross weight ratings and includes requirements for load transfer areas in the base structures of containers. A separate standard, ISO 1496-1, is set for the required stacking strength, or 'maximum superimposed mass' (MSM) for standard containers.

Swap bodies

Swap bodies are standardised in the norm EN 284 for class C (“short” swap bodies of 7.15m, 7.45m and 7.82m external length, though C715 are no longer included in the edition of the standard DIN EN 284: 2007-01), and EN 452 for class A (“long” swap bodies with length between 12.5m and 13.6m). There are two main types of swap bodies: bodies with a hard surface, which may be stackable up to three layers, and bodies with curtains and tarpaulins.

Semi-trailers

As described above in this document, type approval regulation establishes requirements for all different types of vehicles, thus including semitrailers.

To this extent, Directive 96/53/EC lays down dimension and weight limits for road vehicles in international traffic; in its amended version, it also establishes maximum dimensions for vehicle combinations, setting de facto limits on semi-trailer size to be used in EU. The amendment of Directive 96/53/EC intended to, among other things:

- facilitate the use of 45-foot containers in intermodal transport without the need for special permits
- increase the maximum weight of road vehicles taking part in intermodal transport operations to 44 tons

Craneable semi-trailers, in compliance with road vehicle regulation (13.60m - maximum allowed on the road), are loaded onto wagons by means of gantries or mobile cranes equipped with pincers; this requires a handling zone on each side of the vehicle.

CEN EN 16973:2017 standard describes the railway-specific requirements relating to semi-trailers which are transported by rail with pocket wagons. For this, the semi-trailers are meant to be suitable for handling by crane. They are handled by gantry cranes or mobile transhipment equipment by the grappler pockets using grabs and lifted into the pocket wagons. The semi-trailers rest with their wheels on the sunken loading area (pocket) of the wagon and at the front with the fifth-wheel plate on the jack. The king pin is locked in the jack and is responsible for the fixing of the semi-trailer in all directions and hence also for withstanding the relevant forces.

Codification

In order to be transported on the European rail network all the loading units must be “codified” by means of a yellow plate giving information about the dimensions and shape of the unit. The capital letters “C” for the containers and swap bodies and “P” for the semi-trailers in the pocket wagons, allow differentiation between the loading units. Codification is mostly provided by national entities of the European Member States and is valid on all European network (including Switzerland).

The codification is needed to avoid checking for each and every LUs measures and shape before allowing a train on a specific line; coded traffic means that each container is coded, so that the entire train made up of coded containers is itself coded. Codification is also mandatory for a LU to be granted access to some major European ports, such as Rotterdam.

All unaccompanied freight units transported by rail must thus be codified to guarantee gauge-wagon-unit load combination compatibility on a specific track/route - for use in any specific section of the railway network, the loading unit parameters in combination with wagon and network parameters have to ensure compatibility with loading gauge of that section ensuring a safe train passage.

The legal basis for this requirement derives from Directive 2016/767, establishing the essential requirements for railway network safety, based on which the network technical specifications are set in TSI INF. Within these specifications, the choice for the applicable standard relies with the infrastructure manager, who establishes his decision within the network statement.

Network statements are controlled by MS bodies under the Rail Safety Directive, which impose that every train that circulating on the network has to be in compliance with the network statement. Railway Undertakers have thus the obligation to check the route compatibility, which is achieved based on information about loading unit parameters on the codification plate, wagon technical specifications (set in TSI WAG) and network statement. Normally the first check is carried out by terminals before setting up a load plan, meaning that no loading unit can in fact travel in unaccompanied normal rail transport in EU without codification.

Identification

To be put on the market, LUs ownership needs to be unequivocally identifiable. To this respect, two uniform type of owner identification of loading units is now applied: the worldwide BIC-Code for freight containers, which means ISO container but also containers and swap bodies according to CEN norms, and the ILU-Code for European loading units. For maritime transport, where ISO containers are used, owner identification is part of the BIC code and is mandatory according to IMO rules.

The ISO 6346 covers the coding, identification and marking of freight containers: the BIC code. The BIC code, managed by the International Container Bureau (BIC) is made of an owner code, a product group code, a registration number and a check digit.

Table 30: Syntax of a marking of container

ABCD 123 456 7			
ABC	**D**	**123 456**	**7**
Owner code	Product group code	Registration number	Check digit
Assigned by B.I.C.		Assigned by owner	Calculated

In 2011 the European Union approved EN 13044-1, a standard compatible with the world-widespread BIC-codes. The standard EN 13044-1 introduces an owner-code for the identification of European intermodal loading units (e.g. swap-bodies, semi-trailers), the ILU-Code, which is compatible with the worldwide BIC-Code used for containers according to ISO 6346.

This European Standard provides a system for the identification and presentation of information about the Intermodal Loading Unit (ILU). The identification system is intended for general application, for example in documentation, control and communications (including automatic data processing systems), as well as for display on an ILU and other non-ISO containers (i.e. which dimensions and testing parameters differ from those defined by the applicable ISO standards) used in European transport.

This European Standard specifies:

- an ILU identification system with an associated system for verifying the accuracy of its use, having mandatory marks for the presentation of the identification system for visual interpretation, and
- a coding system for data on ILU size and type, with corresponding marks for their display;
- mandatory operational marks;
- physical presentation of the marks on the ILU.

The syntax of the ILU code is similar to the ISO-code. The standard names the International Union of Combined Road-Rail transport companies, UIRR (based in Brussels) as the Administrator of the Code. Like the BIC for containers the UIRR manages the assignment of ILU owner code to applicants. The owners are then responsible for marking the single units by the registration numbers according to the stands EN 13044-1.

Given that the identification is for the owner and not for the LUs, there still are many semi-trailers in EU that are not identified by any code, thus not allowing for a precise counting of LUs in circulation in the EU territory. Not being identified by either does not allow using photo gates if used in intermodal transport, even if used only on road legs. In addition, neither BIC nor UIRR can count the number of loading units that are marked accordingly and there is no data collected from the loading unit owners about how many loading units are actually marked by them.

3.3.2 Regulatory framework

Among the most relevant European laws regulating the multimodal transport market, with particular reference to the procedure to put new LUs on the EU market, there are Directive 2016/797 and Regulation 2018/545. The Directive establishes the conditions to be met to achieve interoperability within the Union rail system in a manner compatible with Directive (EU) 2016/798, while laying up in conditions concerning design, construction and placing on the market of vehicles and LUs, while Regulation 2018/545 establishes practical arrangements for the railway vehicle authorisation and railway vehicle type authorisation process under Directive (EU) 2016/797.

Directive (EU) 2016/797

This Directive concerns the interoperability of the rail system within the European Union, enabling citizens of the Union, economic operators and competent authorities to benefit fully from the advantages deriving from the establishment of a single European railway area. In order to do so, this Directive aims at improving the interlinkage and interoperability of the national rail networks and access to those networks, as well as implementing any measures that may be necessary in the field of technical standardisation, thus concerning, among others, loading unit technical standards: in fact, the quality of rail services in the Union also depends on excellent compatibility between both the characteristics of the network and those of the vehicles (including the on-board components of all the subsystems concerned). Specifically, the conditions laid out in this Directive concern the design, construction, placing on the market, placing in service, upgrading, renewal, operation and maintenance of the parts of that system as well as the professional qualifications of, and health and safety conditions applying to, the staff who contribute to its operation and maintenance.

The Directive does not consider public transport systems such as metros, trams and other light rail systems, as those are usually subject to local technical requirements in their respective Member States, and therefore not subject to licensing within the Union.

With respect to the introduction on the market of new vehicles, Art. 21 of the Directive “Vehicle authorisation for placing on the market” lays out the specific parameters, while Art. 22 “Registration of vehicles authorised to be placed on the market” covers the registration phase of the newly marketed vehicles.

According to Art. 21, the applicant for a new vehicle to be placed on the market shall specify the area of use of the vehicle and include evidence that the technical compatibility between the vehicle and the network of the area of use has been checked. Moreover, the application shall be accompanied by a file concerning the vehicle or vehicle type and including documentary evidence of:

- the placing on the market of the mobile subsystems of which the vehicle is composed in accordance with Article 20, on the basis of the ‘EC’ declaration of verification;
- the technical compatibility of the subsystems referred to in point (a) within the vehicle, established on the basis of the relevant TSIs, and where applicable, national rules;

- the safe integration of the subsystems referred to in point (a) within the vehicle, established on the basis of the relevant TSIs, and where applicable, national rules, and the CSMs referred to in Article 6 of Directive (EU) 2016/798;
- the technical compatibility of the vehicle with the network in the area of use referred to in paragraph 2, established on the basis of the relevant TSIs and, where applicable, national rules, registers of infrastructure and the CSM on risk assessment referred to in Article 6 of Directive (EU) 2016/798.

All matters concerning railway vehicles type and authorisation process are also laid out in Reg (EU) 2018/545, detailed below.

Regulation (EU) 2018/545

This Regulation establishes practical arrangements for the railway vehicle authorisation and railway vehicle type authorisation process under Directive (EU) 2016/797. It emphasizes, among other things, the need to keep the time frames of vehicles authorisation as short as possible in order to reduce length and cost of the process, and, based on the experience of National Safety Authorities, recognizes “pre-engagement” (early contact with the applicant in the form of coordination) as a good practice to facilitate the development of the relationship between the parties involved in the vehicle authorisation process.

This Regulation introduces the concept for which, in order to achieve economies of scale and reduce administrative burdens, vehicle type authorisation should enable the applicant to produce a number of vehicles of the same design and facilitate their authorisation; in this setup, the vehicle type identifies the design that will be applied to all vehicles corresponding to that type. Each new vehicle type should follow the authorisation process and a new type should only be created if authorised.

Following on the precedent, the concepts of variant and version of a vehicle type are introduced in order to provide the possibility of identifying options for configuration or changes during the life cycle of the vehicle within an existing type. The difference between variants and versions is that variants require an authorisation while versions do not.

This Regulation also mandates that the European Union Agency for Railways should set up guidelines describing, and where necessary, explaining the requirements set out in it.

Specific regulation on Loading Units and concerning shipment

In addition to Regulation (EU) 2018/545 and Directive (EU) 2016/797, other standards and rules are laid out in different pieces of legislation and literature. This section will provide a list of the most relevant ones, dividing them in three main categories – containers, cranes and shipment.

Containers

Convention for Safe Containers

In 1972, a conference jointly convened by the United Nations and IMO was held to consider a draft convention prepared by IMO in cooperation with the Economic Commission for Europe.

The 1972 Convention for Safe Containers (CSC 1972) adopted by that conference aims at maintaining a high level of safety of human life in the transport and handling of containers and facilitating the international transport of containers by providing uniform international safety regulations, equally applicable to all modes of surface transport. Among others, this document regulates the following areas of container transport:

- Approval of new containers by design type
- Approval of individual containers
- Approval of existing containers
- Approval of new containers not approved at time of manufacture
- Approval of modified containers

IACS Unified Interpretations

Unified Interpretations are adopted resolutions on matters arising from implementing the requirements of IMO Conventions or Recommendations. Among the ones relevant to the purpose of this study are the following:

- SC84: Purpose Built Container Space
- SC109: Open Top Container Holds - Water Supplies
- SC110: Open Top Container Holds - Ventilation
- SC111: Open Top Container Holds - Bilge Pumping
- SC200: Container storage arrangement for equivalent fixed gas fire extinguishing systems
- SC270: Fire pumps in ships designed to carry five or more tiers of containers on or above the weather deck

The International Maritime Dangerous Goods (IMDG) Code and its 2016 and 2020 updates

The International Convention for the Safety of Life at Sea, 1974 (SOLAS), as amended, deals with various aspects of maritime safety and contains in chapter VII the mandatory provisions governing the carriage of dangerous goods in packaged form. It includes a wide set of rules and provisions relevant to the scope of this study, concerning different normative areas, among which:

- General provisions for the use of multiple-element gas containers (MEGCS)
- Container/vehicle packing certificate
- Segregation of cargo transport units on board container ships
- Shore-side fumigation operations - fumigated containers
- Safe stowage and securing of cargo units and other entities in ships other than cellular containerships
- Container packing certificates/vehicle packing declarations
- Guidelines for the approval of offshore containers handled in open seas
- Guidelines for partially weathertight hatchway covers on board containerships
- Inspections of containers/vehicles carrying packaged dangerous goods
- Provisions for the design, construction and approval of bulk containers
- Provisions for the use of sheeted bulk containers
- Container/vehicle packing certificate
- Provisions for the design, construction, inspection and testing of freight containers
- Requirements for the design, construction, inspection and testing of flexible bulk containers
- Container/vehicle packing certificate
- Provisions for the design, construction and approval of BK1, BK2and BK3 bulk containers other than freight containers

Code of safe practice for cargo stowage and securing code (CSS code)

IMO adopted the Code of Safe Practice for Cargo Stowage and Securing (CSS Code) in November 1991. The purpose of the CSS Code is to provide an international standard to promote the safe stowage and securing of cargoes, and it includes rules on the following topics:

- Cargo stowed in open containers, on platforms or platform-based containers
- Guidelines on the safe stowage and securing of cargo units and other entities in ships other than cellular containerships
- Specialized container safety design
- Container securing dimensions

Cranes

Directive 2006/42/EC

Directive 2006/42/EC, also known as the "Machinery Directive", concerns machinery and certain parts of machinery, thus including cranes. Its main intent is to ensure a common safety level in machinery placed on the market Member States, and to ensure freedom of movement within the European Union by granting that machinery complying with the Directive will have free access to the EU market, and that Member States shall not prohibit, restrict or impede the placing on the market and/or putting into service of said machinery in their territory.

Overview of EU standards

In the framework of CEN standardisation activities, Technical Committee CEN/TC 147 developed a set of standards to define the development and maintenance of safety standards for the design, manufacture and information to be provided for:

1. cranes
2. equipment for the lifting of persons on/with certain cranes;
3. power driven winches and hoists, and their supporting structures;
4. hand-powered lifting machines;
5. non-fixed load lifting attachments; 6. manually controlled load manipulating devices.

Among these standards, the following are related to cranes.

EN 12999

This standard specifies minimum requirements for design, calculation, examinations and tests of hydraulic powered loader cranes and their mountings on vehicles or static foundations. This document applies to loader cranes designed to be installed on: - road vehicles, including trailers, with load carrying capability; - tractors (road or agricultural), where only a towed trailer has capability to carry goods; - demountable bodies to be carried by any of the above; - other types of carriers (e.g. separate loaders, crawlers, rail vehicles, non-seagoing vessels); - static foundations.

EN 13000

This standard is applicable to the design, construction, installation of safety devices, information for use, maintenance and testing of mobile cranes[50]. Examples of mobile crane types are given in Annex A.

EN 13001 1, EN 13001 2 and EN 13001 3

- EN 13001 "Part 1: General principles and requirements" specifies general principles and requirements to be used together with EN 13001 2 and the EN 13001 3 series of standards, and as such they specify conditions and

[50] As defined in ISO 4306 2

requirements on design to prevent mechanical hazards of cranes, and a method of verification of those requirements.

- EN 13001 "Part 2: Load Actions" specifies load actions and load combinations for the calculation of load effects as basis for the proof of competence of a crane and its main components, and it is intended to be used together with the other generic parts of the EN 13001 series of standards.
- EN 13001 Part 3 is composed by 6 different sub standards:
  - Limit states and proof competence of steel structure
  - Limit states and proof of competence of wire ropes in reeving systems
  - Limit states and proof of competence of wheel/rail contacts
  - Limit states and proof of competence of machinery – Bearings
  - Limit states and proof of competence of forged and cast hooks
  - Limit states and proof of competence of machinery - Hydraulic cylinders

EN 13135

This standard specifies requirements for the design and selection of electrical, mechanical, hydraulic, and pneumatic equipment used in all types of cranes and their associated fixed load lifting attachments with the objectives of protecting personnel from hazards affecting their health and safety and of ensuring reliability of function.

EN 13155

This standard specifies safety requirements for the following non-fixed load lifting attachments for cranes, hoists and manually controlled load manipulating devices:

- plate clamps
- vacuum lifters:
  - self-priming
  - non-self-priming (pump, venturi, turbine)
- lifting magnets:
  - electric lifting magnets (battery fed and mains-fed)
  - permanent lifting magnets
  - electro-permanent lifting magnets
- lifting beams
- C-hooks
- lifting forks
- clamps
- lifting insert systems for use in normal weight concrete

EN 13557

This standard specifies health and safety design requirements for controls and control stations for all types of crane. In particular, this standard limit its coverage to specific hazards which could occur during the use of controls and control stations.

EN 13586

This standard specifies design requirements for non-powered access installed on cranes, and specifically covers means of access to control stations and all access required for maintenance and for certain erection and dismantling operations.

EN 15001

This standard applies to bridge and gantry cranes able to travel by wheels on rails, runways or roadway surfaces, and to gantry cranes without wheels mounted in a stationary position. In particular, this document specifies requirements for all significant hazards, hazardous situations and events relevant to bridge and gantry cranes when used as intended and under conditions foreseen by the manufacturer.

EN 15056

This standard specifies safety requirements for spreaders used with cranes designed for the purpose of handling ISO containers based on ISO 668, including other lengths such as 45 ft. The connection between the spreader and the container is made by the use of twistlocks that engage into the container's upper corner castings. The standard deals with all significant hazards, hazardous situations and events relevant to container handling spreaders, when used as intended and under conditions foreseen by the manufacturer.

MODU code

The purpose of the Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU code), 2009, is to recommend design criteria, construction standards and other safety measures for mobile offshore drilling units. In its 1979, 1989 and 2009 editions it includes sections on cranes.

4. Establish EU and Switzerland intermodal network data

Task 3 aims at identifying the intermodal terminals as well as TEN-T core network corridors infrastructure and corresponding capacity limitations for each combination of transhipment technologies and loading unit. Furthermore, measures to overcome the existing limitations will be researched and analysed to make the TEN-T core network corridors suitable for using the respective loading units. An estimate of the costs related to overcoming the criticalities highlighted in the analysis will start from the study of projects currently implemented by the different states involved; an estimate for terminal handling and network capacity for the year 2030 will follow, considering the measures to remove infrastructure limitations.

4.1 Number of terminals handling intermodal loading units in EU today

There are several sources of information to capture the number of terminals handling intermodal loading units in Europe. However, in accordance with the Directive (EU) 2012/34/EU and with reference to the Implementing Regulation (EU) 2177/2017 the European Commission has set-up the Rail Facilities Portal (RFP)[51]. Among other facilities the RFP lists also “intermodal terminals” including their location and characteristic. To analyse this data, the operator of the portal provided us with the data in a database/table format. The RFP covers different types of “intermodal terminals”: rail-road terminals, maritime ports, inland ports, short sea shipping ports, ferry ports, etc. However, what it does not cover facilities without any rail connection. Therefore, further analyses have been made by evaluating the intermodal-map of SGKV[52] with reference to intermodal terminals listed under the category “water-road terminals”. The underlying data base was not available, therefore after applying the respective filters in the web application the terminals per country were manually counted to provide information on the number of IWW and SSS terminals per country. The intermodal-map as a source is considered trustworthy since it had also been used to provide input data for the Rail Facilities Portal in the respective DG MOVE project. By combining the two sources we are able to provide the data shown in Table 31 below about the number of terminals handling intermodal loading units per country in the EU and Switzerland.

Table 31: Number of intermodal terminals in the EU and Switzerland per country

Countries (EU and Switzerland)	Number of intermodal terminals		
	RFP database	Intermodal-map	Total
Germany	201	17	218
France	99	20	119
Sweden	92	4	96
Italy	69	7	76
The Netherlands	28	41	69
Belgium	39	16	55
Spain	48	3	51
Switzerland	47	0	47
Poland	42	0	42
Portugal	29	2	31
Romania	27	0	27
Czechia	22	0	22
Hungary	21	0	21

[51] https://railfacilitiesportal.eu/
[52] http://www.intermodal-map.com/

Countries (EU and Switzerland)	Number of intermodal terminals		
	RFP database	Intermodal-map	Total
Austria	21	0	21
Finland	18	3	21
Slovakia	16	0	16
Denmark	11	5	16
Croatia	14	1	15
Bulgaria	13	2	15
Greece	7	2	9
Ireland	7	2	9
Lithuania	7	1	8
Estonia	7	0	7
Latvia	6	0	6
Slovenia	5	0	5
Malta	0	2	3
Luxembourg	2	0	2
Cyprus	0	1	1
Subtotal EU27	**851**	**129**	**980**
Switzerland	47	0	47
Total	**898**	**129**	**1 028**

Source: Rail Facilities Portal and Intermodal Map (May 2021), KombiConsult research

In total there are 851 intermodal terminals currently listed in the Rail Facilities Portal for the European Union countries and 47 for Switzerland, 898 in total. To gain this number, we filtered the database according to the following criteria:

- “facility type“ with the keyword “intermodal terminal” (key = 2);
- “facility operation status” with status “in operation” (key = 1);
- “country” with EU-countries and Switzerland (self-defined key = “EU”).

Adding the 129 intermodal terminals without rail infrastructure gathered from the intermodal-map a total of 1 028 intermodal terminals in the EU and Switzerland could be identified. With 218 intermodal terminals, Germany has by far the highest number, followed by France with 119 intermodal terminals and Sweden with 96 intermodal terminals. With the highest number in Germany (218 terminals) and the lowest number in Cyprus (one terminal), in average there are about 37 terminals per country in operation.

KombiConsult itself operates an internet database on intermodal terminals (www.intermodal-terminals.eu/database) and recently carried out a study on intermodal terminals in Germany. The database and study revealed that in 2019 about 149 terminals were in operation in Germany. But this number concentrates on intermodal terminals for the transhipment of intermodal loading units from road to rail and/or inland waterway in intermodal transport. Thus, 201 terminals in the RFP database seem to be a reasonable number, as there are other facilities listed as intermodal terminals in the RFP database, such as seaports, for instance. Nevertheless, after a quick check of the 201 German facilities in the RFP database, we identified entries of intermodal terminals with the following issues:

- intermodal terminals that are closed, not in operation or do not provide intermodal services anymore (e.g. Saarbrücken), although they are marked with the key “in operation”;

- intermodal terminals that are closed, but already substituted by new existing terminals, thus are counted twice (e.g. Forst, substituted by Kodersdorf; both are still included as "in operation");
- intermodal terminals that will be substituted by new terminals that are still in planning or in construction phase, thus, both the existing ones and the new planned ones are in the RFP database as "in operation" (e.g. Augsburg, Osnabrück);
- intermodal terminals that are still in the planning phase or under construction (e.g. Duisburg Gateway Terminal) included as "in operation";
- intermodal terminals with slightly different names and quality of parameters (e.g. Berlin Wustermark), though they are the same intermodal terminal;
- intermodal terminals with old and obsolete information, such as operating companies not existing anymore (e.g. MCT in Mannheim and SCT in Stuttgart, now operated by DP World);
- missing intermodal terminals although in operation, e.g. Megahub Lehrte.

We can only assume that also for the other countries there may be such irregularities and there may be less than the 898 intermodal terminals listed in the RFP database as currently in operation in the EU and Switzerland. A quick check showed that 14 terminals are included twice in the database with the same name. There are then 884 intermodal terminals (898 minus 14) listed in the database with the same name. However, as we cannot assess which of the double entries are correct or not, the small number of 14 are neglected and we will still use the characteristics of 898 intermodal terminals in the further analysis.

As concerns the transhipment technology, the RFP portal makes no distinction between the different transhipment technologies other than "gantry crane" and "mobile crane", but even this parameter is not given for all listed intermodal terminals (see also Task 3.2). The RFP does not define mobile cranes in any more detail, so for the purposes of further data analysis we will assume that they are reach stacker devices.

In order to compensate for this deficit, we asked the technology providers and analysed for some of the transhipment technologies the technology providers' websites and other sources such as the selected transport relations and named terminals. An overview of the respective use of different transhipment technologies in intermodal terminals is presented in the following Table 32:

Table 32: Overview of the use of the different transhipment technologies

	Transhipment Technology	Place of use in EU	Number of Terminals
1	Gantry crane	Widely used in Europe	345* - 875*
2	Reach Stacker	Widely used in Europe	375* - 905*
3	Hydraulic Material Handling Crane	Widely used in ports	< 100
4	Mobile Harbour Crane	Widely used in ports	<100
5	RoRo Ramp to/from Ship	Widely used in ports	100 - 200
6	Sidelifter	Used in different European countries, but low prevalence in intermodal transhipments	n/a
7	BOXMover	Used in different European countries, but low prevalence in intermodal transhipments	n/a
8	Mobiler (Rail Cargo Austria)	Mainly used within and to/from Austria and EU relations	< 10
9	Container Mover 3020 (Innovatrain)	Used by Railcare on selected locations in Switzerland: Carouge, Aclens, Bern, Brig, Gwatt, Schafiheim, Balerna,	11

	Transhipment Technology	Place of use in EU	Number of Terminals
		Castione, Domat/Ems and by Smart Rail Logistics between Dresden and Emden	
10	Cargo Beamer next generation (Cargobeamer AG)	Used on selected terminals in Europe: Domodossola, Perpignan, Calais, Kaldenkirchen, Duisburg, Poznan	6
11	Modalohr UIC (Lohr Industrie, VIA)	Used on selected terminals in Europe with own installations: Aiton, Bettembourg, Calais, Le Boulou, Orbassano, Poznan; but wagons are also used in relation with other intermodal terminals where "vertical" lifting is provided	6
12	Nikrasa	Used on selected terminals in Europe: Bettembourg, Budapest, Herne, Padborg, Triest, Verona	6
13	ISU (ÖBB Rail Cargo Austria	Mainly used to/from Austria and EU relations	< 10
14	RoLa Ramp	Used on selected connections in Europe. The focus of the connections is on transalpine freight traffic: Brennersee, Freiburg im Breisgau, Maribor, Novara, Trento, Wels, Wörgl	7
15	Flexiwaggon	Currently no use	0
16	r2l 2.0 road rail link (VEGA)	Used in selected terminals in Europe: Karlsruhe, Rheine, Triest, Verona	4

Source: KombiConsult analysis; * from RFP; estimated

As concerns the number of intermodal terminals per type of loading unit, the RFP database provides information on the acceptance of "container", "swap body", "trailer" and "truck + trailer (RoLa)". For some of these types of loading units the RFP database further distinguishes between different subtypes, for instance for containers there are three selections possible: "1 = ISO containers accepted, "2 = continental containers accepted" and "3 = all container types accepted". But when applying the filter "1 = ISO containers", the RFP database shows only two intermodal terminals that would accept ISO container. As this can obviously not be the case since at least all the seaports and most inland ports (need to) accept ISO containers, we refrain from further analysis of these subcategories.

As can be seen in Table 33, 200 of the 898 intermodal terminals in the RFP database do accept all three types of intermodal loading units of container, swap body and trailer. The largest share of terminals accepts "containers" followed by swap bodies and trailers. Only 33 terminals are said to accept "truck + trailer (RoLa)" which is – again – astonishing since RoLa services are offered only in the seven terminals listed in Table 32. In the RFP possibly also terminals in which RoLa ramps are potentially available are listed, or RoRo terminals in seaports are included since truck and trailer combinations are regularly handled there.

Table 33: Number of terminals per accepted loading units

Container	Swap body	Trailer	Container, Swap body Trailer	Truck + trailer
730	253	248	200	33

Source: KombiConsult analysis; * from RFP; estimated

When combining Table 32 concerning the number of terminals per technology and Table 33 concerning the number of terminals per accepted loading units, the following Table 34 is generated showing the number of terminals per technology and loading unit combination.

Table 34: Number of terminals per technology and accepted loading unit combination

	Transhipment Technology	Type of loading unit			
		Containers	Swap Bodies	Semi-Trailers	Full vehicles
1	Gantry Crane	332 - 875	145 - 559	119 - 533	-
2	Reach Stacker	363 - 905	179 - 592	151 - 564	-
3	Hydraulic Material Handling Crane	< 100	< 100	-	-
4	Mobile Harbour Crane	<100	<100	-	-
5	RoRo Ramp to/from Ship	185	185	185	185
6	Sidelifter	n/a	-	-	-
7	BOXMover	n/a	-	-	-
8	Mobiler (Rail Cargo Austria)	<10	-	-	-
9	Container Mover 3020 (Innovatrain)	11	11	-	-
10	Cargo Beamer next generation (Cargobeamer AG)	-	-	6	-
11	Modalohr UIC	-	-	6	-
12	Nikrasa	-	-	6	-
13	ISU (ÖBB Rail Cargo Austria)	-	-	<10	-
14	RoLa Ramp	-	-	-	7
15	Flexiwaggon	-	-	-	0
16	r2l 2.0 road rail link (VEGA)	-	-	4	-

Source: KombiConsult analysis and RFP

The data is based on the available data from the RFP for the gantry crane and reach stacker technologies and on information obtained from the technology providers and other sources for the other technologies. For the gantry crane and the reach stacker technology a lower as well as an upper bound is provided per technology and LU combination based on the RFP data. The lower bound is directly gathered from the available data, by filtering for both the availability of the respective technology and the acceptance of the respective types of LUs. The Upper bound is established under the following assumptions:

- the total number of intermodal terminals in the EU is 1.028 (as shown in Table 31: Number of intermodal terminals in the EU and Switzerland per country).
- All terminals using either gantry cranes or mobile cranes are technically able to handle containers.
- There are 123 intermodal terminals with information only on the number of gantry cranes but not mobile cranes which are reducing the total possible number of mobile crane terminals by this number.
- There are 153 intermodal terminals with information on only the number of mobile cranes (without gantry cranes) which are reducing the total possible number of gantry crane terminals by this number.
- All terminals entered as accepting containers but not as accepting swap bodies reduce the possible number of terminals handling swap bodies by this number for both technologies.
- All terminals entered as accepting containers but not as accepting swap bodies as well as all terminals entered as accepting swap bodies but not as accepting semi-trailers reduce the possible number of terminals handling semi-trailers by this number for both technologies.
- All 129 terminals gathered from the intermodal-map for IWW and SSS are likely to only handle containers in vertical transhipment and therefore reduce the possible number of terminals handling swap bodies and semi-trailers by this number for both technologies.

For the hydraulic material handling crane and the mobile harbour crane the ranges provided are rough estimates as unfortunately no exact data is available for these technologies. For the Mobiler and the ISU technologies the ranges provided are also estimates, however based on the data available from the providers of the technologies the estimates provide a narrower range.

For the total number of RoRo-terminals, the provided number has been gathered in desk research from previous studies done as part of the motorways of the sea program.[53] It is assumed that all types of loading units can technically be handled in all RoRo-terminals.

For all other technologies the numbers have been gathered from the technology providers or from information published by them.

It is important to note, that the numbers of terminals per technology and loading unit combination cannot be added up to calculate the total number of terminals per technology or loading unit. Terminals which accept multiple types of loading units per technology or are using more than one transhipment technology are consequently counted multiple times, once for each applicable technology and loading unit calculation.

4.2 Today's terminal handling capacity (maximum units per annum) in EU

In the framework of task 3.2 today's terminal handling capacity in the EU and Switzerland, expressed in loading units per annum shall be provided and it was offered to base this information also on the Rail Facilities Portal, since recital 12 of the Implementing Regulation (EU) 2177/2017 stipulates that the handling capacity, is also presented in the RFP web portal. The RFP database contains entries with the information on available capacity with status: “no capacity information”, “Sufficient capacity to accommodate any kind of request”,

[53] https://vayla.fi/documents/25230764/0/Final-II-MoS-study-2018-2+Annex.pdf/9cbe31a9-afde-4c79-9370-394bc864ffa5 ; 25.08.2021.

"Limited remaining capacity", and "Facility is full". An analysis showed that for 879 intermodal terminals from the 898 intermodal terminals (98%) it is marked "no capacity information". Even if these characteristics were provided for the intermodal terminals listed in the RFP, it is not possible to get a figure for the annual handling capacity in loading units.

However, the RFP database contains information on the number of gantry or mobile cranes as the most used transhipment technologies, and the terminal's opening times. This information makes it possible to roughly calculate the annual handling capacity for these transhipment technologies.

The analysis of the 898 intermodal terminals showed the following:

- there are 498 intermodal terminals with information either on the number of gantry cranes, or the number of mobile cranes, or both;
- thus, on the contrary, there are 400 intermodal terminals with no information on the number of cranes at all;
- there are 222 intermodal terminals with information on the number of both gantry cranes and mobile cranes, thus containing both types of cranes;
- there are 123 intermodal terminals with information only on the number of gantry cranes (without mobile cranes);
- there are 153 intermodal terminals with information on only the number of mobile cranes (without gantry cranes);
- there are 345 intermodal terminals with information on the number of gantry cranes, thereof
    - 195 intermodal terminals with the number of gantry cranes and information on opening times;
    - 150 intermodal terminals with the number of gantry cranes and no information on opening times.
- there are 375 intermodal terminals with information on the number of mobile cranes, thereof
    - 219 intermodal terminals with the number of mobile cranes and information on opening times;
    - 156 intermodal terminals with the number of mobile cranes and no information on opening times.
- one intermodal terminal with irregularities on the opening times, in particular Berlin Westhafen (Behala) terminal with opening times from 22:00-24:00.

For the estimation of the annual handling capacity we applied the calculation for our model terminal handling capacity. For a gantry crane container terminal with two cranes the capacity is therefore as shown in Table 35 below.

Table 35: Methodology for calculation of the annual handling capacity (example Gantry Crane)

Subject	Gantry crane	Unit
Nr. of handling equipment	2	nr.
ø handling capacity per hour/crane	30	moves/crane
Handling capacity per hour	60	moves/hour
Operating hours (opening times) per day	14	hours/day
Moves per day	840	moves/day
Operating days per year	250	days/year
Handling capacity per year	210 000	moves/year
Handlings per LU	2	moves/LU
Handling capacity per year	**105 000**	**LU/year**

Source: KombiConsult analysis

For 195 intermodal terminals with gantry cranes and 219 intermodal terminals with mobile cranes we could use information on the terminal opening times from the RFP database. For the remaining entries with information on the number of gantry cranes and/or mobile cranes we used an average of 14 hours that a terminal is opened per day. For the actual calculation of the total capacity, the number of handling equipment per terminal is used. Each unit of handling equipment listed in the RFP database therefore contributes to the total handling capacity. One gantry crane for example provides a handling capacity of 52 500 per year (half of the handling capacity calculated above for a terminal with two gantry cranes).

After applying the calculation for each of the 498 intermodal terminals using gantry cranes and mobile cranes, we obtain a total operational handling capacity of about 144 million loading units per year. This makes a capacity of about 289 000 loading units per year and intermodal terminal.

Table 36: Handling capacity per type of crane, and in total (498 intermodal terminals in loading unit per year)

Subject	Gantry crane	Mobile crane	Unit
Handling capacity (entries with opening times)	56 145 000	35 288 000	LU/year
Handling capacity (entries without opening times)	34 493 000	17 771 000	LU/year
Operational handling capacity per year	143 697 000		

Source: KombiConsult analysis

As mentioned above, the necessary information on the type and number of cranes and opening times is available for only 498 intermodal terminals (~ 55%) of the 898 intermodal terminals. If we assume that for the remaining 400 intermodal terminals, where this information is missing in the RFP, the average parameters for the number of cranes and opening times would be the same, we would obtain a total capacity of about 261 million loading units per year.

Table 37: Handling capacity for cranes in all intermodal terminals in loading units per year

Subject	Handling capacity (LU/year)	Share (%)
Handling capacity with information on cranes	143 697 000	55%
Handling capacity with no information on cranes	117 570 000	45%
Operational handling capacity per year	261 267 000	100%

Source: KombiConsult analysis

This number is likely to overestimate the actually available terminal handling capacity, the reasons for which are likely the following:

- the underlying calculation of the handling capacity assumes a full utilization of the transhipment equipment within an efficient and specialized terminal environment without unplanned waiting times, downtimes and additional loading unit handlings within the terminal.
- resulting from the characterisation in the RFP, deep sea terminals with rail access are also included as intermodal terminals in this calculation. Seaport terminals generally have a larger number of cranes for all services, the seaside, rail and storage, and with mostly opening times of 24 hours a day and seven days a week they can easily provide handling capacities over a million loading units per year and terminal. The RFP does not distinguish the number of cranes per section and connected mode of transport in the terminals although it should – by its own

definition – focus on the "rail" facility within a (seaport or inland port) terminal. For instance, in 2019 the main ports in the European Union handled about 107 million TEU[54]. Converting this number with 1.7 TEU per loading unit, it is about 63 million loading units they handled in this particular year. The capacity of these terminals might be higher, as we assume that not all seaports reached their full utilisation. Thus, seaports alone account for a large part of the calculated capacity which is used also for deep sea shipping and not for short sea shipping alone.

- In many cases where both Gantry Cranes and Mobile Cranes (Reach stacker) are available in an intermodal terminal, the Mobile Cranes have a rather supportive character, by serving e.g. external interim storage areas. Thus, in those cases the capacity of Mobile Cranes does not add to the total intermodal handling capacity of the terminal.
- Based on the data from the RFP database the handling capacity of intermodal terminals was estimated on the number and type of cranes and opening times. In praxis the capacity may be limited by other factors such as the use of – particularly for mobile cranes – also depot handlings, the total length of handling rail tracks and their arrangement, the buffer space, or other local criteria as well.
- In the RFP data about the terminal handling equipment (and opening times) might be more likely to be available for larger and more well-known terminals. If this is the case, the average terminal handling capacity of about 289 000 loading units per year calculated for the 498 terminals with handling equipment entries would not be representative of the 400 terminals without handling equipment entries.

For the reasons explained above the data obtained from the rail facilities portal appears to be unsuitable to estimate the available handling capacity for different technology and loading unit combinations in Europe. An estimate based on our model terminal handling capacity per technology and LU combination and the number of terminals per technology and LU combination determined in task 3.1 and shown in Table 34 is provided in Table 38 below. The estimate has been calculated by multiplying the assessed number or range of terminals by the assumed terminal handling capacity per technology and LU combination, taking into account the data from the RFP about the type, but not the amount of, terminal handling equipment per terminal. For technologies where the model terminal handling capacity had been calculated to be different for varying container sizes (e.g. 20' and 40'), a value roughly in the middle between the two calculated terminal handling capacities has been used.

It is important to note, that the handling capacity per technology and loading unit combination cannot be added up to calculate the total handling capacity per technology or type of loading unit. Terminals which accept multiple types of loading units per technology or which use more than one transhipment technology consequently appear multiple times with their full capacity in the calculation, once for each applicable technology and loading unit calculation.

[54] https://de.statista.com/statistik/daten/studie/28764/umfrage/containerumschlag-in-der-eu-27/

Table 38: Handling capacity per technology and LU combination in Europe

	Transhipment Technology	Type of loading unit			
		Containers	Swap Bodies	Semi-Trailers	Full vehicles
1	Gantry Crane	34 860 000 – 91 875 000	15 225 000 - 58 695 000	16 660 000 - 74 620 000	-
2	Reach Stacker	14 201 856 - 35 406 831	7 003 119 - 23 161 154	5 668 123 - 21 171 003	-
3	Hydraulic Material Handling Crane	< 4 307 568	< 4 307 568	-	-
4	Mobile Harbour Crane	< 2 372 649	< 2 372 649	-	-
5	RoRo Ramp to/from Ship	25 900 000	25 900 000	32 375 000	32 375 000
6	Sidelifter	n/a	-	-	-
7	BOXMover	n/a	-	-	-
8	Mobiler (Rail Cargo Austria)	< 334 884	-	-	-
9	Container Mover 3020 (Innovatrain)	365 787	365 787	-	-
10	Cargo Beamer next generation (Cargobeamer AG)	-	-	359 646	-
11	Modalohr UIC	-	-	342 994	-
12	Nikrasa	-	-	840 000	-
13	ISU (ÖBB Rail Cargo Austria)	-	-	< 600 000	-
14	RoLa Ramp	-	-	-	476 757
15	Flexiwaggon	-	-	-	0
16	r2l 2.0 road rail link (VEGA)	-	-	560 000	-

Source: KombiConsult analysis

Using the approach described above, the values shown in the table can be provided as a rough estimate of the technically feasible current terminal handling capacity per technology and loading unit combination. The following comments are intended to provide a better understanding of the figures presented, especially with regard to the quality and completeness of the available data:

- terminals using both, the gantry crane and the reach stacker technology are included in the gantry crane and the reach stacker numbers, as it is impossible to determine how the two technologies are used in the actual terminal operation from the available data (e.g. whether they are both used for intermodal transhipments or if one is used for other operations within the terminal).

- Some of the terminals, especially for technologies like Nikrasa, ISU and r2l, are likely already included in the gantry crane or reach stacker terminals, as these technologies are used to enhance the capabilities of already existing terminals to tranship not only craneable but also non-craneable semitrailers. Furthermore, for these technologies, factors like the available necessary additional equipment could not be taken into account, therefore the shown terminal handling capacity for these technologies is the total handling capacity based on crane capacity of terminals involving these technologies.
- For all technology and LU combinations full terminals specialised on the specific technology and loading unit combination were assumed. As already mentioned, terminals might use not only one but two or more different transhipment technologies, might tranship different types of loading units, are exposed to unproductive times not taken into account at this point (e.g. due to set-up times, waiting times, disruptions and other factors) or might have a different number of terminal equipment available to them than assumed for the model.

For the reasons stated above, the figures shown do provide an estimate of the potential orders of magnitude for the various technology and loading unit combinations, without being able to accurately reflect the actual handling capacity in Europe for each combination. For a precise determination of the actual available capacity, a separate study would be necessary, in the context of which contact would have to be made with all European intermodal terminals to correctly take into account the local characteristics.

4.3 Today's use of the particular technology (units carried/transhipped per annum)

The data on today's use of the particular transhipment technology and how many units they have been carried / transhipped annually should be also determined from the RFP database. However, the RFP database does not provide such figures. As mentioned before, it does not even distinguish between the different transhipment technologies other than gantry and mobile cranes, but which are, of course by far the most used technologies in the intermodal business at present.

As the RFP does not distinguish special technologies, nor provide any data on today's use, the exercise was supplemented by interviews with the technology providers or users from task 1 and 2. When doing that, we had to agree upon a reference year, which should not be 2020 for two reasons: at the moment of data collection the business year might not be closed formally and secondly COVID-19 might have created a "non-normal" situation. We therefore proposed to use the year 2019 as a reference for all technologies that were in operation in the entire year and "a 12 month period" for all technologies which have started within or after 2019. Hereby, we identified the following issues:

- a separate assessment on how many units have been carried/transhipped for the technologies that are widespread and used all over the European Union and Switzerland was impossible. There is no such information available, how many loading units were carried/transhipped i.e. via Gantry crane, Reach stacker, Hydraulic material handling crane or Mobile harbour crane.
- For some of the technologies a separate assessment was not possible either, as they are integrated in and transhipped via other technologies (e.g. Nikrasa, ISU, transhipped via Gantry - and/or Mobile Crane technologies).

In order to overcome the first issue, for this task the standard and widespread vertical transhipment technologies, i.e. Gantry crane, Reach stacker, Hydraulic material handling crane or Mobile harbour crane, will be grouped together as one element.

The second issue has turned out to be relatively insignificant, as the handling figures for the non-standard vertical transhipment technologies are significantly lower than those for the standard vertical transhipment technologies and fall within the range of uncertainty included in our calculation of the handlings done by standard vertical transhipment technologies.

Table 39: Overview of today's use of the particular technology and loading unit combination

	Transhipment Technology	Type of loading unit			
		Containers	Swap Bodies	Semi-Trailers	Full vehicles
1	Standard vertical transhipment technologies	63 453 329	4 488 816	4 284 779	-
2	RoRo Ramp to/from Ship	Included in Semi-Trailers number	Included in Semi-Trailers number	<9 907 500	<14 417 800
3	Sidelifter	Mainly support technology	-	-	-
4	BOXMover	Mainly support technology	-	-	-
5	Mobiler (Rail Cargo Austria)	No numbers available	-	-	-
6	Container Mover 3020 (Innovatrain)	320 000	Included in Containers number	-	-
7	Cargo Beamer next generation (Cargobeamer AG)	-	-	17 000	-
8	Modalohr UIC	-	-	102 000	-
9	Nikrasa	-	-	8 000	-
10	ISU (ÖBB Rail Cargo Austria)	-	-	No numbers available	-
11	RoLa Ramp	-	-	-	512 440
12	Flexiwaggon	-	-	-	n/a
13	r2l 2.0 road rail link (VEGA)	-	-	12 000	-

Source: KombiConsult analysis

Table 39 above shows the values calculated or obtained for today's use of the technology and loading unit combination.

Some values were obtained directly from the technology providers whereas others were calculated from different sources:

The values for Standard vertical transhipment technologies include values for all mode of transport combinations as shown in more detail below. For this group of technologies, a calculation of today's use was done based on the analyses of transported volumes done in the 2020 report on combined transport[55] for rail and Eurostat data for IWW and SSS.[56] The breakdown per connected mode of transport is shown in Table 40 below.

Table 40: Overview of today's use of vertical technologies per mode of transport

Standard vertical transhipment technologies	Type of loading unit			
	Containers	Swap Bodies	Semi-Trailers	Full vehicles
Rail	16 370 976	4 488 816	4 284 779	-
IWW	8 400 000	-	-	-
SSS	38 682 353	-	-	-
Total	**63 453 329**	**4 488 816**	**4 284 779**	**0**

For rail, the 2020 report on combined transport provides a total of 24.8 m TEU transported in 2019 in European unaccompanied rail-road intermodal transport, from which the values for transports between and with non-EU countries (except for Switzerland) are subtracted. Further information is provided on the share of these volumes between different types of LUs, based on which the total transported TEU per LU-type was calculated. Assuming two transhipments of the LU within the transport chain and on average 1.7 TEU per LU for containers and swap bodies and 2.2 TEU per semitrailer the estimated LU-handlings in rail-road intermodal transport per LU type is calculated.

For IWW and SSS vertical technologies it is assumed, that only containers are transhipped. In chapter 2.1.6 a figure of around 4.2 million containers transported on IWW was already assessed based on the Eurostat database. Assuming two transhipments per transported container the shown value is calculated.

Eurostat provides a value for the volume (in TEU's) of containers transported to/from main ports in Europe in short sea shipping for 2019.Again assuming 2 transhipments per loading unit and assuming 1.7 TEU per loading unit the shown value is calculated.

The other values are obtained from information provided or published by the technology providers, with the noteworthy exception of the RoRo technology, which is another widespread technology with no single provider.

The RoRo volumes were also deduced from the available Eurostat data. There are factors that limit the informative value and accuracy of the figures given:

- the Eurostat data differentiates between mobile self-propelled units and mobile non-self-propelled units for which information about the gross weight of goods transported to/from main ports in Europe is provided.
    - The category mobile self-propelled units not only include road goods vehicles and accompanying trailers which are relevant for this study, but also passenger cars, and buses, accompanying trailers/caravans, motorcycles, trade vehicles (including import/export motor vehicles), live animals on the hoof as well as other mobile self-propelled units.
    - The category mobile non-self-propelled units not only includes unaccompanied road goods trailers, semi-trailers and Shipborne port-to-port trailers carrying intermodal loading units which are relevant for this study but

[55] 2020 Report on Combined Transport in Europe, November 2020. The Report aims to provide an assessment of the entire European combined transport market (https://uic.org/spip.php?action=telecharger&arg=3200).
[56] Eurostat.eu.

also unaccompanied caravans and other road, agricultural and industrial vehicles, rail wagons, shipborne barges engaged in goods transport and other mobile non-self-propelled units.

- The share of these different types of transported units in the total goods weight is unknown. Due to the inclusion of this unknown share of different types of mobile self-propelled and non-self-propelled units in the data only an upper bound for the number of handlings of intermodal loading units in RoRo transport can be provided.
- As containers and swap bodies on port-to-port trailers (called roll trailers and cassettes in this study) cannot be differentiated from semi-trailers in the data, only figures for the LU types of full vehicles (based on mobile self-propelled units' data) and semi-trailers (including containers and swap bodies; based on mobile non-self-propelled units' data) are provided for the RoRo technology.

To calculate the upper bounds for the actual transhipment of full vehicles and semi-trailers an average gross weight of goods of 20 tons per transported loading unit was assumed. Therefore, the number of LUs can be calculated by dividing the total gross goods weight per unit category by the 20 tons of goods assumed per loading unit. Like before one transported loading unit is assumed to be transhipped twice during one transport, therefore the resulting number of LUs is multiplied by two to calculate the LU handlings.

The RoLa handlings come from the UIRR statistic about RoLa transports, again assuming two transhipment per transport.[57]. One thing that is noticeable is, that the value for today's use of the RoLa technology is higher than the value provided for today's handling capacity. One likely reason for this is, that the existing RoLa connections run for far lower distances than the 450 km/ 850 km assumed for this study. On short RoLa distances like Wörgl – Brenner the wagon sets can be used for multiple round trips per day, thereby eliminating the need for a separate wagon inspection before each transport. This in turn leads to the train having a shorter stay in the terminals and increases the handling capacity per terminal by reducing throughput time.

4.4 TEN-T corridors, or parts of TEN-T corridors, where terminals with particular transhipment technology are available

Regulation (EU) 2021/1153 geographically defines the TEN-T Corridors [58].

The TENtec portal and its interactive viewer[59] are the graphical visualisation of the comprehensive and core network and the TEN-T corridors. The Regulation (EU) 1315/2013 does not name "intermodal terminals", but "Maritime Ports", "Inland Ports" and "Rail Road Terminals (RRT)" as the nodes in which different modes of transport are connected. The following maps illustrates the alignment of the TEN-T Corridors and the RRT listed in the TENtec portal.

[57] http://www.uirr.com/de/media-centre/annual-reports/annual-reports/mediacentre/1582-uirr-annual-report-2019-20.html.

[58] Regulation (EU) 2021/1153 establishing the Connecting Europe Facility (CEF) for the period 2021-2027 adopted in July 2021.

[59] https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html

Figure 9: TEN-T Corridors and Rail-Road-Terminals (RRT)

Source: KombiConsult analysis based on TENtec Viewer (23.06.2021)

Under this point, a list was prepared showing the individual TEN-T core network corridors, and the various transhipment technologies available along the corridors. The TENtec portal formed the basis of the list, mainly for the widespread technologies, and was supplemented by data from the RFP database, where it is marked if, and if yes, on which Rail Freight Corridor[60] an "intermodal terminal" is located as well as interviews with other technology providers and users of specific loading unit / transhipment technologies and/or combinations. Still, the following analysis is only able to combine data from a few select

[60] The Rail Freight Corridors are established under Regulation (EU) 913/2010. Rail Freight Corridors and TEN-Corridors are generally aligned, despite several routing differences.

sources and is therefore unlikely to provide complete information on all terminals along the TEN-T Corridors.

From the data in the TENtec Portal, only nodes with categories "Ports" and "Rail/road terminals" were available. The analysis of the data from the TENtec portal also revealed that there is no distinction between different transhipment technologies used in the Ports and Rail/road terminals. Under the assumption that at least one of the widespread Crane and Reach Stacker technologies, in particular Gantry Crane, Reach Stacker, Hydraulic Material Handling Crane, and Mobile Harbour Crane, is used in every port and rail road terminal listed in the TENtec portal, we could identify the following numbers of terminals on each of the respective core network corridors.

Table 41: Number of TEN-T Ports and TEN-T RRT (according to TENtec OMC) & number of terminals according to RFP

TEN-T corridor / RFC corridor	TENtec OMC			RFP
	Ports	RRT	Total	Total
Baltic Adriatic / RFC 5	11	20	31	78
North Sea – Baltic / RFC 8	32	24	56	100
Mediterranean / RFC 6	19	20	39	77
Orient / East – Med / RFC 7	23	19	42	81
Scandinavian – Mediterranean / RFC 3	29	23	52	82
Rhine – Alpine / RFC 1	23	13	36	141
Atlantic / RFC 4	22	14	36	50
North Sea Mediterranean / RFC 2	32	12	44	88
Rhine – Danube / RFC 9	26	20	46	20
Total*	**141**	**108**	**249**	**324**

Source: KombiConsult analysis based on TENtec OMC (22.06.2021; filtered by core network) and RFP; * Total is not the sum of all TEN-T / RFC corridors

Apart from the Crane and Reach Stacker transhipment technologies, we could identify the following TEN-T core network corridors, where terminals with a particular transhipment technology handling certain types of loading units are available. As for task 3.3 we are combining the standard vertical transhipment technologies into one item carrying that name.

Table 42: Transhipment technologies per TEN-T corridors

	Transhipment Technology	Type of loading unit			
		Containers	Swap Bodies	Semi-Trailers	Full vehicles
1	Standard vertical transhipment technologies	All TEN-T corridors			-
2	RoRo Ramp to/from Ship	All TEN-T corridors (coastal areas only), not necessarily for transports between two terminals on the same corridor			
3	Sidelifter	Used as support technology	-	-	-
4	BOXMover	Used as support technology	-	-	-
5	Mobiler (Rail Cargo Austria)	Could not be accurately determined,	-	-	-

	Transhipment Technology	Type of loading unit			
		Containers	Swap Bodies	Semi-Trailers	Full vehicles
		identified relations to/from Austria: probably BAC, OEM, RD			
6	Container Mover 3020 (Innovatrain)	NSB: Emden, Dresden OEM: Dresden RALP; Switzerland		-	-
7	Cargo Beamer next generation (Cargobeamer AG)	-	-	RALP: Domodossola, MED: Perpignan, NSM: Calais, BAC, NSB: Poznan	-
8	Modalohr UIC	-	-	NSM: Bettembourg, Calais MED: Orbassano BAC, NSB: Poznan	-
9	Nikrasa	-	-	NSM: Bettembourg MED, OEM, RD: Budapest BAC, MED: Triest –SCAN-MED: Verona	-
10	ISU (ÖBB Rail Cargo Austria)	-	-	Could not be determined, with relations to/from Austria: probably BAC, OEM, RD	-
11	RoLa Ramp	-	-	-	RD: Wels, RALP, NSM: Freiburg im Breisgau, MED, RALP: Novara, SCAN-MED: Brenner, Wörgl, Trento, BAC, MED: Maribor
12	Flexiwaggon	-	-	-	Currently no use
13	r2l 2.0 road rail link (VEGA)	-	-	BAC, MED: Triest NSM: Bettembourg; NSB, RALP: Köln	-

Source: KombiConsult analysis based on TENtec OMC (22.06.2021) and analysis of the technology provides; abbreviated names of the nine core network corridors

4.5 Type of upgrade needed per TEN-T corridor to use loading unit/transhipment technology

This section describes the different types of structural interventions required to enlarge the railway clearance gauge to allow for the transit of the previously analysed LUs. No other infrastructure limitations related to rail or inland waterways or roads were analysed as part of this study.

For the analysis reference was mainly made to the “Measuring and upgrading the clearance gauge of railway lines: market study and feasibility study” commissioned in 2016 by the European Commission.

Clearance gauge

The codified clearance gauge of a given railway section is defined according to the most limiting height and width profile encountered in the length of the section. For a given section of line, the limiting profile may be related to a tunnel in the section, but it can also depend on features such as over-bridges, station platforms and overhead or lineside equipment. It is therefore a single local element that determines the limiting profile of the line.

Commission Regulation (EU) 1299/2014 on the Technical Specification for the Interoperability relating to the “Infrastructure” subsystem of the rail system in the European Union (“Infra TSI”) amended by Implementing Regulation (EU) 2019/776 lays down the technical specifications of the rail infrastructure and includes in an Annex the so called TSI Categories of Line. Parameters are, according to Annex table 3 for freight traffic the traffic code, gauge, axle load, line speed and train length. The gauge or structure gauge (TSI point 4.2.3.1) defines the space in relation to the reference track that shall be cleared of all objects or structures and of the traffic on the adjacent tracks, to allow safe operation on the reference track. It is defined on the basis of the reference contour by application of the associated rules. The Infra TSI differentiates the Gauges GC, GB, GA, G1, S and IRL1. The Infra TSI does not further specify these values but refers to their definition in the European Standard DIN EN 15273-3. [61] The standard defines three types of structure gauges, namely

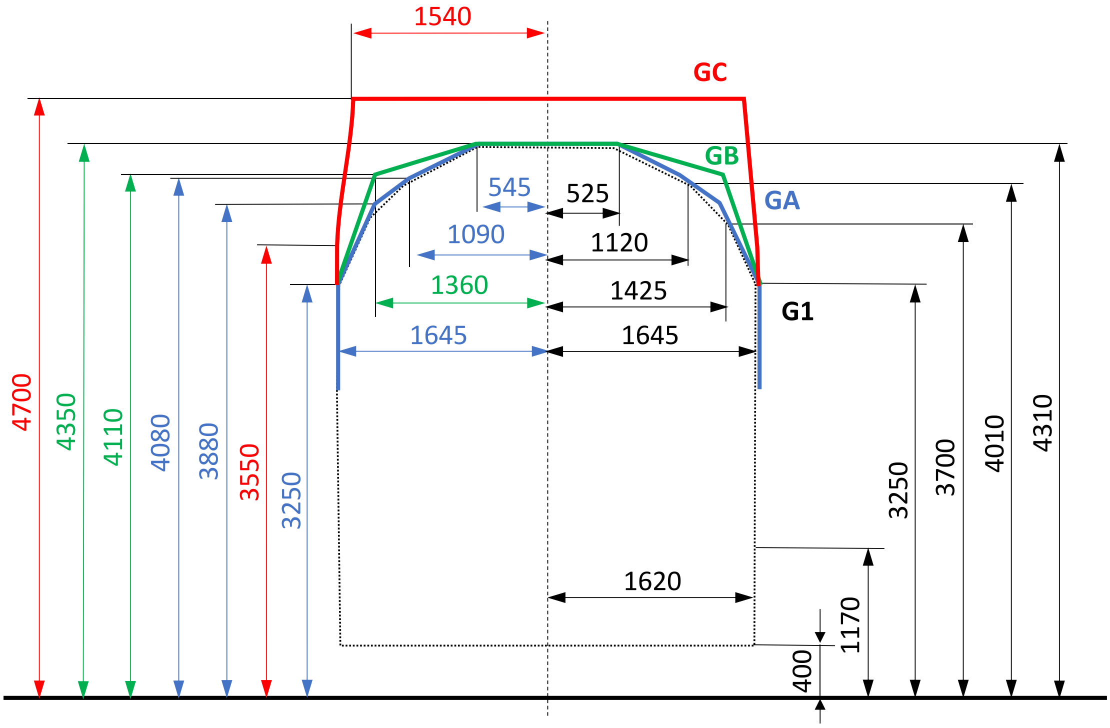
- the structure verification limit gauge, which is the space not to be encroached upon at any time which sets the limit for normal operation
- the structure installation limit gauge, space not to be encroached upon taking into account a maintenance allowance and the
- structure installation nominal gauge, which is the space to be cleared of any structure to enable train operations and track maintenance by incorporating allowances for safety, maintenance as well as reserve allowances defined by the person responsible for the infrastructure.

With respect to DIN EN 15273-1 it further defines the reference profile and associated rules. The gauge is generally split into two parts: its upper parts and its lower parts. The limit between the two parts shall be defined for each gauge. There are specific rules associated with each part.
The reference profile is normally determined for a straight, flat, nominal gauge, cannot-free track. The profile considers the vehicle envelope and certain displacements. The reference profile is an intermediate profile that is part of the agreement but that shall not be confused with the construction gauge nor the structure gauge (on straight track or other).
Generally added to this profile is widening according to the line (radius, cannot) and speed (cannot deficiency) and certain allowances to cover random phenomena and to ensure track maintenance. These are called the associated rules. Technical interoperability conditions are defined in EN 15273-1:2013+A1:2016, Annex A. The application of “international” or “reduced” interoperability gauges depends on international regulations or even bilateral or multilateral agreements. The gauge choice is fixed by each network.

Annex C of the EN 15273-3 presents the details of the international gauges G1, GA, GB, and GC (of the upper part) and GI1, GI2 and GI3 for the lower part of the gauge.

[61] Railway applications – Gauges – Part 3: Structure gauges; English version EN 152733: 2013+A1:2016

Figure 10: dimensions of Gauges G1, GA, GB and GC according to DIN EN 15273-3



Gauges G1, GA, GB and GC according to DIN EN 15273-3:2013+A1:2016 © KombiConsult GmbH

It's Annex D presents the details of the gauges for multilateral and national agreements such as G2, GB1 and GB2, which are national variants of the international gauges, and other codes which are completely different, e.g. for broad gauge lines in Portugal, Spain or Finland.

Calculations of the structure gauge shall be carried out using the kinematic model in accordance with the requirements of sections 5, 7 and 10, Annex C and Annex D, Point D4.8

Infrastructure TSI does however not indicate the Combined Transport Profile number as a parameter when defining the EU railways system. The CT profile number is resulting from IRS 20596-6, the system applied for several decades in order to ensure a safe operation of intermodal loading units loaded on compatible wagon when transported on codified lines (see Table 27 and Table 28).

The P400 is the standard in use by the market that identifies rail lines with a gauge allowing the loading of semi-trailers with a width of > 255 mm (and the equivalent P400 marking) on pocket wagons. This nomenclature indicates that the maximum height at which a semi-trailer can be transported by rail is limited to 4 metres. This limit is set from the base of the wagon to the top of the semi-trailer, with the suspension being airless in order to comply with that height. The 4m height is a request from the road industry to make maximum use of the official European road and motorway dimensions, which set the height of trucks at 4m[62]. The coding of intermodal transport lines helps establish which of the intermodal transport profiles, when loaded on a given wagon marked for intermodal transport, can be allowed to run along a given route. Unfortunately, not all lines across Europe are codified for intermodal transport and some of the codes are to be considered only informative: this means that the process of establishing which intermodal transport profile can be allowed to run along a route, requires specific checks.

[62] https://www.uirr.com/en/news/mediacentre/1846-intermodal-the-increasing-importance-of-p400.html

Clearance gauge enlargement

Typical steps to be undertaken to remove clearance gauge restrictions and upgrade the track to the P400 standard are the following:

1. Measuring of the tunnels and other structures along the track;
2. Re-codifications, if possible;
3. If re-codification is not possible the following further steps should be considered:
   - surveys for the executive design of interventions;
   - tunnel upgrade works;-.

First of all, 3D measurements can be carried out on the selected line, in order to precisely assess the geometry of the obstacles faced on the line. This information makes it possible to identify which sections can potentially be coded P400 and which are not. Compatibility is determined through virtual overlapping of the current contours of the infrastructure with the dynamic envelope of a trailer-wagon system; this dynamic envelope has the dimensions of a 4m-high trailer loaded on a 33 cm-high pocket wagon, as the P400 is defined. This procedure results in the identification of the sections in which the rolling stock profile and the infrastructure overlap.

There are innovative and low cost laser based techniques to measure the current infrastructure contours. The measurement process can be done quite easily and it does not require to stop the line. The required equipment includes a convoy led by a locomotive, followed by a train car containing the office for acquisition and registration, and by a second train car carrying the dynamic laser scanner device. The cost to measure could be less than 100 euros per km (e.g. for the OEM CNC an estimation of 400 k€).

The application of this procedure on the railway lines of interest often leads to the identification of a large gap between the current coding of the line and the actual gauge. Quite often lines that are not certified for the P400 profile can currently accommodate the passage of intermodal trains with P400 profile. For these lines, network upgrades are therefore not necessary or much less expensive than the interventions described in the next sections.

Where infrastructure restrictions are identified, most of the time they are in tunnels, or under over-bridges.

Tunnels upgrade works include several types of interventions:

- tunnel vault works;
- trackbed lowering;
- replacing ballasted track with slab track, which leads to
  - a) lower construction height of the track superstructure,
  - b) higher stability of the track alignment / reduced track displacement (allowing reduced safety margins for definition of the clearance gauge)
- replacing overhead contact line with rigid conductor rail, which reduces the construction height of the catenary system;
- third track (this measure has temporary impact on the line capacity);
- replacement of double-track by single-track along the centre axis of a tunnel (this measure has a permanent impact on line capacity and is only recommended for lines / line section with low capacity utilisation)[63]

[63] One recent example, where this solution has been implemented is the Karawanken tunnel between Austria and Slovenia (Villach – Jesenice))

- adjustment of one track in a double-track tunnel and operation of P400-train only on that track in both directions (measure puts high requirements on traffic management and may have certain impacts on capacity)[64]

Restrictions due to low over-bridges can be addressed by:

- trackbed lowering;
- powerless overhead line sections (possible up to a several hundred meters, but often only needed on shorter sections; powerless sections should not be installed, where trains usually have to stop or run at very low speed).

As an alternative to structural interventions, the use of lower pocket wagons can also be considered.

Tunnel vault works

Tunnel vault works consist in a punctual increase of the clearance gauge which intervenes only in the overlap section (mostly located in the upper corners of the transported trailer) and therefore does not envisage an overall widening of the tunnel. The complexity of the operation and consequently its cost strongly depends on the overlapping depth.

The overlapping sections have been classified into 4 classes of depths which are:

- under 5 cm;
- from 5 to 10 cm;
- from 10 to 20 cm;
- over 20 cm.

Considering large depths (over 20 cm) a deep lining repair is required. As the depth of the overlapping decreases, the structural intervention becomes less complex until, on the case of depths of less than 5 cm, a coating operation is enough to address the issue.

Table 43: Vault works typology by overlapping depth

Overlapping depth	Type of works
Over 20 cm	Type A - Deep lining repair
From 10 to 20 cm	Type B - Lining repair
From 5 to 10 cm	Type C - Shotcrete arch segment
Under 5 cm	Type D - Coating operation

Source: “Measuring and upgrading the clearance gauge of railway lines”, Final Report 2016

Types A and B lining repairs will include also:

- installation of retaining anchorages;
- tunnel segment destruction.

Instead, type C work will include:

- installation and fixation of a reinforcing cage;

[64] One example, where this solution has been used for many years is the so-called 4-m-corridor on the Lötschberg pass line.

- shotcrete projection on the tunnel segment.

Figure 11: Tunnel vault works

Source: Adif, "Evaluation of rail motorway cost"

Roadbed lowering

Roadbed lowering is an alternative to clearance gauge widening, often cheaper and less impactful on train circulation as it offers, depending on the number of tracks, the possibility of alternating traffic on the line.

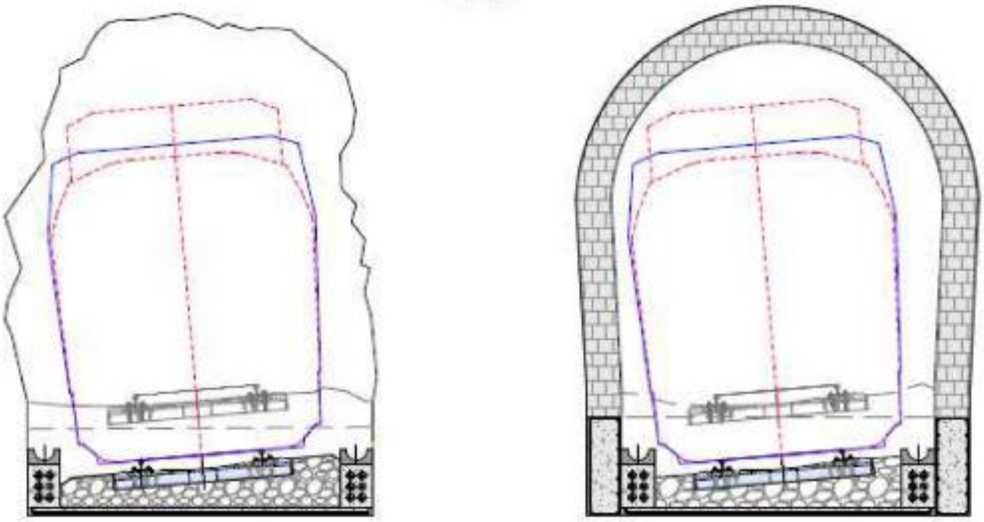
However, this operation also requires:

- changes to the sewage and drainage systems;
- resolution of interference with technological sub-services;
- and often additional underpinning.

In comparison with tunnel vault works, roadbed lowering intervention is more appropriate for the following situations:

- short tunnels (< 500 m);
- gauges overlapping for more than the half of tunnel length;
- specific situation for which vault works are very expensive;
- no concrete apron to modify;
- no reinforced concrete sidewalls to modify;
- partial service interruption by direction.

Figure 12: Platform lowering



Source: Adif, "Evaluation of rail motorway cost"

Third track

A third alternative used to increase the clearance gauge of a tunnel is the construction of a third track laid in the middle of the tunnel – the Gemmenicher tunnel being a good example of this solution.

The Gemmenicher tunnel or Botzelaar tunnel is an 870m long three-track rail tunnel between the stations of Montzen, in Belgium, and Aachen-West, in Germany. A third, coiled track is installed in the centre of the tunnel for special transport exceeding the gauge of the other two tracks. The track can be used in both directions, but when using the coiled track, no other traffic can cross in the tunnel.

In 2008 the tunnel was electrified with electrified busbars on the tunnel ceiling. The conductor rail above the right-hand track in the direction of Aachen-Montzen was offset towards the tunnel axis, so that it can also be reached by pantographs from locomotives on the LU track. Train journeys exceeding the loading gauge, which must use the track loop, can also be carried out with electrical traction.

Figure 13: Gemmenicher/Botzelaar tunnel

Source: Adif, "Evaluation of rail motorway cost"

Lower pocket wagons

Currently, the P400 parameter is the standard for intermodal transport. To comply with this standard, enlargement of the gauge to a P400 compatible infrastructure is a possibility, as seen above, and so is the use of lower pocket wagons in order to fit in lower tunnels.

While the "standard" pocket wagon's floor is 33 cm above the top of the rail, giving a total height of 433 cm for the system wagon-trailer, different pocket wagons are commonly used for trailer transportation. For instance, the following height of floor are commonly used:

- 27 cm with a low-floor wagon;
- 23 cm with the Modalohr wagon.

For instance, with 27 cm wagons, a P394 gauge would be enough to run 4m high trailers on trains. Even more, the top of a 4-meter-high semi-trailer stands at 4.23 m if put on a Modalohr wagon.

Such low pocket wagons are getting more commonly used by intermodal operators and are nowadays being brought forward by manufacturers, since they can enable intermodal transport of semi-trailers on lines that comply with a lower standard, e.g. P394.

This possibility however raises interoperability questions. It moreover shifts the responsibility to provide for the possibility to run trains with P400 profile, and the costs thereof, from the infrastructure manager to railway and terminal operators.

Cost estimation for tunnel vault and roadbed lowering works

The study "Measuring and upgrading the clearance gauge of railway lines: market study and feasibility study" carries out an accurate estimation of tunnel vault works and roadbed lowering work costs: work cost estimations are done considering the extent and the type of work proposed and distinguishing, in the case of vault work, among partial and total traffic interruption scenarios.

The study analysed the costs of four French lines (Paris-Metz, Metz-Strasbourg, Dijon-Mulhouse and Paris-Marseille) with a total of 30 tunnels to be upgraded to the P400 parameter.

Starting from the data reported in the final report, it was possible to determine the range of variation of the unit cost per km of tunnel upgrading.

Table 44: Cost range estimation for each technical solution and options [M€/km]

Technical solution	Min	Max	Average
Vault work with partial traffic interruption	16	86	49
Vault work with total traffic interruption	10	56	30
Roadbed lowering works	18	30	22

Source: PwC analysis based on "Measuring and upgrading the clearance gauge of railway lines: market study and feasibility study"

As presented in Table 44 above, the most expensive intervention is that of vault works with partial traffic interruption. Specifically, the vault work intervention with partial traffic interruption varies from 16 M€/km to 86 M€/km, while the same intervention with total traffic interruption span from 10 M€/km to 56 M€/km. The average unit cost of roadbed lowering is less than that of the other interventions: with a range of costs from 18 M€/km to 30 M€/km, the average value is equal to 22 M€/km. It does not take into account the consequences and costs due to traffic interruption.

However, the costs of these operations appear to be very specific to each tunnel studied, and can hardly be approximated using unit costs, in fact, the results reported in the study show investment costs per metre of operation with strong disparity in the results. It is important to note that each tunnel upgrade has unique characteristics related also to the morphology of the area, the extension of the intervention as well as the orographic conditions.

Review of safety margins for definition of the clearance gauge

The definition of the clearance gauge for intermodal transport of semi-trailers takes into account safety margins for various aspects. Relevant aspects that are considered in setting safety margins are:

- settings in the roadbed sub-structure;
- changes in the rail profile due to rail wear;
- changes in the wheel profile due to wheel wear;
- lateral track displacement in curves;
- dynamic behaviour of the suspension in the rail running gear;
- deviations in the placement of the loading unit / semi-trailer on the rail wagon, when loading;
- dynamic movement of the loading unit / semi-trailer during the train run (including dynamic behaviour of the suspension system of the semi-trailers, when carried on a wagon).

In some cases, reconsidering the adopted safety margins and the methodology for their calculation and application could possibly lead to the recoding of the line to allow for the loading of semitrailers on the wagons. For instance, a more frequent supervision of the track (especially of the track geometry) or automated measurements by mean of Intelligent Video Gates at the exit of intermodal terminals (or when entering critical line sections) could open for reducing certain safety margins.

4.6 Kilometres/network percentage per TEN-T corridor where loading units can be transported (loading gauge, bridges, water levels, etc.)

The main objective of this task is to determine the kilometres and the percentage of TEN-T core network, including a breakdown per TEN-T corridor, allowing for the use of the loading units handled by a particular transhipment technology, taking into account the different network limitations (rail loading gauge, bridges, water levels etc.) and mapping the blocking infrastructure elements. The process of mapping the entire network also makes it possible to identify the most critical areas for intermodal transport, which will then be further investigated.

We focused our analysis on the TEN-T core network corridors. With this purpose, we have first analysed the status of the TEN-T corridors as represented in the TENtec[65] and RINF[66] databases[67]. The two databases map the status of the infrastructure with regards to several parameters, but among these only the “standard combined transport profile number for semi-trailers" is relevant for determining the network limitations related to the intermodal transport. The two databases obviously do not give information on the specific blocking

[65] https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html
[66] https://rinf.era.europa.eu/RINF/
[67] To analyse this data, the operators of the portal provided us with the data in a database/table format

infrastructure elements on a line section. We have consulted other sources, which do not provide such information either. Moreover, the two databases and other consulted sources do not provide information on other network limitations than the intermodal transport profile (for rail, inland waterway and road). As a consequence, this analysis will only concern rail and focus on the "standard combined transport profile".

The "standard combined transport profile number for semi-trailers" defines the compliance of the railway network with regard to the P400 gauge, which is the standard that identifies rail lines allowing the loading of P400 semi-trailers on pocket wagons.

As mentioned above, the analysis leverage on the TENtec and RINF databases. RINF stands for Register of Infrastructure and is the main tool for describing the static rail network characteristics and capabilities as required by the Directive (EU) 2016/797 on rail Interoperability, including all the relevant information for the Route Compatibility, the Network Statement and the Route Book. The RINF consists of a centralised database hosted and managed by the EU Agency for Railways (ERA), describing: Operational Points (OP) representing stations, junctions, sidings, etc.; Section of Lines (SoL) describing the characteristics of tracks which link Operational Points together.

The methodology adopted to assess the most relevant intermodal transport bottlenecks – with respect to P400 compliance – is described below with respect to both databases.

Overview of the status of compliance of the TEN-T network to P400 profile according to TENtec and RINF data

The aim of this section is to investigate the rate of compliance with the P400 profile[68] of the TEN-T core network corridors for each Member State. The analysis relies on data for year 2017 (last year for which data are available) coming from both TENtec and RINF databases.

As a preliminary finding it should be highlighted that – for both databases – data were not available for all sections of the TEN-T core network corridors. The part of the network for which data is not available is hereafter referred at as "N/A".

The table below summarises the compliance rate to P400 profile for each Member State according to the RINF and TENtec databases.

Table 45: Status of compliance of the TEN-T core network corridors to P400, RINF and TENtec databases

	RINF database			TENtec database		
Country	**Non Compliance**	**Compliance**	**N/A**	**Non Compliance**	**Compliance**	**N/A**
Austria	19%	80%	2%	3%	97%	0%
Belgium	18%	82%	0%	6%	88%	6%
Bulgaria	77%	8%	14%	35%	7%	58%
Croatia	64%	0%	36%	21%	79%	0%
Czechia	N/A	N/A	100%	59%	20%	21%
Denmark	N/A	N/A	100%	0%	96%	4%
Estonia	N/A	N/A	100%	N/A	N/A	100%
Finland	1%	67%	32%	100%	0%	0%
France	39%	0%	61%	N/A	N/A	100%
Germany	N/A	N/A	100%	5%	94%	2%
Greece	100%	0%	0%	N/A	N/A	100%
Italy	46%	27%	28%	69%	29%	2%

[68] To assess the compliance status, all sections currently equipped with a P400 profile or higher were considered compliant, while lower profiles indicate a non-compliance status.

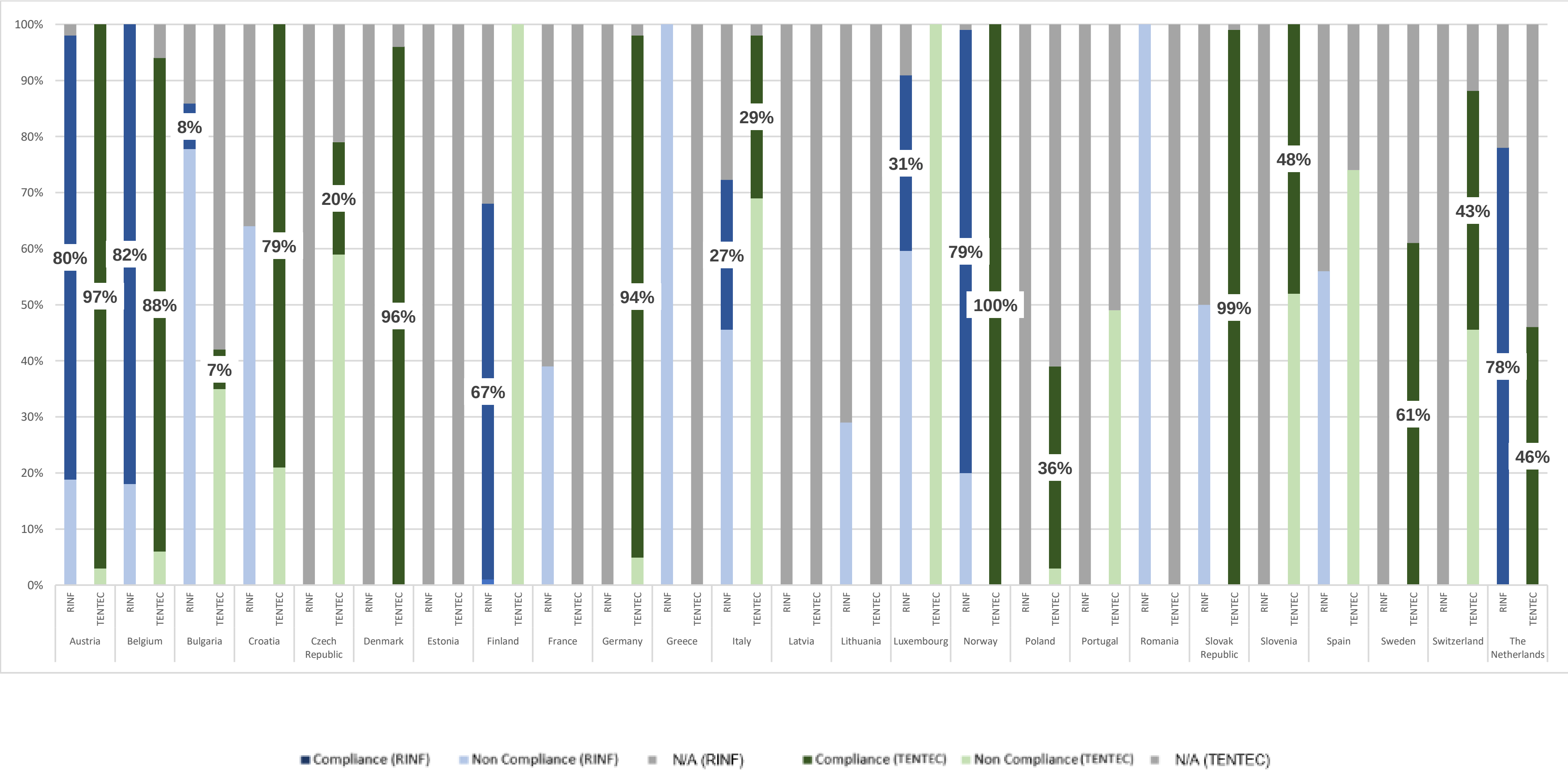
	RINF database			TENtec database		
Country	Non Compliance	Compliance	N/A	Non Compliance	Compliance	N/A
Latvia	N/A	N/A	100%	N/A	N/A	100%
Lithuania	29%	0%	71%	N/A	N/A	100%
Luxembourg	59%	31%	9%	100%	0%	0%
Norway	20%	79%	1%	0%	100%	0%
Poland	N/A	N/A	100%	3%	36%	61%
Portugal	N/A	N/A	100%	49%	0%	51%
Romania	100%	0%	0%	N/A	N/A	100%
Slovak Republic	50%	0%	50%	0%	99%	1%
Slovenia	N/A	N/A	100%	52%	48%	0%
Spain	56%	0%	44%	74%	0%	26%
Sweden	N/A	N/A	100%	0%	61%	39%
Switzerland	N/A	N/A	100%	46%	43%	12%
The Netherlands	0%	78%	22%	0%	46%	54%
Hungary	-	-	-	0%	100%	0%
Ireland	-	-	-	N/A	N/A	100%

The “compliance map” presented below was developed on the basis of TENtec geo-referenced data on the status of compliance of the TEN-T core network corridors to P400. Unfortunately RINF database currently does not provide for geo-referenced data.

Figure 14: Status of compliance of the TEN-T core network corridors to P400, TENTec database

Figure 15 shows the different compliance rates for each Member State according to the RINF and TENtec databases.

*Figure 15: Comparison of TEN-T core network corridors compliance status to P400 parameter in RINF and TENtec database**



**Hungary and Ireland are not shown in the graph as data are only available in the TENtec database and cannot be compared with RINF*

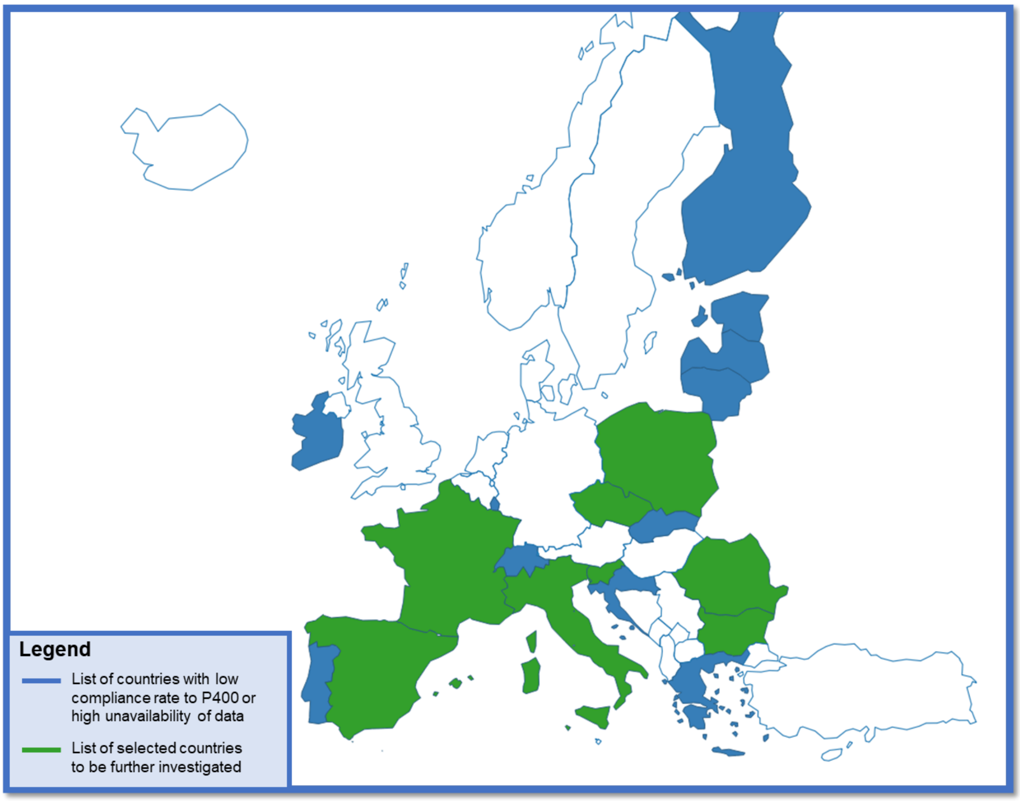
Selection of Member States for in depth analysis

The analysis Figure 15 suggests that the two databases are strongly in contrast, often presenting opposing compliance rates. It was therefore decided to enrich the analysis by directly consult the infrastructure managers. However, in consideration of budget and time constraints the consultation was limited to eight Member States in the period between May and September 2021.

Initially, 18 Member States were shortlisted in consideration of their low rate of compliance or extensive lack of data with respect to the parameter “standard combined transport profile number for semi-trailers” as reported in the RINF and TENtec databases. These 18 Member States, supposedly presenting low compliance of their TEN-T core network corridors to P400 standard are coloured in either green or blue in Figure 15.

To shortlist the final eight Member States for in depth analysis, it was considered to prioritise countries presenting large networks and being strategic for the EU intermodal transport. Finally, it was also considered to select a balanced sample of Member States from a geographic perspective. The eight shortlisted Member States are coloured in green in the EU map below (Figure 16).

Figure 16: List of 8 Member Sates’ network to be further investigated in the present study



In-depth analysis of eight strategic countries for the intermodal transport in Europe

To investigate the status of the network of the eight selected Member States a dedicated consultation was launched with the relevant local Infrastructure Managers. The consultation, supported by the RFC Managing Directors, was aimed at collecting the following information:

- status of compliance of the network with respect to the "standard combined transport profile number for semi-trailers" parameter;
- blocking infrastructure elements on non-compliant lines;
- past and planned investments and related costs to overcome the limitation.

Data on the status of compliance of the national infrastructure network have been collected for the Italian, Czech, French, Spanish, Slovenian and Bulgarian railway network. For Romania and Poland the consultations were not successful and therefore there is no information available to share.

In addition, infrastructure managers from Italy, Spain, Czechia, France and Bulgaria provided some information with regard planned investments to overcome the P400 limitations and their costs. However, the information does not present the same level of detail for all countries. Specifically, for Italy and Spain, it was possible to carry out a more in-depth analysis thanks to the information shared in relation to upgrade-only interventions at parameter P400.

The following sections present the consultation outcome for the investigated countries.

Bulgaria

For an in-depth analysis of the Bulgarian railway network, collaboration with the National Railway Infrastructure Company (NRIC) was started.

Based on RINF and TENtec data, the Bulgarian rail network had compliance values of 7% in the TENtec database and 8% in RINF, quite consistent data that show a critical situation for the Bulgarian network in terms of allowing P400 loading gauge.

From the data provided by the infrastructure manager, the critical situation is fully confirmed, showing that the entire network is currently not compliant with the P400 parameter. The TEN-T core network corridors are currently mainly equipped with P389 and P364 parameters. Values below P400 indicate the inability to allow the passage of semi-trailers to be transported on standard 4m*4m pocket wagons. Figure 17 shows the level of compliance to P400 of the Bulgarian TEN-T core network corridors.

Figure 17: Status of compliance of the Bulgarian TEN-T core network corridors to P400 in 2021 (NRIC database)

Currently, several modernisation works are planned by 2030 involving almost the entire Bulgarian network. These interventions include also upgrading the network to P400, bringing the compliance status of the network to 71% by 2030. Other projects concerning sections Brusartsi - Mezdra (2037), Mezdra - Sofia (2034), Radomir - Kulata (2034) and Ruse - Gorna Oryahovitsa – Dimitrovgrad (2034) are scheduled, but their completion is foreseen beyond 2030 and therefore not shown on the map.

Figure 18: Status of compliance of the Bulgarian TEN-T core network corridors to P400 in 2030 (NRIC database)

Table 46: Compliance rates for Bulgaria to P400, 2021 – 2030

	Compliance	Non-compliance
2021	0%	100%
2030	71%	29%

Table 47 shows the compliance rates of updated data for Bulgaria by TEN-T core network corridors. Bulgaria in particular is crossed only by the Orient/East-Med corridor which will therefore have a 100% non-compliance rate in 2021 and 29% in 2030.

Table 47: Compliance rates for Bulgaria by TEN-T corridors, 2021 – 2030

	Corridors	Compliance	Non-compliance
2021	Orient/East - Med	0%	100%
2030		71%	29%

Taking into account the above information, Bulgaria's current status presents a low level of compliance with the P400 standard (0%), with clear improvements by 2030 (71%). However, as noted in section 4.5, although many railway sections are not yet certified for P400, they nonetheless have all the technical requirements to allow for the transit of intermodal trains with P400 profile. In this sense, a measurement campaign could be sufficient to certify compliance with the parameter "number of standard combined transport profile for semi-trailers". As proof of this, information gathered from industry stakeholders[69] on the possibility to operate intermodal trains with a P400 profile shows a 95% compliance rate on Bulgarian sections, clearly a different scenario.

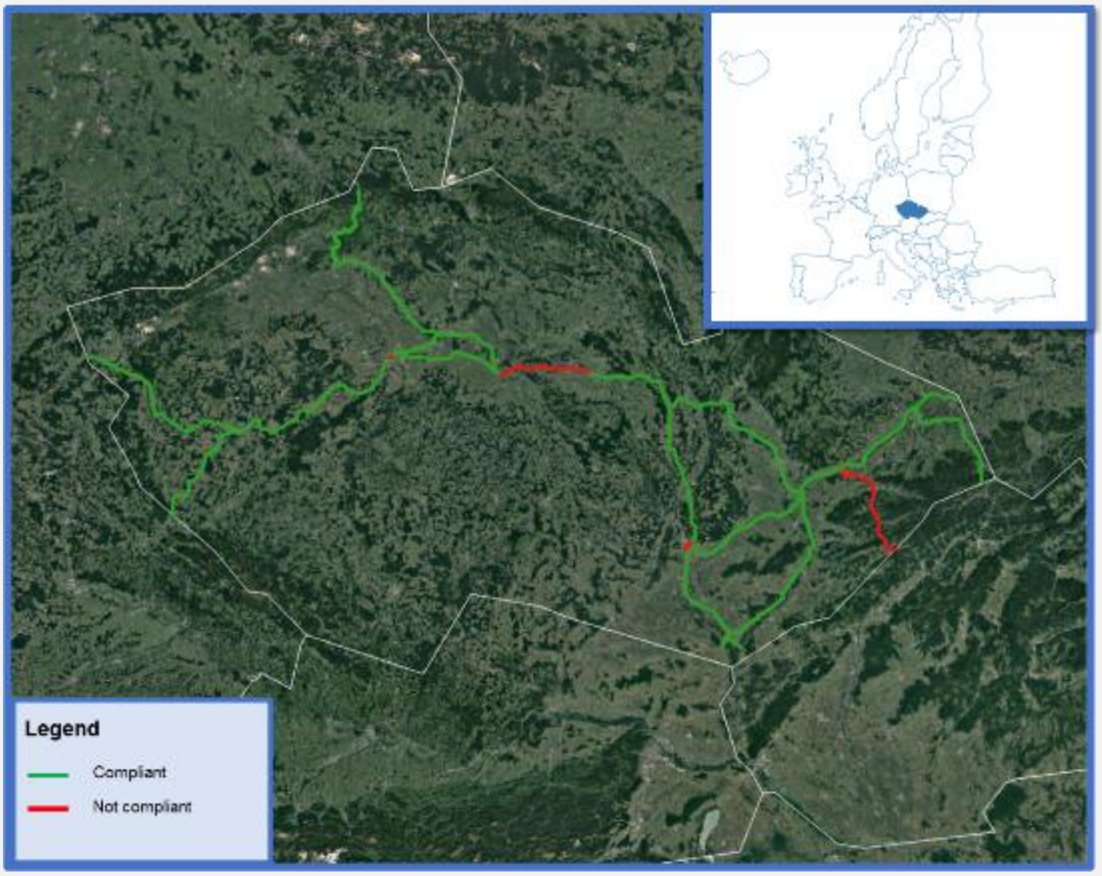
[69] The European Commission received information from industry stakeholders on the possibility to operate intermodal trains with a P400 profile concerning 13 Member States. See Table 1 of Annex 3 where information received by the European Commission is summarized.

Czechia

Similarly to what has been done for Bulgaria with NRIC, the Czech Rail Infrastructure Manager Správa Železnic was contacted to collect additional information on the national sections of the TEN-T network.

Figure 19 shows the level of compliance of the Czechia TEN-T core network corridors.

Figure 19: Status of compliance of Czechia TEN-T core network corridors to P400 in 2021 (Správa Železnic database)



As per the updated data, 88% of the Czech sections of the TEN-T core network corridors are compliant with the parameter "equal to or greater than P400". The analysis shows that the only sections that are currently non-compliant with respect to the parameter "standard combined transport profile number for semi-trailers" are the following:

- St. Kolin - Pardubice
- Hranice na Morave - Horni Lidec / Luky pod Makytou
- Praha Hla ni nadrazi - Praha Vrsovice
- Brno node (Modřice - Brno hlavní nádraží, Brno hlavní nádraží - Brno-Maloměřice st.6 and Brno-Černovice odbočk - Brno hlavní nádraží).

From the information provided in the consultation phase with the Infrastructure Manager, it was indicated that the Praha-Vršovice/Praha hlavní nádraží line is scheduled to be upgraded to P400 by 2030. In addition, the TEN-T CNC 2021 Project List also includes a project for the construction of a new high-speed line on the Praha <--> Usti n. Labem II section. These additional interventions bring the compliance level of Czechia's network to 89%.

Figure 20: Status of compliance of Czechia TEN-T core network corridors to P400 in 2030 (Správa Železnic database)

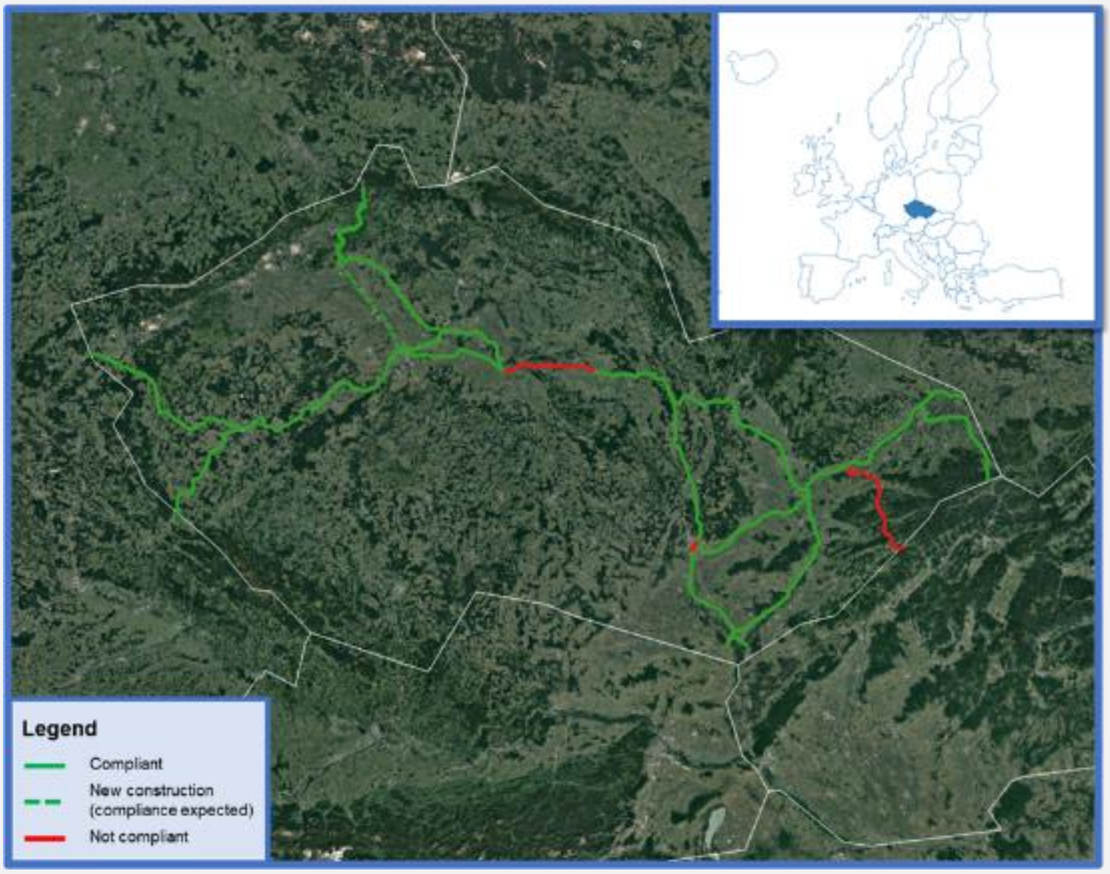


Table 48: Compliance rates for Czechia to P400, 2021 - 2030

	Compliance	Non-compliance
2021	88%	12%
2030	89%	11%

Table 49, show slightly different compliance rates values for Czechia's sections of the TEN-T core network corridors.

Table 49: Compliance rates for Czechia by TEN-T corridors, 2021 - 2030

	Corridors	Compliance	Non-compliance
2021	Baltic – Adriatic	89%	11%
2030		94%	6%
2021	Orient/East-Med	89%	11%
2030		92%	8%
2021	Rhine – Danube	86%	14%
2030		87%	13%

However, information received from industry operators[70] suggest a 95% compliance rate for the Czech network on the possibility of running intermodal trains with a P400 profiled.

[70] The European Commission received information from industry stakeholders on the possibility to operate intermodal trains with a P400 profile concerning 13 Member States. See Table 1 of Annex 3 where information received by the European Commission is summarized.

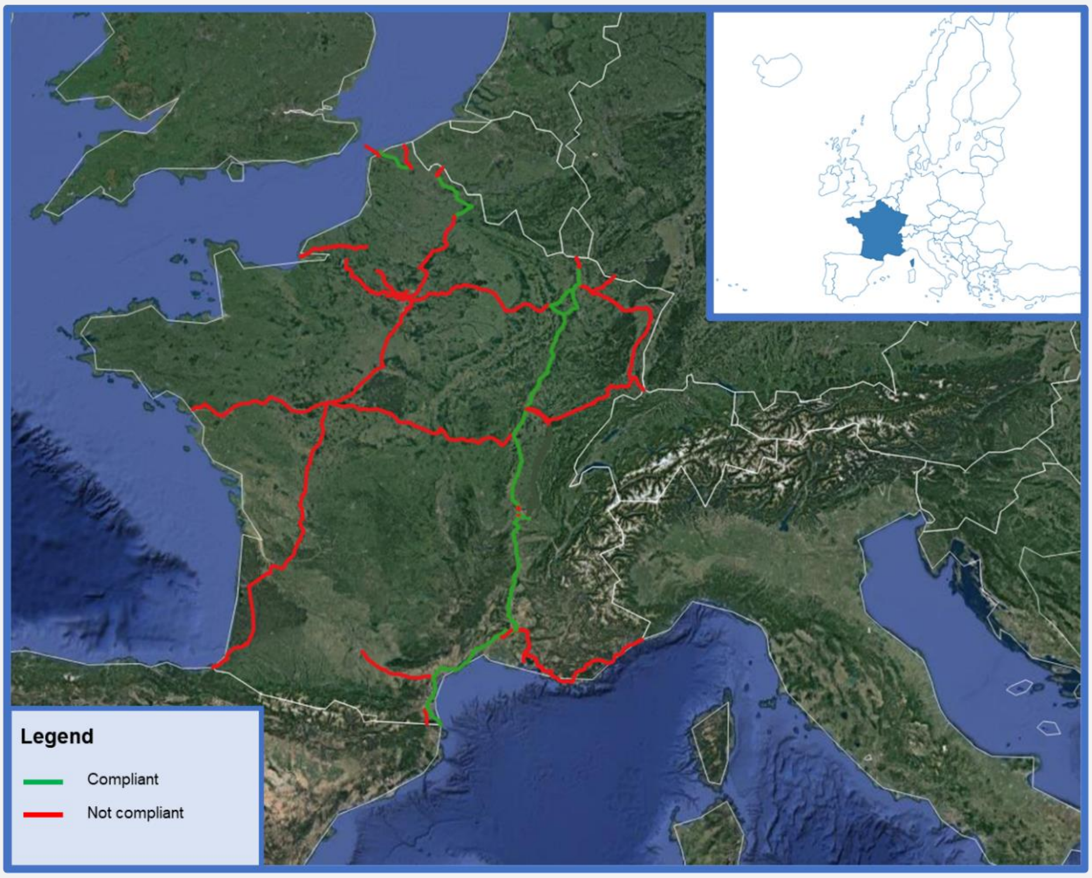
France

In order to further investigate the compliance status of the French network with respect to the P400 profile and identify the most critical areas of the network, a consultation was conducted with SNCF reseau, the company in charge of managing and maintaining the railway infrastructure in France.

With the information provided, an analysis of the French TEN-T core network corridors was carried out, updating the data in the RINF and TENtec databases, which presented high percentages of N.A. sections for France (61% RINF and 100% TENtec), making it difficult to fully understand the current state of the French TEN-T core network corridors.

Figure 21 shows the level of compliance of the French TEN-T core network corridors in 2021.

Figure 21: Status of compliance of the French TEN-T core network corridors to P400 in 2021 (SNCF reseau database)



The processed data show a critical situation for the French network with only 25% of the sections currently compliant with the parameter “equal to or greater than P400”. The remaining 75% of the sections have a lower profile, making them non-conforming to the parameter “standard combined transport profile number for semi-trailers”.

As can be seen from the image above, the only compliant sections are those listed below:

- Calais - Lille
- Lille - Somain
- Somain - Toul
- Toul – Lyon
- Lyon – Avignon

- Avignon – Montpellier
- Montpellier – Narbonne
- Narbonne – Perpignan
- Perpignan – Border ES/FR.

These sections amount to 1 271 km of the 5.150 total network kilometres, crossing France from North to South, down to the Spanish border. Other compliant sections belonging to the comprehensive network and therefore not considered in this analysis are present, but always in proximity of the sections listed above. Although the entire central-western part of France, from north to south, is unsuitable for the intermodal transport of semitrailers having a profile not compliant with P400 standard, other sections of the French network are at least possibly compliant, as per studies made by Railway Undertakers of the North Sea Mediterranean CNC in collaboration with the engineering department of SNCF Réseau. The scope of the study, which included collecting data measures for 6 French tunnels and 2 Swiss tunnels, was to check the real gauge limitation for P394 and P400 trains to circulate on the sections between Bettembourg and Basel.

By 2030, the compliance status of the French TEN-T core network corridors will increase to 46% considering the construction of new railway lines and upgrading of existing ones planned on the network.

In particular, the TEN-T CNC 2021 Project List includes plans for the construction of the line Saint Laurent de Mure – Border FR/IT II/Modane (Lyon – Turin) and for the upgrade of the Strasbourg JCT <--> Border F/D II / Bundesgrenze F/D (project to improve rail accessibility in Strasbourg port). In addition, under the assumptions of this report, all sections planned to be constructed within 2030 – for which the compliance status is unknown – have also been considered compliant to P400.

Figure 22: Status of compliance of the French TEN-T core network corridors to P400, in 2030 (SNCF reseau database)

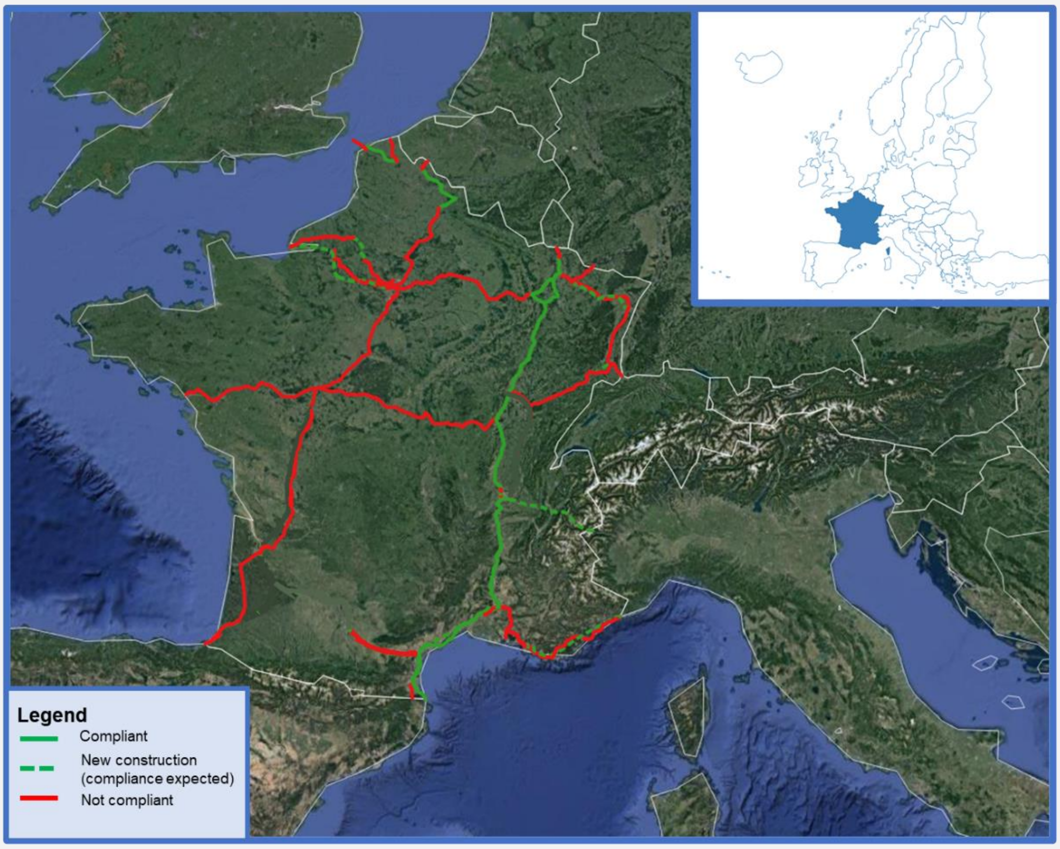


Table 50: Compliance rates for France to P400, 2021 - 2030

	Compliance	Non-compliance
2021	20%	80%
2030	37%	63%

Table 51 shows the compliance rates of updated data for France by TEN-T core network corridor.

Table 51: Compliance rates for French by TEN-T corridors, 2021 – 2030

	Corridors	Compliance	Non-compliance
2021	Atlantic	2%	98%
2030		14%	86%
2021	Mediterranean	48%	52%
2030		66%	34%
2021	North-Sea Mediterranean	49%	51%
2030		52%	48%

Italy

With the aim of verifying the Italian railway network compliance status with respect to the parameter "standard combined transport profile number for semi-trailers", Rete Ferroviaria Italiana S.p.A. (hereinafter RFI) was contacted and an in-depth analysis was performed on the Italian TEN-T core network corridors.

The analysis was carried out investigating the PIR database (Prospetto Informativo della Rete) - prepared by RFI - and comparing it with the data included in TENtec and RINF databases.

Figure 23 shows the updated level of compliance of the Italian TEN-T core network corridors in 2021.

Figure 23: Status of compliance of the Italian TEN-T core network corridors to P400 in 2021 (RFI database)

As depicted in the map, most of the sections are currently non-compliant with the P400 parameter (57% of the network is equipped with a lower parameter). More specifically, the following consideration can be highlighted:

- the whole Southern-Italy TEN-T core network corridors is non-compliant, except for the Napoli -Roma section;
- Central-Italy also has a critically low status of compliance. Only the Livorno - Bologna and Ancona - Bologna sections are currently compliant with P400;
- North-Eastern Italy shows the highest percentage of compliance, with most lines already equipped with P400 or a higher profile. In particular, the sections Verona – Vicenza – Padova (conventional line), Bologna – Verona, Venezia – Trieste (conventional line), Cervignano del Friuli - Austrian border and Verona – Fortezza

– Brennero are currently compliant with the parameter "standard combined transport profile number for semi-trailers";

- in the North-West, the lines currently compliant with P400 are the Verona – Brescia – Milano (conventional line), Milano and Novara nodes, and the Milano – Novara – Torino line.
- As it can be seen from Table 52, the current compliance status of the Italian TEN-T core network corridors is around 40% whereas 60% of the network is still equipped with a profile lower than P400. The percentage of N/A sections, as a result of the consultation with the Italian Infrastructure manager, is now nil since information was collected for all the lines.

Taking into consideration the "Piano Commerciale 2021"[71] and the projects included in the TEN-T CNC Project List 2021, by 2030 the following lines will be updated, increasing overall Italian network compliance rate:

- Pisa – La Spezia (Livorno – La Spezia – Civitavecchia)
- Arona – Domodossola – (Gallarate)
- Bologna – Firenze
- Firenze node
- Bari – Taranto
- Salerno – Rosarno
- Milano – Tortona (Terzo Valico entrance)
- Ravenna Port railway connections

The new construction lines that will be built with a profile equal to or greater than P400 are:

- Treviglio – Verona Porta Nuova (High Speed)
- Vicenza – Padova (High Speed)
- Verona – Vicenza (High Speed)
- Orbassano – Avigliana
- Lyon – Turin railway line (cross border section)
- Napoli – Foggia – Bari
- Tortona – Genova (Terzo Valico)

[71]https://www.rfi.it/content/dam/rfi/chi-siamo/piano-commerciale/edizione-feb 2021/Piano%20Commerciale_ed_feb_2021.pdf

Figure 24: Status of compliance of the Italian TEN-T core network corridors to P400 in 2030

As a result of the above-mentioned planned interventions, the compliance status of the Italian TEN-T core network corridors will increase from 43% to 81%, with a clear improvement also in the southern part of the peninsula.

Table 52: Compliance rates for Italy to P400, 2021 - 2030

	Compliance	Non-compliance
2021	43%	57%
2030	81%	19%

Table 53 shows the compliance rates of updated data for Italy by TEN-T core network corridor.

Table 53: Compliance rates to P400 for Italy by TEN-T corridors, 2021-2030

	Corridors	Compliance	Non-compliance
2021	Baltic – Adriatic	66%	44%
2030		98%	2%
2021	Mediterranean	54%	46%
2030		93%	7%
2021	Scandinavian - Mediterranean	27%	73%
2030		63%	37%
2021	Rhine – Alpine	50%	50%
2030		57%	43%

Slovenia

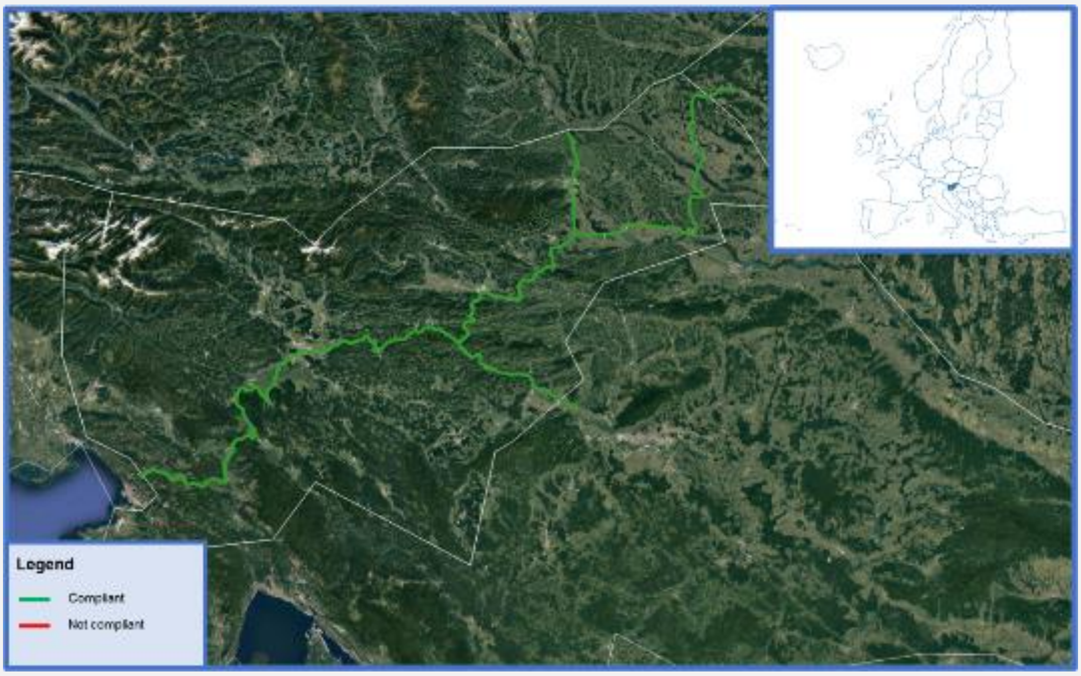
The update procedure conducted for the other states was also repeated for Slovenia and was accompanied by cooperation with Slovenske železnice – Infrastruktura, the Slovenia Infrastructure Manager.

The analysis of the RINF and TENtec databases revealed strongly conflicting data (RINF 0% compliance and 100% N/A, TENtec 48% compliance and 0% N/A), which did not allow a correct understanding of the current situation on the Slovenian network. Further investigation was therefore necessary in view also of Slovenia's strategic position in the European network.

The data collected and processed show that the Slovenian TEN-T core network corridors have a very good level of compliance with respect to the parameter "standard combined transport profile number for semi-trailers", with a percentage of 100% which corresponds to 451 km of network.

Figure 25 shows the level of compliance of the Slovenian TEN-T core network corridors.

Figure 25: Status of compliance of the Slovenian TEN-T core network corridors in 2021 (Slovenske železnice – Infrastruktura database)



The following lines are also planned to be completed by 2030 and will be equipped with a profile equal to or greater than the P400:

- Divaca - Koper
- Sezana (border IT/SLO) - Divaca
- Divaca - Postojna
- Postojna – Ljubljana

Figure 26: Status of compliance of the Slovenian TEN-T core network corridors to P400 in 2030 (Slovenske železnice databases)

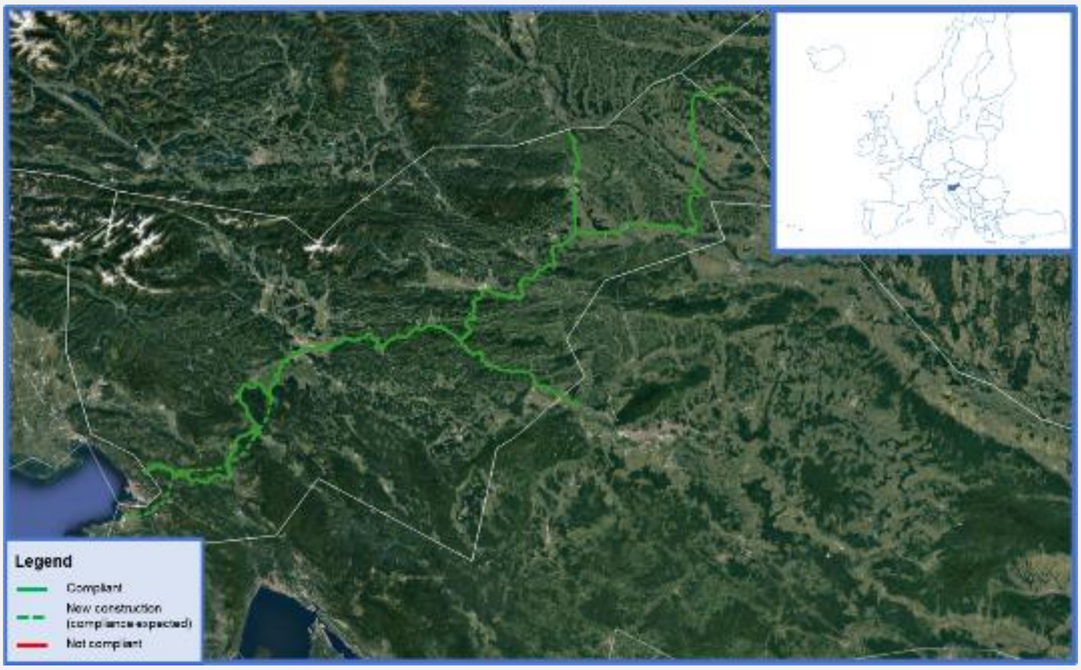


Table 54: Compliance rates for Slovenia to P400, 2021 - 2030

	Compliance	Non-compliance
2021	100%	0%
2030	100%	0%

Table 55 shows the compliance rates of updated data for Slovenia by TEN-T core network.

Table 55: Compliance rates for Czechia by TEN-T corridors, 2021 – 2030

	Corridors	Compliance	Non-compliance
2021	Baltic – Adriatic	100%	0%
2030		100%	0%
2021	Mediterranean	100%	0%
2030		100%	0%

Spain

The analysis of the RINF and TENtec databases described above showed a high level of criticality for the Spanish network with respect to the parameter “standard combined transport profile number for semi-trailers”. Both databases, accordingly, reveal a compliance rate of 0% and 44/26% of N/A sections. The use of different profiles from the standard ones is very frequent, with considerable difficulties of integration with the European network. Considering the extension of the railway network, the Spanish infrastructure manager ADIF was contacted to collect additional information on the Spanish TEN-T core network corridors.

The analysis of the collected data confirmed the low level of compliance of the Spanish TEN-T core network corridors, with only 300 km of network equipped with a profile equal to or higher than P400, corresponding to 6% of the total network.

Figure 27 shows the level of compliance of the Spanish TEN-T core network corridors.

Figure 27: Status of compliance of the Spanish TEN-T core network corridors to P400 in 2021 (ADIF database)

Currently, the only two compliant lines are the Barcelona (Morrot and Can Tunis terminals) - French Border new line, passing through Girona, and the La Coruña – Vigo line, in the North-West of Spain. The latter line is completely isolated from the other P400 lines but development plans for the Atlantic CNC alignment could bring connections to this line.

By 2030, the conventional line Zaragoza – Algeciras passing through the Madrid node will be upgraded to P400. In addition, the new construction lines La Pola – La Seca (tùnel de Pajares) and Pantoja – Càceres – Badajoz will comply with the parameter “standard combined transport profile number for semi-trailers” by 2030. This will increase the compliance of the Spanish TEN-T core network corridors from 4% to 25%.

Figure 28: Status of compliance of the Spanish TEN-T core network corridors to P400 in 2030 (ADIF database)

Table 56: Compliance rates for Spain to P400, 2021 – 2030

	Compliance	Non-compliance
2021	6%	94%
2030	26%	74%

In the assessment of the compliance status of the Spanish network in 2030, only the currently planned interventions have been considered. However, consultations with the infrastructure manager ADIF revealed that the ultimate goal remains to have a fully P400 compliant TEN-T core network corridors for freight transport by 2030, therefore an investment plan aimed to overcome the limitations is currently under study.

Table 57 shows the compliance rates of updated data for Spain by TEN-T core network corridor.

Table 57: Compliance rates for Spain by TEN-T corridors, 2021 – 2030

	Corridors	Compliance	Non-compliance
2021	Atlantic	5%	95%
2030		31%	69%
2021	Mediterranean	6%	94%
2030		34%	66%

Total kilometres of TEN-T Core network corridor sections that do not meet the P400 standard

After having analysed the RINF and the TENtec databases and having conducted a direct consultation on infrastructure managers of eight Member States, the precise number of kilometres of TEN-T core network corridors to be upgraded to parameter P400 remains unknown and difficult to estimate, because, as shown in the previous sections, data provided by different sources generally differs or is incomplete.

However, for the purpose of this assignment, different considerations and assumptions can be made in order to come up with a rough estimation of the number of kilometres that would require to be upgraded to comply with the P400 parameter.

On one hand, for Member States whose infrastructure managers were reached by the direct consultation, the level of compliance of the network and the corresponding kilometres to be upgraded to P400 were determined considering accurate data validated directly by the infrastructure managers.

On the other hand, for Member States that were not involved in the consultations with infrastructure managers, the level of compliance of the network and the corresponding kilometres to be upgraded to P400 were assumed to be as reported in the TENtec database. TENtec data was preferred to RINF data because the later does not provide information on the corridor to which each section belong. Finally, sections for which compliance to P400 is unknown were assumed to be not compliant.

Table 58 below provides for the estimation of the number of kilometres of the TEN-T core network corridors that are not certified for the P400 profile.

Table 58: Estimation of the kilometres of TEN-T core network corridors not codified for the P400 profile or above

Compliance analysis	Length of the corridors [km]	Corridor length not codified for P400 profile [km]	Corridor length not codified for P400 profile [%]
8 Member States involved in IMs consultation	17 943	12 694	71%
Other Member States	24 297	9 312	38%
Total	42 240	22 006	52%

As presented in Table 58 above, there are 22 006 km of network that should be upgraded in order to be certified for the P400 profile. However, this figure is likely to be overestimated for two reasons. Firstly, it is unknown if all of these sections for which P400 compliance data is not available are actually not compliant. Secondly, it is the case that quite often lines that are not certified for the P400 profile are actually already in use by the rail industry for the operation of intermodal trains with P400 profile.

Indeed, as explained in Task 3.5, many railway sections are not certified for P400, but have all the technical requirements to allow the passage of intermodal trains with P400 profile. In this respect, a measurement campaign could be sufficient to certify compliance with the parameter “standard combined transport profile number for semi-trailers”.

The European Commission received information from industry stakeholders on the possibility to operate intermodal trains with a P400 profile concerning 13 Member States. This information was used to review the number of kilometres of the TEN-T core network corridors currently not codified for P400 profile.[72]. Table 59 below present the estimation of the kilometres of TEN-T core network corridors not allowing the operation of intermodal trains with P400 profile or above.

[72] Please see Table 1 of Annex 3 where information received by the European Commission is summarized.

Table 59: Estimation of the kilometres of TEN-T core network corridors not allowing the operation of intermodal trains with P400 profile or above

Compliance analysis	Length of the corridors [km]	Corridor length not allowing the operation of P400 profile trains [km]	Corridor length not allowing the operation of P400 profile trains [%]
8 Member States involved in IMs consultation	17 943	11 560	64%
Other Member States	24 297	3 319	14%
Total	**42 240**	**14 879**	**35%**

As estimated in Table 59, there are 14 879 km of TENT core network corridors would require infrastructural works on some parts of their length (where blocking infrastructure elements, like tunnels, are located) for allowing the operation of intermodal trains with a P400 profile. This figure is significantly lower than the 22 006 of kilometres of the TEN-T core network corridors that are not certified for the P400 profile (see Table 58).

Still, it should be considered that the length of network actually requiring infrastructural upgrade might be even shorter than what has been reported in Table 59, because the information received by the European Commission covered only 13 Member States out of the 27 presenting a rail network.

Using the same information and assumptions as for the estimation reported on Table 59 above, it is possible to estimate the number of kilometres of each TEN-T core network corridor that require infrastructural works on some parts of their length for allowing the operation of intermodal trains with a P400 profile (see Table 60). Sections overlapping between two or more corridors have been included in the calculation of each corridor.

Table 60: Estimation of the kilometres of TEN-T core network corridor not allowing the operation of intermodal trains with P400 profile or above by corridor

TEN-T Corridor	Length of the corridors [km]	Corridor length not allowing the operation of P400 profile trains [km]	Corridor length not allowing the operation of P400 profile trains [%]
Atlantic	5 762	5 625	98%
Baltic - Adriatic	4 212	413	10%
Mediterranean	7 858	5 552	71%
North Sea - Baltic	4 871	291	6%
North Sea - Mediterranean	4 461	3 262	73%
Orient/East - Med	5 636	1 043	19%
Rhine - Alpine	3 258	1 110	34%
Rhine - Danube	5 505	360	7%
Scandinavian - Mediterranean	8 756	2 401	27%

As reported in Table 60, the Atlantic corridor is the one presenting the largest number of kilometres not allowing operation of intermodal trains.

Other corridors requiring extensive upgrade of their infrastructure are the Mediterranean corridor and the North Sea - Mediterranean corridor.

4.7 Total investment to remove barriers/ blockades/ limitations on TEN-T core network corridors for loading unit (taking into account current initiatives)

The aim of this section is to estimate the cost of investment needed to remove barriers, blockades and other sort of limitations on the TEN-T core network corridors for allowing the operation of intermodal trains. For this study, it is proposed to be achieved by multiplying the kilometres of network not allowing the operation of freight trains presenting a P400 profile by a unit cost per kilometre.

Ideally, the calculation should consider the specific type of limitations to be overcome on a line section requiring upgrade, as well as specific unit costs per type of infrastructure limitation to be removed (taking into account that some limitations may be removed without substantial costs). However, the analysis carried out under Task 3.6 did not allow for the identification of the critical areas of the TEN-T core network corridors with specification of the infrastructure limitations (tunnels, bridges, water levels etc.). Nevertheless, as part of Task 3.6, it was roughly estimated that 14 879 km of corridor lines do not allow the operation of freight trains presenting a P400 profile.

Hence, next sections will focus on the review of different sources of information with the aim of collecting materials that can be used for estimating a generalised unit cost per kilometre for the infrastructural upgrade of network to allow for the operation of trains with a P400 profile.

The upcoming section analyses the description and cost of projects included in the 2021 Project List of the TENT core network corridors and upgrading the loading gauge.

The section after the next reports on relevant loading gauge upgrade projects and their costs collected through the consultation with infrastructure managers.

Analysis of projects included in the 2021 TEN-T CNC Project List

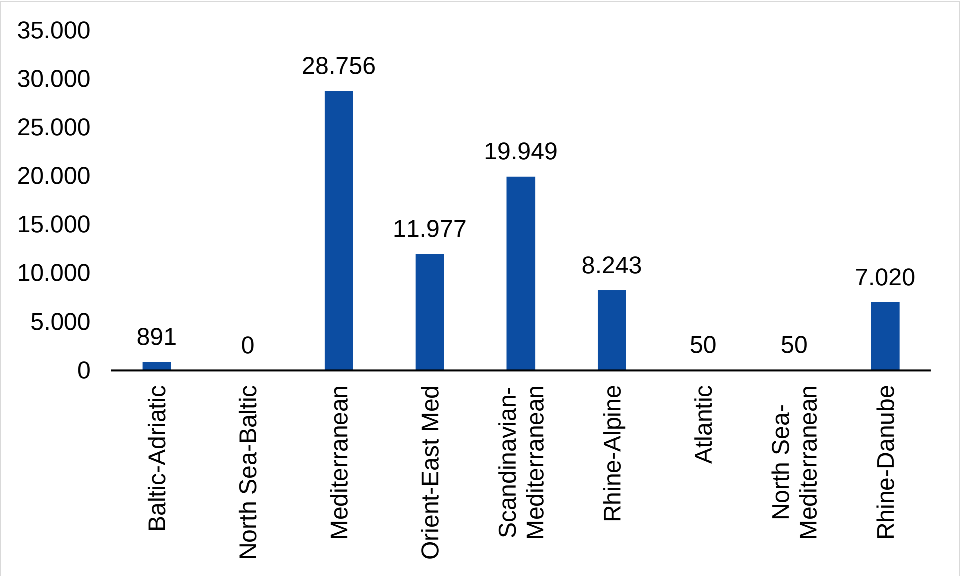
The TEN-T CNC Project Lists (PLs) are the main tool for the European Commission to monitor the progress of the corridor development. Each of the nine TEN-T corridors has elaborated a list of projects that are relevant to complete the TEN-T Core network in accordance with Reg. (EU) 2013/1315 and 2013/1316.

The updating process of the nine PLs takes place once a year and requires the collaboration of infrastructure managers and Member State representatives. The information collected is then consolidated into a single PL for all nine corridors and published by the European Commission.

For the purpose of this study, the latest available version of the TEN-T CNC Project List was used, which was published in May 2021. The overall list containing projects from all Member States was then filtered to highlight only those projects that insist on achieving the intermodal gauge parameter (P400 profile).

Annex 3 summarises the main information of the 36 projects related to achieving the compliance with the P400 profile, including project description, completion date and cost. Considering the projects presented in the annex a breakdown of costs by TEN-T corridor is presented in the Figure 31.

Figure 29: Breakdown of network upgrade costs to P400 by TEN-T corridor [M€]



The overall cost of those projects is 76 936 M€. However, this cost is of little use for the purpose of this study because the displayed costs by corridors in most cases cover for several interventions not only related to the P400 parameter. More specifically, only 4 out of the 36 projects are specifically focused on the upgrade of the infrastructure to the P400 parameter. Hence, their cost can be specifically associated with the upgrade to the P400 parameter. For the remaining projects the cost for upgrading to the parameter "standard combined transport profile number for semi-trailers" cannot be isolated.

Analysis of projects collected during consultations with the infrastructure managers

As mentioned above, infrastructure managers from Italy, Spain, Czechia, France and Bulgaria provided some information with regard planned investments to overcome the P400 limitations and their costs. Nevertheless, only for Italy and Spain, it was possible to carry out a more in-depth analysis thanks to the information shared in relation to upgrade-only interventions at parameter P400.

Italy: The project concerns the Valico Luino, the border crossing between Italy and Switzerland, with the reclassification from P/C 50 coding to P/C 80 coding of the entire line by 2021.

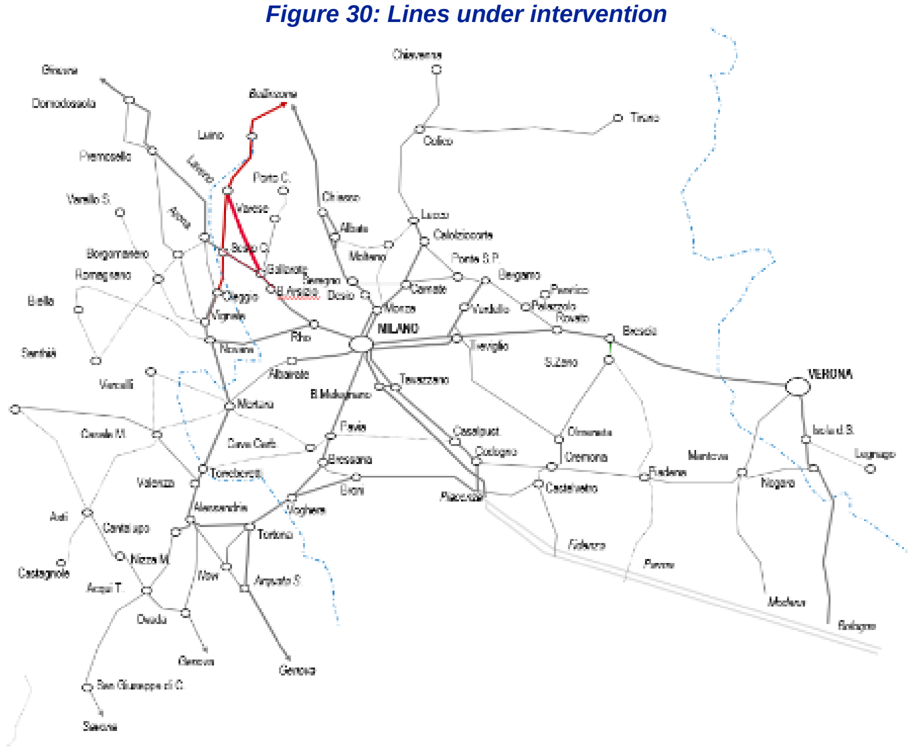
Specifically, the lines involved are:

- Oleggio - Pino Tronzano (simple track) – 64 km;
- Laveno – Gallarate (simple track) – 31 km
- Sesto Calende - Gallarate - Busto Arsizio (double track) - 25 km

Characteristics:

- 94 km of the line is single track
- 24 km is double track
- Electrified line.

Figure 30: Lines under intervention



The project also includes:

- upgrading to 750m train length at Ispra, Laveno, Luino, Porto Valtravaglia and Pino T
- implementation of ACC in Laveno, Luino, Maccagno and Pino T
- Level Crossing suppression.

Main interventions:

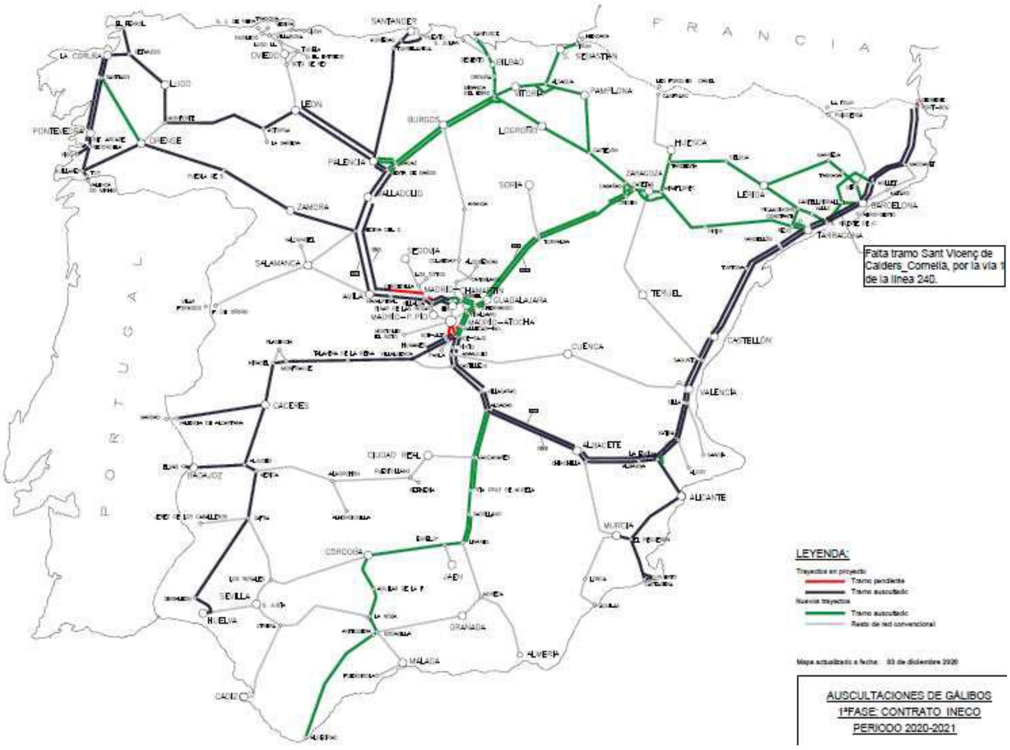
- 22 single-track tunnels of which:
  - N°9 < 500 m
  - N°9 > 500 m
  - N°2 > 1 000 m
  - N°2 > 2 000 m
- lowering of the railway level
- rigid catenary on the Sesto Calinda bridge
- 5-arch overpass at Busto Arsizio
- minor works.

Planned costs: 205 million, of which 120 million for the PC80/410 profile.
Time: 2015 - 2021

Spain: Since December 2019, Adif is analysing the following corridors in relation to the costs of upgrading to the standard parameter for intermodal transport:

- Madrid – Valencia (300 km)
- Zaragoza – Madrid – Algeciras (730 km)
- Mediterranean Corridor (1 300km)

Figure 31: Corridors under analysis



Estimated costs:

For the corridor Zaragoza – Madrid – Algeciras, the analysis took into account the interference of the tunnels and overbridges present in the corridor, identifying the relevant interventions needed and the estimated costs.

For tunnels, estimated budget considering 5 200€/m of interference setting a minimum amount of 500 000€/tunnel. This estimate only takes into account civil works, therefore interventions to the signalling system, electrification and other works are not included.

For overbridges, the estimated budget varies between 200 000€ - 800 000 €/overbridge depending on:

- Platform lowering / bridge raising.
- Single track line / double track line.

Specifically, there are many different types of interventions in tunnels to increase clearance gauge:

- Punctual increase of clearance (3 400 €/m according to SNCF Works - Poitiers tunnel).
- Platform lowering. Depending on the Depth and geotechnical conditions.
- Tunnel enlargement. Conventional methods (9 000 -12 000 €/m depending on traffic interruption time, 8 hours/day or 24 hours/day and other conditions). New methods TIT Tunnel in Tunnel method / TEM Tunnel Enlargement Machine (14 000 €/m + 8mill € preliminary works at the frontal)
- Other systems affecting capacity; a third track laid on the middle of the tunnel.

In general terms, preliminary cost analysis of the tunnel, overbridges and stations interventions considering rigid catenary in some tunnel lead to an overall estimate for the upgrade operation according to the selected profile of:

GEC16	AF 4.0 IP	GEB16
196 100 000 €	41 100 000 €	26 100 000 €

Czechia: With regard to the planned interventions in Czechia for upgrading the network to the P400 parameter, currently the only planned intervention concerns section Praha Hla ni nadrazi - Praha Vrsovice. The estimated cost for the overall reconstruction is 163.048.271 €. However, it is not possible to isolate costs for P400 compliance.

France: For France a total raw cost of upgrading to the parameter “standard combined transport profile number for semi-trailers” was estimated at €1.6 billion for 130 tunnels. The length of the network that requires upgrade was not provided.

Assessment of the total investment required to upgrade the TEN-T network to P400 parameter

The analysis of the 2021 TEN-T CNC Project List and of the projects collected throughout the consultation of the infrastructure managers allowed for the identification of three projects that can be used as input for calculating a generalised unit cost per kilometre to upgrade the network to P400 level. These projects were selected because they provide for the number of kilometres of line that need to be upgraded and specific cost of intervention for upgrading the infrastructure to enable the operation of trains with a P400 profile. The three projects are:

- The upgrade to P400 of the Valico Luino has a total cost of € 120 million. The section involved has a total length of 118 km, of which 94 km is single track and 24 km double track. By dividing the total cost of the operation by the total kilometres, a unit cost per kilometre of 1 million €/km was obtained.
- The upgrade of the Zaragoza - Madrid - Algeciras corridor to the P400 has a total estimated cost of 196 million €, considering the length of the corridor of 730 km, the unit cost per km is equal to 268 000 €/km.
- The P400 loading gauge upgrade project on the railway access from Milan/Novara to Genoa has a total cost of 35 million €. The sections involved are Novara - Alessandria - Novi Ligure and Milano – Pavia – Tortona, with a total length of 166 km. The unit cost per kilometres is therefore equal to 210 000 €/km

Considering the above-mentioned projects, a cost range between 210 000 €/km and 1 million €/km was derived. The cost range is particularly wide and is strongly influenced by the orographic condition, the morphology of the area, the number of tunnels and their length. As an example, the Valico Luino project presents a very high unit cost of 1 million €/km, due to the fact that it is a cross-border section with critical orographic conditions and around 15 km of tunnel.

These unit costs per kilometre of network to be upgraded were calculated with reference to the kilometres of the sections were the limitations (e.g. tunnels, bridges, shelters, etc.) are encountered. It is very important to note that, typically, not all kilometre of a section actually need to be upgraded.

With the aim of estimating the total investment necessary to remove the identified limitations, three possible cost scenarios for the upgrade to P400 were established:

- 210 000 €/km = low scenario
- 344 000 €/km = medium scenario
- 1 million €/km = high scenario

The medium scenario was derived taking into consideration the weighted average of the cost values of the projects selected for cost estimation analysis against their length (km).

For each of the three scenarios, the total costs of overcoming the criticalities of the rail network were calculated by multiplying the respective unit cost by the kilometres of the network to be upgraded previously identified in task 3.6.

Considering the estimation of number of kilometres not allowing the operation of freight trains presenting a P400 profile (see Table 59 in Task 3.6), it is possible to calculate the expected overall investment cost to upgrade the entire TEN-T core network corridors (see Table 61).

Table 61: Cost scenarios to upgrade the TEN-T CNC network to allow for the operation of trains with a P400 profile

		Low scenario Unit cost: 210 000 €/km	Medium scenario Unit cost 344 000 €/km	High Scenario Unit cost 1 000 000 €/km
	Corridor length to be upgraded [km]	**Upgrading cost [M€]**	**Upgrading cost [M€]**	**Upgrading cost [m€]**
8 Member States involved in IMs consultation	11 560	2 428	3 977	11 560
Other Member States	3 319	697	1 142	3 319
Total	**14 879**	**3 124**	**5 118**	**14 879**

According to these calculations an estimate of the total costs of upgrading the entire TEN-T core network corridors to allow for the operation of trains with a P400 profile ranges between 3 124 M€ and 14 879 M€. According to the Medium scenario the overall cost would be equal to 5 118 M€. These cost estimations should be used cautiously because they are based on the assumption that each kilometre has to be upgraded. Moreover they are based on unit costs derived from a very limited number of projects. The availability of cost information on a larger number of relevant project could improve significantly the reliability of the calculated unit costs.

Furthermore, it is important to underline that projects collected in the consultation phase with the infrastructure managers regards cases of hard infrastructure upgrade to P400 standard. However, in some cases, lighter interventions, such as repositioning of signals or shelters, or limited to few kilometres affected by blocking elements, or even re-codification, might be sufficient. Unfortunately, information on the cost of this type of intervention was not identified, therefore the unit cost ranges provided above might be excessive if applied to network sections that require light interventions.

4.8 Overview of TEN-T core network, including breakdown per TEN-T corridor or parts of it, where network capacity problems exist today

While precise information on capacity problems for the core network does not exist in a comprehensive source, the Work Plans of the European Coordinators for the nine Core Network Corridors and in particular the corresponding Corridor Studies are expected to include such analysis for the different modes per corridor. The results of the analysis of the Corridor Study update 2 of spring 2021 is presented in Annex 2.

The individual corridor studies have approached the question in differing ways and to different extents and the results have been processed differently. Furthermore, the capacity of linear infrastructures is only a minor aspect of these studies, therefore, a comprehensive and comparable analysis of the different corridors is difficult, however, the following general statements can be derived regarding the most impactful and critical capacity constraints:

- The largest capacity limitations exist on the north-south corridors crossing the Alps, and their access lines.
- Additionally, in the hinterland of Belgian, Dutch and German seaports freight trains are suffering from capacity constraints of the rail infrastructure.
- Finally, within urban nodes, where far distance passenger trains, regional and commuter trains as well as freight trains are using almost the same infrastructure capacity problems exist and require careful consideration of the competing priorities between passenger and freight transport.

Most analysis focused on rail, while also road capacity limitations exist in urban areas for the same reason. Capacity issues for inland waterway and short sea shipping, the two other modes of transport relevant for this study, are mentioned only at very specific places where locks need to be improved.

For many of those issues corresponding infrastructure upgrades or new built projects have already been identified and are included in the Work Plans of the European Coordinators.

4.9 Total cost of removing network limitations per TEN-T corridor (terminals, infrastructure, etc.)

The main objective of this task is to estimate the total cost of removing network limitations per each TEN-T corridor by considering both the costs of upgrading the Core Network Corridors to P400 parameter and the costs for the upgrade and construction of new terminals. This task builds on the outcomes of Task 3.4 and Task 3.7.

Investment into the upgrading of the infrastructure

The cost of upgrading the TEN-T Core Network Corridors to allow the operation of P400 profile trains can be estimated by multiplying the number of kilometres not allowing the operation of freight trains presenting a P400 profile (see Table 60 in Task 3.6) by the unit cost per kilometre for the low, medium and high cost scenarios (see Table 61). However, in this section of the report only the Medium unit cost scenario is considered.

Table 62 shows the costs of upgrading the rail network to allow the operation of intermodal trains broken down by TEN-T corridor according to the Medium unit cost scenario.

Table 62: Total cost of upgrading each TEN-T Core Network Corridor to allow the operation of P400 profile trains

TEN-T Corridor	Corridor length to be upgraded [%]	Corridor length to be upgraded [km]	Upgrading Cost [M€]
Atlantic	98%	5 625	1 935
Baltic-Adriatic	10%	413	142
Mediterranean	71%	5 552	1 910
North Sea-Baltic	6%	291	100
North Sea-Mediterranean	73%	3 262	1 122
Orient/East-Med	19%	1 043	359
Rhine-Alpine	34%	1 110	382
Rhine-Danube	7%	360	124
Scandinavian-Mediterranean	27%	2 401	826

The Atlantic corridor rail network is the one currently requiring the highest upgrade investment cost to comply with the parameter “standard combined transport profile number for semi-trailers”; the Atlantic Corridor runs through Spain and France, countries with low compliance rates. It is closely followed by the Mediterranean Corridor, which runs from Spain to Hungary via northern Italy, and the North Sea - Mediterranean Corridor, which crosses Europe north to south from Belgium and the Netherlands to southern France.

Investment into new terminals

This second part of the analysis aims at identifying the investment costs associated with the construction of new intermodal terminals to make each technology fully operational in all TEN-T Core Network Corridors.

A mapping of intermodal terminals by type of transhipment technology in Europe is presented in Task 3.4. Specifically, Table 42 identifies the Corridors of the TEN-T Core Network where terminals with specific transhipment technologies handling certain types of loading units are available. The following considerations can be made from the results of this analysis:

- Vertical transhipment technology are currently present in all corridors. Therefore, these technologies are considered to be fully operational and the construction of new dedicated terminals equipped with such transhipment technology is considered not necessary for the network operation. The same consideration can be made for RoRo Ramp to/from Ship.
- It is currently not possible to map the exact location on TEN-T corridors of Sidelifter and BOXMover transhipment technologies. These technologies are mainly used as supporting equipment in intermodal terminals and not as the main technology for rail-road transhipment. Therefore, there is no need for dedicated terminals as these technologies can be easily integrated into existing intermodal terminals.
- Terminal equipped with Mobiler (Rail Cargo Austria) are not exactly located, though this technology appears to be available in the Baltic-Adriatic, Orient/East - Med and Rhine-Danube Corridors. Therefore, for the remaining Corridors the integration of this technology is required in existing intermodal terminals or in the construction of new terminals.

- Container Mover 3020, Cargo Beamer next generation and Modalohr UIC are currently only present in few Corridors. For the remaining Corridors, specific dedicated terminals are required to make the technology fully operational.
- Helrom technology was removed from our analysis and therefore the construction of dedicated terminals will not be explored further.
- The Flexiwaggon technology does not require dedicated terminals and can be easily integrated within the existing intermodal terminals network.
- Finally, the Nikrasa, ISU and r2l 2.0 technologies, although not currently present in all corridors, do not require the construction of new terminals, but can be integrated into existing intermodal terminals where vertical technologies such as gantry cranes and or reach stackers are in use.

In order to roughly estimate the minimum investment needed in new terminals, the following assumption were adopted:

- It was assumed that at least two terminals per corridor per each technology should be present. This requirement is the minimum condition to make each technology fully operational in all TEN-T Core Network Corridors. According to this requirement it is therefore foreseen that in corridors that are not yet equipped with a specific technology, as minimum two dedicated terminals are built at the beginning and at the end of the corridor.
- It was furthermore assumed that per each technology a terminal should be available every 850km of corridor.[73]

Based on these assumptions, Table 63 provides for the minimum number of terminals per technology that each TEN-T corridor should have. Overall, a minimum of 68 terminals per technology are required.

Table 63: Minimum number of terminals required per technology and per TEN-T corridor.

TEN-T Corridor	Length of the network [km]	Minimum number of terminals per technology
Atlantic	5 762	8
Baltic-Adriatic	4 212	6
Mediterranean	7 858	10
North Sea-Baltic	4 871	7
North Sea-Mediterranean	4 461	6
Orient/East-Med	5 636	8
Rhine-Alpine	3 258	5
Rhine-Danube	5 505	7
Scandinavian-Mediterranean	8 756	11
Total	**-**	**68**

[73] Under Task 1.2 two intermodal chain scenarios are proposed. The second scenario implies that a typical door-to-door intermodal chain is 1000 km long, which can be further split into one leg of 850km by train and two last mile legs by road of 75km each.

As regards the technologies to be implemented, the following four transhipment technologies are not available in each corridor and should therefore be provided by building new dedicated terminals:

- Mobiler;
- Container Mover 3020;
- Cargo Beamer;
- Modalohr UIC;

Overall terminals cost is composed of the construction of a new terminal including infrastructure and superstructure: to calculate it, the unit cost from sub-task 2.6, 2.7 and 2.8 are considered and multiplied with the number of new terminals. Table 64 identifies the number of new terminals required per each corridor and transhipment technologies and the associated unit investment cost per terminal type.

Table 64: Investment costs into new terminals

Transhipment Technologies	Corridors to be improved	Number of new terminals	Building unit costs [M€]
Mobiler	Atlantic, North Sea-Med, Mediterranean, Rhine-Alpine, North Sea Baltic, Scan-Med	47	6
Container Mover 3020	Atlantic, Baltic-Adriatic, Mediterranean, North Sea-Med, Rhine-Danube, Scan-Med	49	6
Cargo Beamer	Atlantic, Orient East-Med, Rhine-Danube, Scan-Med	34	38
Modalohr UIC	Atlantic, Orient East-Med, Rhine-Alpine, Rhine-Danube, Scan-Med	39	19
Total		**169**	**-**

As per the results of the analysis above, 169 new terminals for a total investment cost of roughly 2 617 million of € is needed.

Summing up the construction costs of the new terminals with those of upgrading the entire TEN-T Core network corridors for the operation of P400 profile trains, leads to a total investment cost of almost 8 billion of €. This investment is necessary to upgrade the entire network of intermodal transport in Europe, in order to overcome the existing criticalities – in terms of P400 compliance – and allow the operation of all kind of LUs in circulation.

Table 65: Total investment costs for the upgrade of the network and building of new terminals

Costs	[M€]
Upgrading costs TEN-T core network corridors	5 118
New terminals building costs	2 617
Total	**7 735**

4.10 2030 potential terminal handling capacity in EU

Following the estimation previously carried out in Task 3.2 concerning the assessment of today's handling capacity for each loading unit and transhipment technology, the main purpose of Task 3.10 is to estimate the trend to the year 2030.

The analysis was developed around:

- a stakeholder's consultation with technological providers and terminal operators;
- analysis of the TEN-T CNC Project List 2021;

However, since during the consultation phase no useful information about expansion plans or construction of new terminals has been collected, the implementation of this Task largely relies on the analysis of the projects included in the TEN-T CNC Project List 2021.

Analysis of the number of projects included in the 2021 TEN-T CNC Project List

The TEN-T CNC Project List 2021 includes 837 projects classified as "multimodal" or "maritime". Among these 108 are specifically related to the upgrade, expansion, or the construction of new terminals.

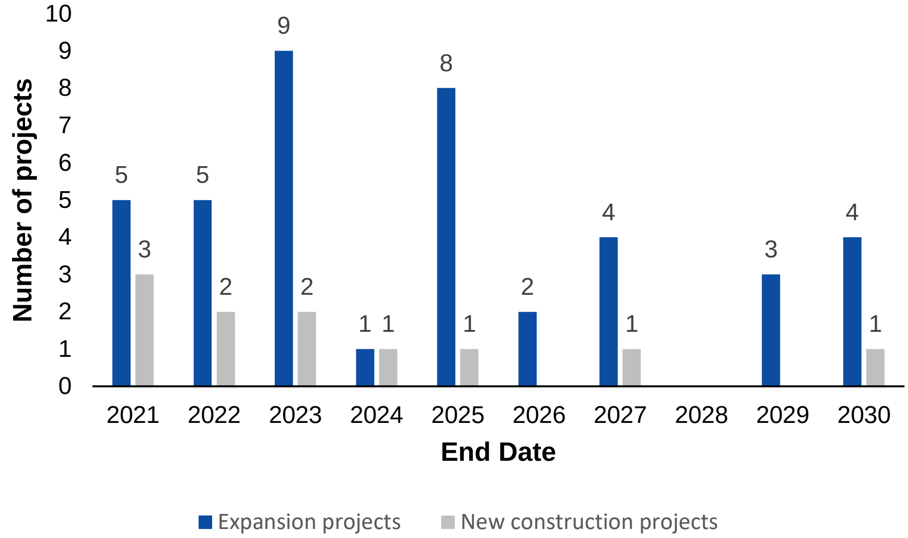
Among the 108 selected projects, 23 projects concern the construction of new terminals[74].

85 further projects concern expansion or upgrade works of existing terminals. Some of these refer to the same terminal but are divided into several phases of work. These projects were grouped and counted only once. As a result, expansion or upgrade works are currently planned for 64 terminals in total.

For the remaining 87 projects focusing on the construction of new terminals (23 projects) or on the expansion of capacity (64 projects), the "end date" parameter was analysed to understand if the capacity increase is expected before or after 2030. It was found that: 52 projects are planned for completion in the target period; 25 projects have already been completed, as their end date is before the year 2021; 4 projects have a completion date after 2030; finally, 6 projects do not provide for this information. Figure 32 below shows the distribution of the 52 projects by year of completion.

[74] In particular the construction of the following terminals is planned: 1 in Austria (Wien), 3 in Bulgaria (Plovdiv, Vidin, and Ruse), 1 in Denmark (Copenhagen Malmö Port), 1 in Czechia (Ostrava), 1 in France (Marseille), 3 in Germany (Hannover, Duisburg and Lübeck), 1 in Greece (Thriasio), 3 in Spain (Antequera, León and Terragona), 1 in Hungary (Budapest), 1 in Italy (Verona), 1 in Poland (Port of Świnoujście), 2 in Portugal (Port of Lisboa and Port of Sines), 2 in Romania (Timisoara and Craiova), 1 in Sweden (Göteborg) and 1 in Slovakia (Zilina).

Figure 32: Temporal distribution of the projects selected for the report



Looking at the time distribution of projects, it is clear that most projects are planned to be completed in the first five years (37 projects in total of which 28 expansion projects and 9 new construction projects, or 71% of the total), while only 15 projects (13 expansion projects and 2 new construction projects, or 29% of the total) have a completion date between 2026 and 2030. Therefore, it is reasonable to expect that over the next years other terminal projects with planned completion date on the period 2026-2030 will be developed and added to the TEN-T CNC Project List. Specifically, for the purpose of this exercise it is assumed that the number of projects planned for completion in the time period 2026-2030 will be increased from 15 projects to 37. Hence, over the entire period 2021-2030, it is expected that 56 terminals on the TEN-T core network corridors will undergo capacity upgrading or expansion works and 18 new terminals will be built.

As reported in Task 3.4 there are 249 intermodal terminals (RRTs + maritime terminals) the TEN-T core network corridors. Based on our analysis and assumptions, by 2030, 56 intermodal terminals out of 249 (22%) will increase their capacity. In addition, 18 new terminals will be built resulting on 7% increase on the overall number of terminals.

Analysis of the capacity increases resulting from projects included in the 2021 TEN-T CNC Project List

Unfortunately, several of the identified projects are poorly described and lack information on actual and planned capacity. This is the case for all of the 23 projects concerning the building of new terminals. The same applies to for 54 out of 64 projects concerning terminal upgrading or expansion in terms of capacity. However, for 10 terminal projects information on capacity increase is available (see Table 3 in Annex 3).

By analysing the 10 projects, the following estimates of capacity growth can be derived.

Table 66: Capacity growth trend analysis

Project name	Actual handling capacity [TEU/year]	Future capacity [TEU/year]	Start year	End year	Cost [m€]	Capacity Δ%
Terminal Graz Süd Expansion	230 000	500 000	2018	2026	72.44	117%
Trimodal Port of Linz - Rail connection and port enhancement	-	450 000	2017	2023	122.9	-
Investing in the upgrade of the RSC terminal Rotterdam servicing combined transport operations across Europe	350 000	400 000	2018	2022	8.8	14%
Extension of the combined transport terminal Clésud Miramas.	50 00	75 000	2019	2023	10.5	50%
Shunting locomotives purchase for the intermodal terminals in Kutno, Brzeg Dolny and Gliwice	-	-	2019	2021	2.59	5%
Upgrade Cargo Center Wien South - Phase 2	210 000	315 000	2022	2023	19.6	50%
Increase the efficiency of current Alcantara container terminal	576 641	662 347	2021	2038	122	15%
Enlargement of the container terminal at quay VII increasing the potential up to a maximum of 1 200 000 TEU (dimension 200m, 18m depth)	-	1 200 000	2019	2021	187	-
Container berth upgrade in the Port of Dunkerque	600 000	900 000	2016	2018	65	50%
Expansion of Deepwater Container Ter-minal DCT Gdansk - Construction of T2 Terminal	-	2 500 000	Unknown	Unknown	157.81	-

As it can be seen in Table 66, the capacity growths for the 10 selected projects are very different from each other and for some of them the current handling capacity is not available. However, by considering the 6 projects for which complete information is available, it is observed that the growth in terminal handling capacity ranges between a maximum value of 117% and a minimum of 14%, with an average value of 49%.

Estimation of terminal handling capacity in 2030

As described earlier it is expected that by year 2030, 22% of the intermodal terminals in the TEN-T core corridors network will undergo capacity related works. Assuming that each of these terminals will benefit from an average capacity increase of 49% it is expected that the total handling capacity of existing terminals in the TEN-T core network corridors will experience an overall capacity increase of 11% by 2030. Similarly, it can be assumed that roughly 22% of all existing EU terminals will be upgraded or expanded in terms of capacity allowing for an overall handling capacity increase of 11% by 2030.

In addition, it is assumed that 18 new terminals will be built in the TEN-T core network corridors. Handling capacity of new terminals is unknown, but, for the purpose of this exercise, it is assumed that it will be equivalent to the average capacity of existing terminals. Therefore, it can be estimated that the 249 terminals in the TEN-T core network corridors will increase by 18 units (+7%) and by 7% in terms of handling capacity. Similarly, it is assumed that the total handling capacity of all EU terminals will increase by 7% by 2030 thanks to the construction of new terminals.

Therefore, according to our analysis and assumptions it is estimated that based on current plans the overall EU terminal capacity will increase by 18% by 2030 for effect of both upgrade and expansion of existing terminals and construction of new terminals.

Today's terminal handling capacity, expressed in terms of LU/year, was previously calculated in Task 3.2. resulting in a total value for Europe and Switzerland of 261 267 000 LU/year. By applying the growth rate of 18% to 2030 an estimated potential terminal handling capacity of 308 295 060 LU/year is obtained.

However, for the same considerations outlined in Task 3.2[75], this figure is likely to overestimate the 2030 terminal handling. Therefore, this estimate does not provide a solid basis for further analysis.

4.11 2030 network capacity in comparison to terminal handling capacity

The objective of Task 3.11 is to compare the TEN-T core network corridors capacity per loading unit and transhipment technology per mode in 2030 with the terminal handling capacity for each loading unit and transhipment technology in 2030. This comparison aims at identifying those loading units and transhipment technologies for which the network and terminal capacity are expected to be balanced and those for which either the network or the terminal handling capacity would need to be adjusted in order to better match the other.

To accomplish this goal, this document makes use of findings from previous Tasks: potential terminal handling capacity in 2030 was investigated in Task 3.10, while Task 3.8 assessed the TEN-T core network corridors capacity and related capacity problems; in addition, Tasks 3.5 and 3.9 identified the necessary network upgrades to P400 and the construction of new terminals with the necessary investment costs.

However, due to the limited information gathered from the infrastructure managers and the scarce availability of corridor studies exploring the subject in depth, for both the previous tasks (Task 3.8 and 3.10) it was not possible to break down this estimate by loading unit

[75] As explained in Task 3.2, the calculation estimate of current terminal handling capacity was made on the basis of the information reported in the (RFP) Rail Facilities Portal, which only provides information on the number of gantry or mobile cranes as the most used transhipment technologies, and the terminal's opening time. In addition, the necessary information on the type and number of cranes and opening times is available for only 498 intermodal terminals (~ 55%) of the 898 intermodal terminals. Therefore, this information made it possible only to roughly calculate the annual handling capacity, but did not provide a solid basis for further analysis.

and transhipment technologies. For this reason, the main outputs of Tasks 3.8 and 3.10 were considered to set up a general comparison of the estimates to 2030.

The following considerations can be made:

- as regard TEN-T core network corridors capacity, based on Task 3.8 analysis of the main capacity bottlenecks currently existing in the TEN-T corridors, it is expected that the EU core transport network will not reach full capacity by 2030.
- with regards to potential terminal handling capacity in 2030, according to the analysis carried out in Task 3.10, the general growth trend is estimated equal to +18% by 2030. This capacity increase is driven by the construction of new terminals as well as the expansion of existing terminals.

Based on the outcomes reported above it is not possible to make a proper comparison between the expected TEN-T core network corridors capacity and the terminal handling capacity in 2030. However, in this context, it should also be considered that the Sustainable and Smart Mobility Strategy[76] by the European Commission set as the target that the rail freight traffic should increase by 50% by 2030. If this target will be met, the expected growth in terminal handling capacity by 18% by 2030 would not be sufficient.

5. Comparative analysis of different transhipment technologies

Based on the results of tasks 1 – 3 which looked at the transhipment technologies separately, this task provides the comparative analysis of the previously assessed transhipment technology and loading unit combinations for different modes of transport.

Overall, 25 distinct technology and loading unit combinations used in either rail, IWW or SSS and road intermodal transport were described and analysed in the previous tasks. Of these combinations six are used for all modes of transport, two more are used in rail-road as well as IWW-road intermodal transport, three are used exclusively for SSS-road intermodal transport and 14 are used exclusively in rail-road intermodal transport. This results in a total of 39 different technology, loading unit and mode of transport combinations to be analysed and compared in this task (22 for rail-road, eight for IWW-road and nine for SSS-road).

Table 67: Technology, loading unit and mode combination matrix

	Transhipment Technology	Mode of transport road and …			
		… Rail	… IWW	… SSS	
1	Gantry Crane	Ct 20’, Ct 40’, ST	Ct 20’, Ct 40’	Ct 20’, Ct 40’	
2	Reach Stacker	Ct 20’, Ct 40’, ST	Ct 20’, Ct 40’		
3	Hydraulic Material Handling Crane	Ct 20’, Ct 40’	Ct 20’, Ct 40’	Ct 20’, Ct 40’	
4	Mobile Harbour Crane	Ct 20’, Ct 40’	Ct 20’, Ct 40’	Ct 20’, Ct 40’	
5	RoRo Ramp to/from Ship			ST, Rolltrailer, Cassettes	
6	Sidelifter	Ct 40’			
7	BOXMover	Ct 40’			

[76] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM/2020/789 final

	Transhipment Technology	Mode of transport road and …			
		… Rail	… IWW	… SSS	
8	Mobiler (Rail Cargo Austria)	Ct 30’			
9	Container Mover 3020	Ct 20’, Ct 40’			
10	Cargo Beamer next generation	ST non-craneable			
11	Modalohr UIC	ST non-craneable			
12	Nikrasa	ST non-craneable			
13	ISU	ST non-craneable			
14	RoLa Ramp	ST & Truck			
15	Flexiwaggon	ST & Truck			
16	r2l 2.0 road rail link	ST non-craneable			
	Number of Analysis	22	8	9	
		39			

Source: KombiConsult analysis;

The comparative evaluation in all subtasks of task 4 is based on the previously described model assumptions. Changing one or more of the underlying assumptions (e.g., loaded goods weight, weight per loading unit, transport distance, share of road distance, …) could significantly change the results of the comparison of the technology and loading unit combinations. This is especially important when considering a shipper’s perspective, who must consider a bunch of different factors in their choices which are highly unlikely to be fully consistent with the assumptions made here.

5.1 Total system costs

Task 4.1 aims to establish the total system costs for a typical 600 km and 1 000 km door-to-door intermodal transport chain for the transport of one loading unit carrying 20t (or less if technology restrictions apply), including main regional differences, if any. The total system costs per transhipment technology and loading unit combination in our model transport chain of 600 km and 1 000 km distance have already been established as comparative costs in the individual fact sheet. Included in the costs shown in the fact sheets are costs for the two road legs of 75 km each, the costs for the main leg of 450 km or 850 km distance, the costs for two transhipments, the loading unit costs as well as the intermodal organizational costs. Depending on the circumstances other cost factors not included in our analysis might be relevant in practice. These cost elements were chosen in order to enable the specific comparison between different transhipment technology and loading unit combinations as well as between different intermodal modes of transport for a 600 km and 1 000 km door-to-door transport.

To allow a more realistic and feasible comparison with road-only transport and to comply with information of previous study results for task 4, we have now adjusted the road leg transport costs for the different intermodal transport chains in agreement with DG MOVE.

Rather than calculating the road transport costs between the shipper and the terminal based on the individual material and operational costs we have now applied a lump sum for the road leg transport that in addition to the driving time also takes into account the loading or unloading of the loading unit at the “door”. It is assumed that this lump sum varies depending on the type of loading unit as these vary in the equipment and processes required. For containers the lump sum is assumed to be 175 € and for semi-trailers it is assumed to be 150 € per road leg. For the technologies used in accompanied intermodal transport the previous detailed calculation based on material and operational costs will still be applied, however an additional hour for the time spent at the shipper will be considered for the time-based cost elements. This approach is the same as for the road-only alternative because the road legs in accompanied intermodal transport should not differ from road-only transport. Consequently, the road-only transport is also calculated using the assumptions already described for the technology fact sheet elements and an additional hour each for the loading and unloading at each end of the transport chain. These additional times will only be used for the cost comparison. The comparison of the total transport duration will not include these processes at the shippers but only the driving and terminal times for the road legs.

In the fact sheets both, the costs for the transport of all LUs on the assumed train, barge or ship as well as the costs per loading unit are provided. From here on we will conduct the further analysis on the loading unit cost basis only.

The comparative costs per LU will also be compared to the costs of road-only transport, the total costs of which have been determined based on the same costs and assumptions used for determining the road leg costs which are described in chapter 3.2.3. As the road-only vehicle and LU a truck and semi-trailer combination was chosen for the comparison with all technology and loading unit combinations. For the 600km road-only transport the comparative costs were calculated to be 636 € per LU. For the 1 000 km road-only transport the comparative costs were calculated to be 1.021 € per LU. Full capacity utilization was assumed for road-only transport due to the assumed truck carrying only one LU.

The comparative costs for the 600 km transport chain for all technology and LU combinations as well as road-only transport are shown in Figure 33 and the comparative costs for the 1 000 km transport chain for all technology and LU combinations as well as road-only transport are shown in Figure 34. The blue (600 km) and orange (1 000 km) columns show the comparative costs calculated for the full transport chain for each technology and loading unit combination. The horizontal grey (600 km) or yellow (1 000 km) line shows the constant costs for road-only transport over the same distance.

Figure 33: Total system ~~costs for the 600 km model transport chain per LU~~

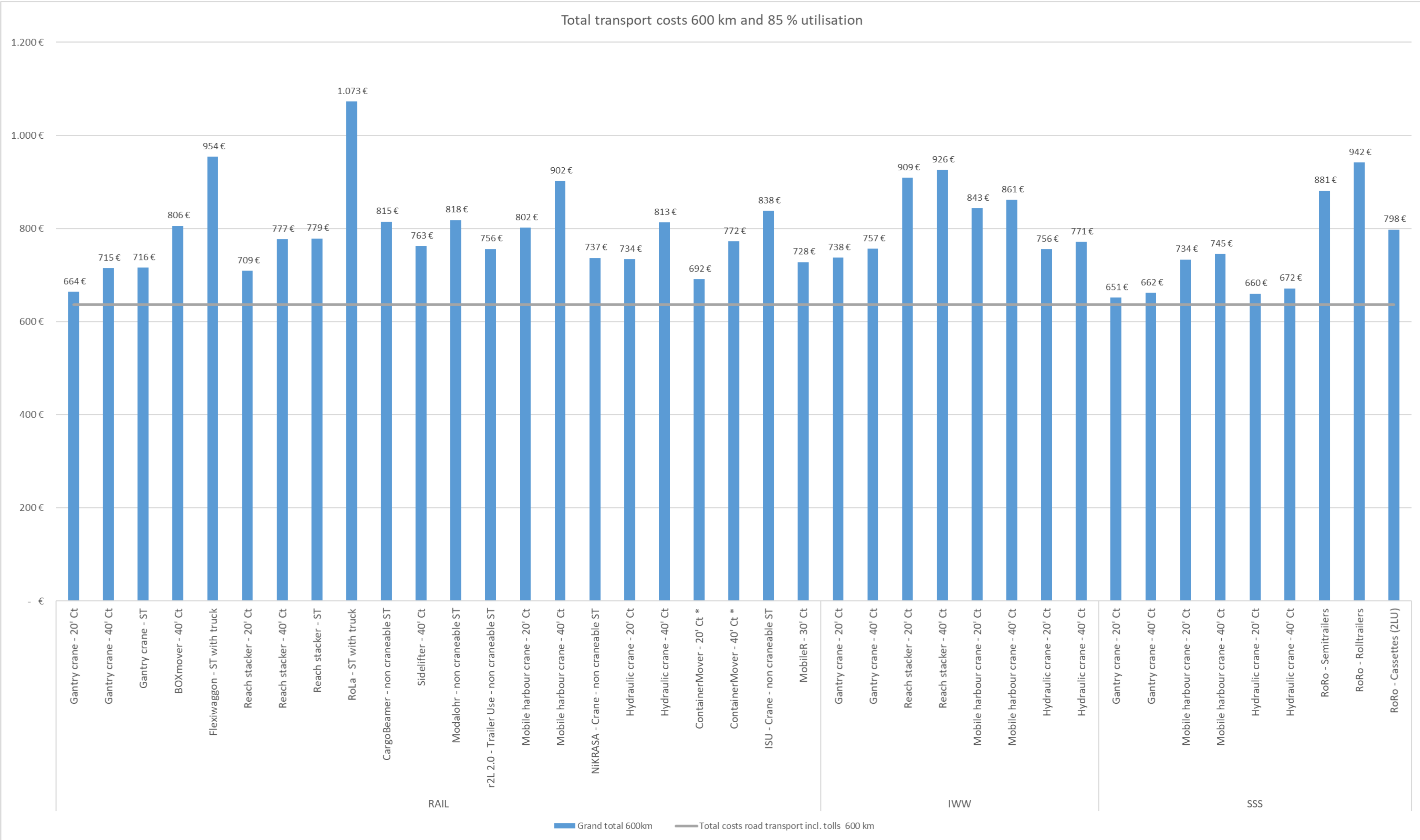
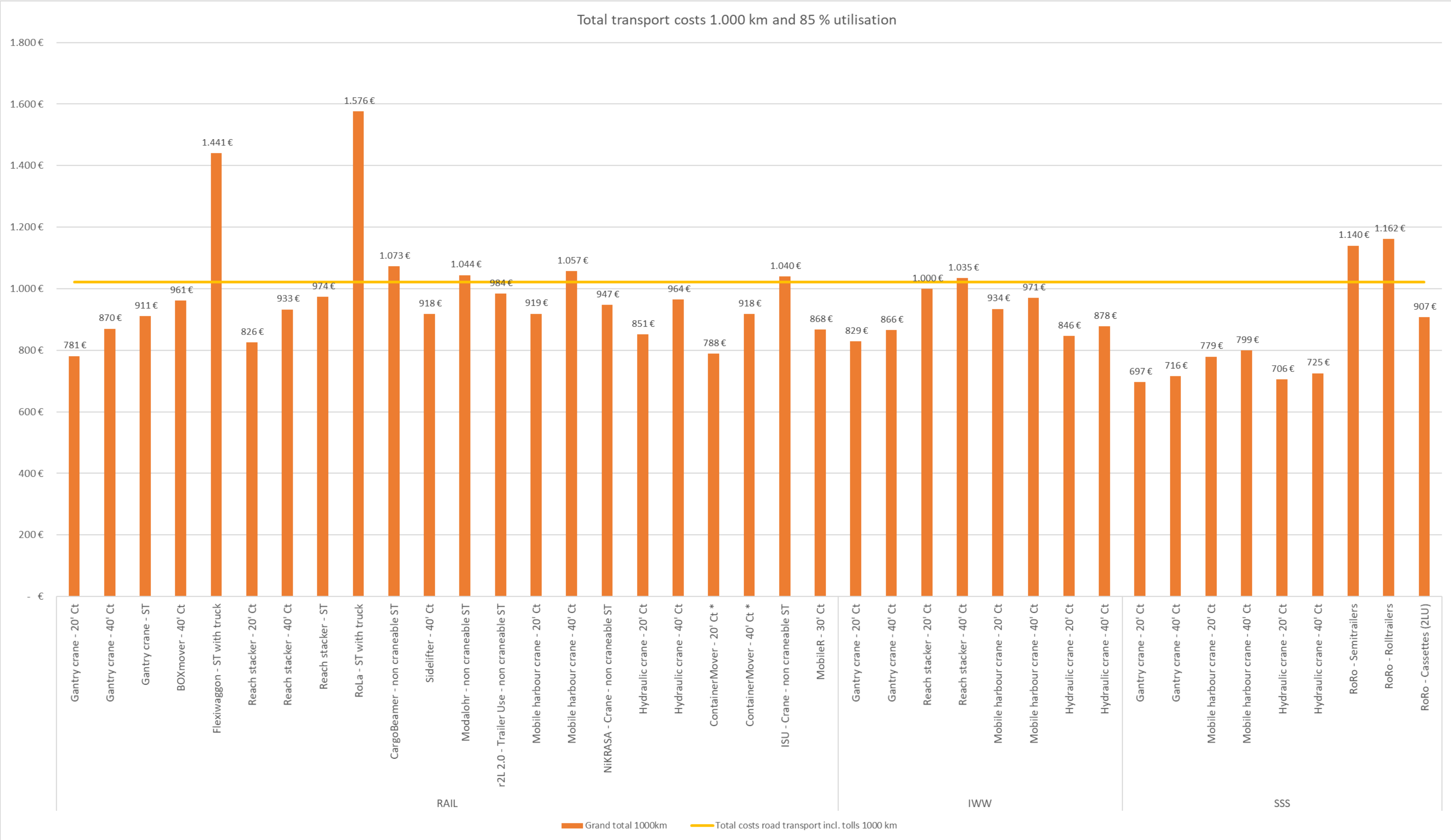


Figure 34: Total system costs for the 1 000 km model transport chain per LU



We will first analyse the 600 km transport distance in more detail. As can be seen in Figure 33 for the 600 km transport chain, all the intermodal transport chains have higher comparative costs than the road-only variant assumed for this study.

One fact that immediately becomes noticeable is that the two technologies for accompanied intermodal transport are also the two technologies with the highest comparative costs. One explanation for this a comparatively low transport efficiency. Because the loading unit consists of the semitrailer as well as the truck, additional dead weight from the trucks own weight as well from the rail wagons for providing additional loading length for the truck and the club car for the truck drivers is being transported on the main leg. Both technologies have the lowest share of loading units as well as loaded goods compared to the total train weight. Furthermore, the full vehicle loading unit, because of the included truck, has the highest cost per hour of all loading unit types which further increases the comparative system costs. The same arguments can be made for the SSS RoRo technologies which also show relatively high prices, especially compared to SSS vertical transhipment technologies.

One other fact about the loading units is also apparent. As can be seen, the smaller and less complex a loading unit is, the lower the comparative costs of the transport chain are likely to be. This is especially apparent for technologies used to tranship different types of loading units like the gantry crane or the reach stacker. In all these cases the comparative costs for the 20’ container are lower than for the 40’ container which in turn has lower cost than the semi-trailer. The highest comparative costs can then, as have previously been discussed, be observed for technologies transhipping full vehicles. This observed cost curve for the different transhipment and loading unit combinations is a direct consequence of the assumption of equal payload weights for each of the different loading unit types. Not only are the smaller and less complex loading units cheaper in their own investments and maintenance than the larger and more complex ones, but also more of them can be loaded on the train, barge or ship. This has a big impact on the comparative costs per loading unit, as the available capacity is more efficiently utilized and the fixed transport costs are distributed over more loading units.

If instead of the loaded goods weight the loaded goods volume were the determining factor in allocating the goods to loading units, the order of comparative costs per loading unit would be different. For example, a 40’ container has twice the volume of a 20’ container. For low density goods where weight is not an issue throughout the transport chain, instead of one 40’ container two 20’ containers might be necessary to transport the same volume of goods. Not only would this lead to an increase in loading unit costs, but also the number of required loading unit handlings and associated costs would double. Furthermore, depending on the main leg characteristics, it might not be possible to transport double the amount of 20’ containers than 40’ containers on the same train, barge or ship, thereby necessitating more main leg trips and further increasing transport costs. All these effects would cause the total transport costs of the same amount of goods to be higher for smaller loading units than for larger loading units which is in clear contrast to the observations made in our model. It is therefore important to note that the choice of the most efficient, cheapest or otherwise best suited type of loading unit for a specific transport depends strongly on the characteristics of the transported goods (and other external factors), the variety of which was impossible to include for this model analysis. Thus, we did not reply to the question which loading unit technology combination is the best to transport 20 tons of cargo, but demonstrated the cost differences for different type of loading unit technology combination.

In this context it is important to note, that the weight per loading unit is lower for the ContainerMover (20’: 13.3 t; 40’: 11.7 t) and the hydraulic crane (20’: 19.8 t; 40’:18.2 t) due to the lower maximum transhipable weight for these technologies. Because of the lower load weight, and the weight having been the limiting factor to capacity without reaching full train length, more loading units can be transported on the main leg and the main leg costs are accordingly distributed over more loading units, effectively lowering the comparative transport costs per loading unit. When not using number of loading units but the loaded goods weight as the basis for comparison more loading units are consequently necessary to transport the same loaded goods weight as with other technologies which would thereby increase costs as explained above.

When comparing the three different main leg modes of transport based on the six technology and LU combinations which are used for all modes, for each combination SSS sits at first place offering the lowest comparative costs. For 20’ containers and the gantry crane with 40’ containers rail comes second and IWW third and for the mobile harbour crane and the hydraulic crane with 40’ containers IWW is second and rail third when comparing the costs per LU. SSS having the lowest comparative costs per LU of the modes of transport for the vertical transhipment technologies used on all modes can easily be explained, because the ship offers a larger LU capacity than the train or barge, thereby allowing for greater transport efficiency on the main leg.

The higher load capacity of a barge compared to a train also has an impact on the comparison between rail and IWW, however this impact is smaller, especially for the 20’ container, because the gap in the load capacity in number of loading units is smaller than in comparison with the ship. In our model environment the barge offers less than double the LU-capacity compared to the train for 20’ containers, due to weight limitations, which is one explanation why the train has lower comparative costs in this instance. For 40’ containers however, the barge capacity is more than double the train capacity and we can see the costs gap getting smaller when observing the gantry crane for both modes of transport and 40’ containers compared to the 20’ containers.

For the mobile harbour and hydraulic crane another effect also becomes noticeable when comparing the costs differences for 20’ and 40’ containers on different modes for these technologies. Although they have higher comparative costs for transhipping 20’ container in IWW transport compared to rail transport, their comparative costs for 40’ containers in IWW transport compared to 40’ containers in rail transport are lower. They have a limited reach (~60 m radius) and must be relocated more often during the loading/unloading of a long train (length ~500 m) than during the loading/unloading of a compact barge (length ~100 m). Within one relocation cycle they can tranship less 40’ containers than 20’ containers, due to the larger loading length of the 40’ container compared to the 20’ container. Relocation therefore has a larger per unit impact on the total transhipment times and costs for longer LUs. Because of this noticeable effect these two technologies show lower comparative costs per loading unit for transhipping 40’ containers to IWW compared to rail.

For the 600 km and the 1 000 km intermodal transport chain the road legs and transhipments are the same and the difference is only in the main leg distance and duration.

When now looking at the comparative costs for the 1 000 km transport chain in Figure 34 some technology and loading unit combinations fall below the comparative costs of road-only transport. Only nine entries show higher comparative costs than the road-only transport alternative compared to all technology and loading unit combinations for the 600 km transport chain. These nine technologies and loading unit combinations already showed high comparative costs for the 600 km transport chain.

Almost all technologies could lower the difference in comparative costs from the intermodal to the road-only transport when increasing the transport distance from 600 km to 1 000 km. Only for the technologies used in accompanied intermodal transport the difference in comparative costs between intermodal and road-only transport increases.

Because the difference between the transport distances only impacts the main leg duration and costs, it can be concluded, that in our model these technologies would profit from shorter main leg distances as every main leg kilometre has slightly higher comparative costs than a kilometre in road transport. When comparing our model assumptions to the use cases of accompanied intermodal transport in Europe, the actual distances are often times lower than in our model (e.g. Wörgl – Brennersee 96 km; the Freiburg – Novara route being an exception with close to 450 km transport distance). Furthermore, accompanied intermodal transport is mainly deployed on routes on which natural or artificial obstacles and/or organizational restrictions impair or prevent road-only transport. Examples are transports between England and mainland Europe or across the Alps through Austria or Switzerland. In conclusion, it can be noted that our model assumptions set unfavourable framework conditions for accompanied intermodal transport and that these differ greatly from the real operational areas and conditions of the respective technologies.

In line with the observations on the loading unit types for the 600 km transport chain, it can be observed that smaller and less complex loading units benefit more from the increase in the main leg distance than larger and more complex loading units. The reasons for this have already been described in detail and again are due to the better capacity utilization on the main leg means of transport of smaller loading units given our assumption of equal payload weight, where technically possible, for each loading unit type.

For Figure 35 the transhipment cost ranges determined for the different technology and loading unit were incorporated into the comparative costs for the 600 km transport chain. The blue block shows the upper and the lower bound of the cost range for each technology and loading unit combination with the horizontal black line showing the comparative road-only costs. The figure shows, that in five cases the comparative costs for road-only transport fall into the comparative cost range of the technology and loading unit combination. In these cases, regional differences can therefore have a decisive influence on the financial decision for or against the specified technology and loading unit combination when compared to road-only transport.

In all other cases the costs range is entirely above the comparative road-only costs.

The comparative costs including the transhipment cost range for the 1 000 km intermodal transport chain is shown in Figure 36. Here the orange blocks provide the information about the upper and the lower bound of the cost range per technology and loading unit combination. Again, the black line shows the comparative costs for the road-only alternative. With the increase in transport distance, only seven technologies can be observed for which the road-only alternative falls within the comparative cost range.

Five technologies, the two technologies analysed for accompanied intermodal transport, the CargoBeamer as well as the SSS RoRo transport of semitrailers and of containers on cassettes are located above the road-only comparative costs with their full comparative cost range. The remaining 28 of the 39 analysed technology and loading unit combinations have their full comparative cost range fall below the road-only comparative costs.

Figure 35: Cost range for the 600 km model transport chain per LU based on transhipment cost range

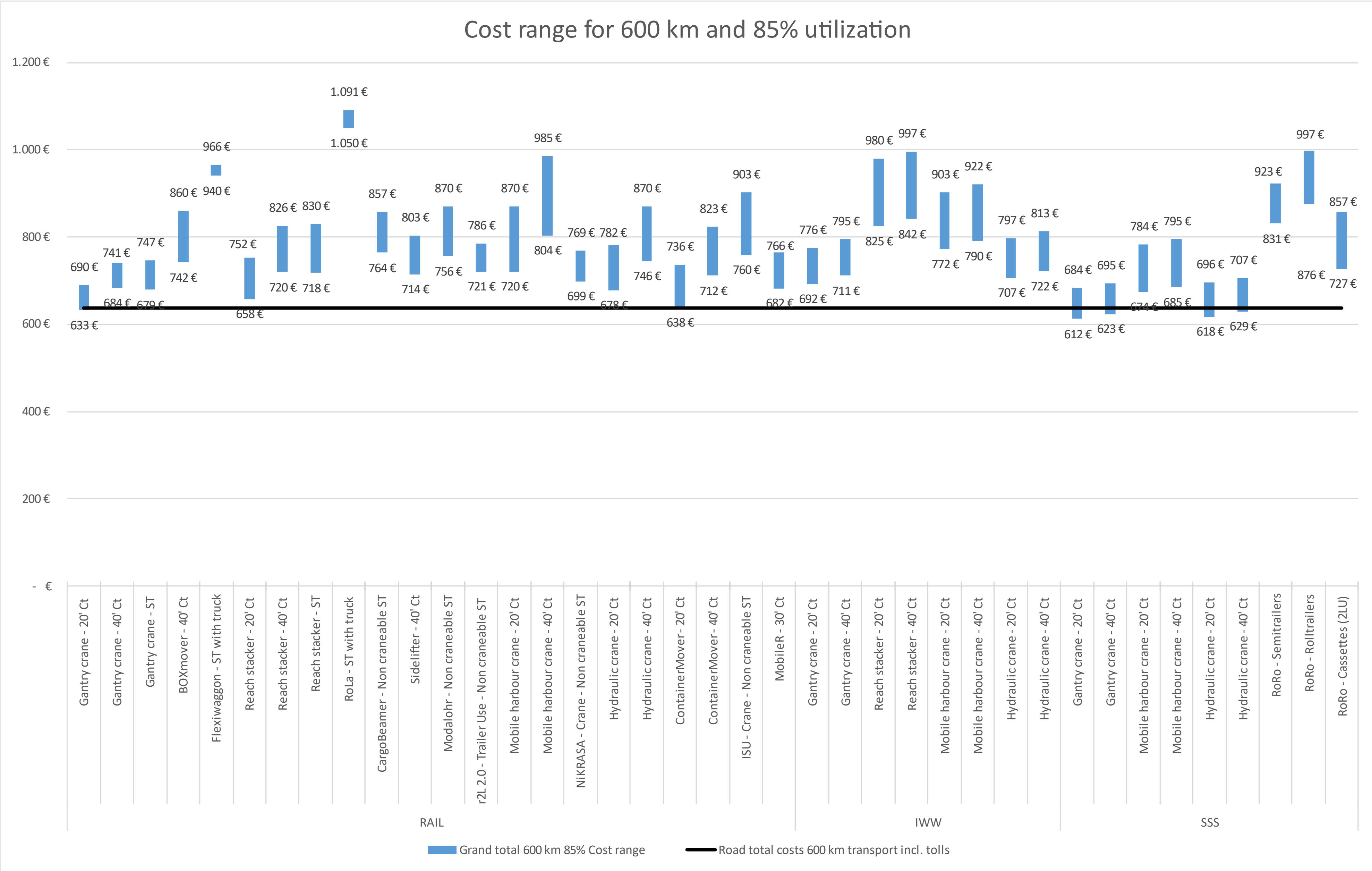
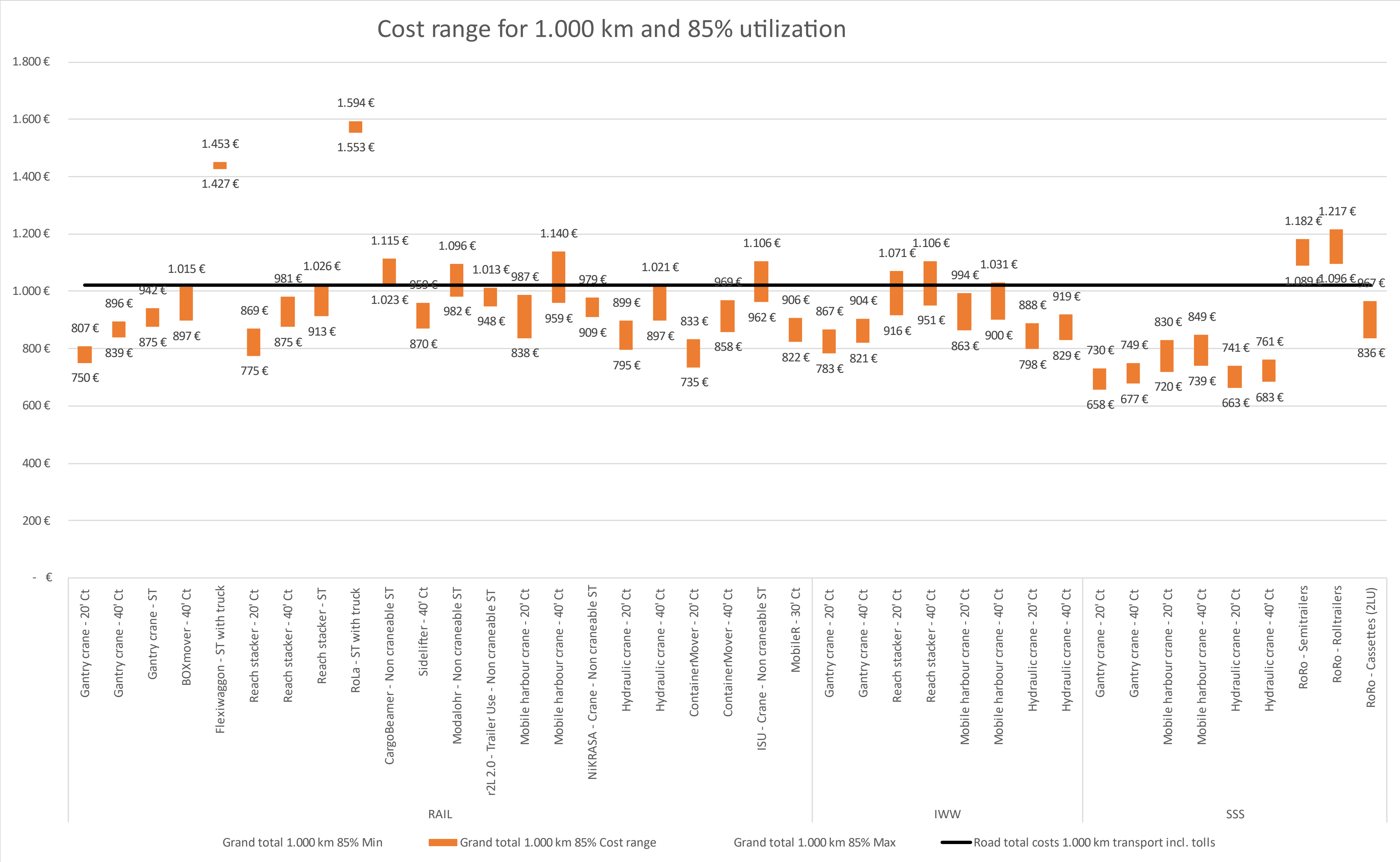


Figure 36: Cost range for the 1 000 km model transport chain per LU based on transhipment cost range



5.2 Competitiveness for shippers/clients for a typical 600 km/1 000 km door-to-door operation

In this task today's competitiveness of the technology and loading unit combinations for shippers/clients for a typical 600 km/1 000 km door-to-door operation was evaluated by means of a weighted scoring model. The weighted scoring model was chosen as different quantitative but also qualitative criteria with different degrees of influence are used when evaluating the competitiveness of each technology and loading unit combination. For this goal the weighted scoring model has advantages, as it makes it possible to compare different types of influencing criteria based on a points system. Furthermore, the influencing criteria are assigned different weights, between 0 % and 100 %, which enables the inclusion of varying degrees of influence in the evaluation.

In the weighted scoring model used for this task, each technology and loading unit combination as well as the road-only alternative will be scored for each criterion in whole numbers from 1 to 25, with 25 being the best possible score. The scored points per criteria will then be multiplied by the weight of the criteria and summed up in order calculate the total competitiveness score for the technology and loading unit combination. Although the scoring values will be whole numbers, the results might not be and will be shown with two decimals. The weights for all criteria together sum up to 100%, therefore the total score for each technology and loading unit combination will also be between 1 and 25 points with 25 being the best possible score.

Although the weighted scoring model aims to establish some degree of objectivity in its results, it is also important to be aware of the subjectivity that feeds into the model and the evaluation at various points. This applies to the definition of the criteria, the weighting of the criteria and the scoring of points for the qualitative criteria.

The selected criteria - cost, delivery time, availability and network coverage - were pre-selected by DG MOVE for evaluating the competitiveness and the choice is therefore not influenced by the authors' personal biases.

The allocation of the weight per criterion followed three principles which were decided upon beforehand to reduce potential subjective influences. These were, that no single criterion should have majority over the others, all criteria should have at least 10% weight and the less sound and objective the basis for the scoring of the criterion is, the less weight should be allocated to it. Based on these principles the weights were allocated as follows:

- Cost: 45%
  This criterion assesses the costs for the transport of one loading unit in our model transport chains. In our experience cost is amongst, if not the most important criterion in logistics and is therefore allocated the highest weight of 45%. Furthermore, the comparative costs per technology and loading unit combination were established in detailed research and based on standardized guidelines and are therefore highly objective.
- Delivery time: 25%
  This criterion assesses the delivery time for one loading unit in our model transport chains. Although delivery time is not as influential as costs in most cases, it can be very important and we therefore decided to place it behind cost with the second highest weight of 25%. As for cost, the transport duration for each technology and loading unit combination was previously established in detail based on standardized guidelines and is therefore an objective criterion.
- Availability: 15%
  This criterion assesses the availability of terminals for a specific technology and loading unit combination in the EU and Switzerland. The decision on how the

allocate weight to the availability criterion was quite difficult. Availability, or better unavailability, of an option can be argued to be the most decisive criterion. Whether a technology and loading unit combination is available or not for an upcoming transport on both ends of the operation decides whether it is included in the further decision-making process at all. However, once availability has been confirmed this criterion might have no further direct impact on the choice between multiple available technology and loading unit combinations. The fact that we award points for this criterion based on the available terminals per technology and loading unit combination was ultimately decisive for the weighting of availability with only 15%, because this basis is less sound than for the previous criteria. For some technologies and loading unit combinations the number of terminals or a range thereof could only be estimated due to an insufficient data basis and it was also not possible to reliably allocate the terminals for technologies used on different modes of transport to these modes. We therefore had to rely on our own expertise and judgement when scoring this criterion for the different technology and loading unit combinations.

- Network coverage: 15%
  This criterion assesses the current network coverage (for the TEN-T core network corridors) of the technology and loading unit combinations. This criterion is likely to have a strong correlation with the availability criterion, because the more terminals for a specific technology and loading unit combination there are, the more likely it is for the terminals to cover a larger part of the TEN-T core network corridors. Furthermore, the same issues regarding the objectivity of the scoring described for availability apply to network coverage as well. It is therefore allocated the same weight of 15 %.

Because costs and delivery time have a high degree of objectivity, a sub score will be shown for these two criteria. The same will be done for the availability and the network coverage criteria before calculating the total score.

The scoring for the cost criterion was done based on the comparative costs already assessed in detail for task 4.1. From the calculated comparative costs for all technology and loading unit combinations for the 600 km distance first the highest and the lowest values were determined. Then the difference between these two values was divided by 25, to determine 25 cost intervals, one for each scoring value. The same was done for the 1 000 km transport distance. The resulting min. and max. costs and the resulting interval-width are shown in Table 68. By basing the comparative cost score on mathematically determined intervals a high degree of objectivity is achieved.

Table 68: Comparative costs scoring intervals

Basis for cost intervals					
		Min.	**Max.**	**∆**	**Interval width**
Transport distance	**600 km**	636 €	1 073 €	436 €	17 €
	1 000 km	697 €	1.576 €	879 €	35 €

For the scoring of the second criterion, delivery time, we will use the values determined for the total duration of the 600 km and the 1 000 km transport chains of the individual technology and loading unit combinations. An overview of the total duration of the 600 km transport chains is provided in Figure 37 and of the 1 000 km transport chains in Figure 38.

Figure 37: Total duration of the 600 km transport chain

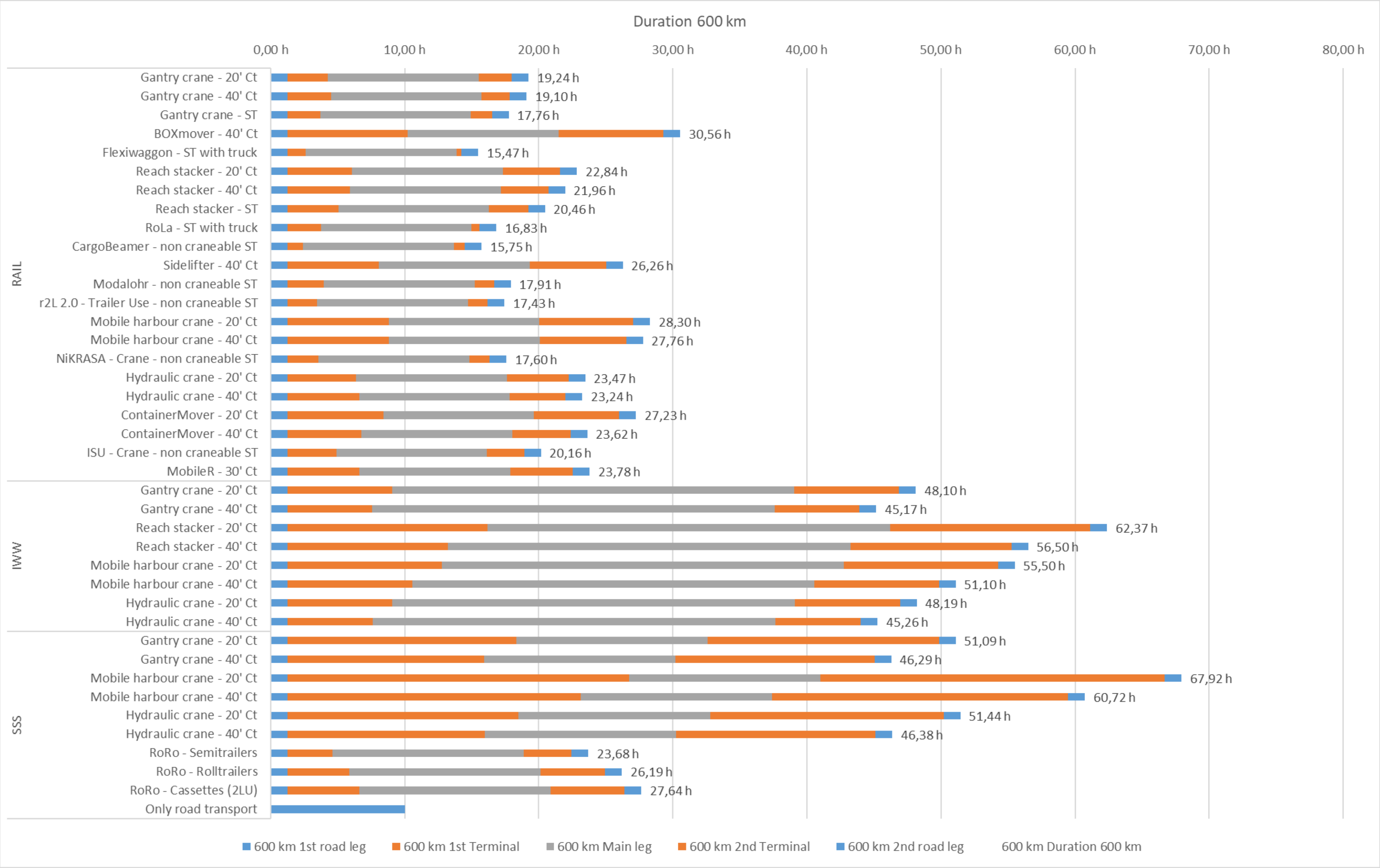
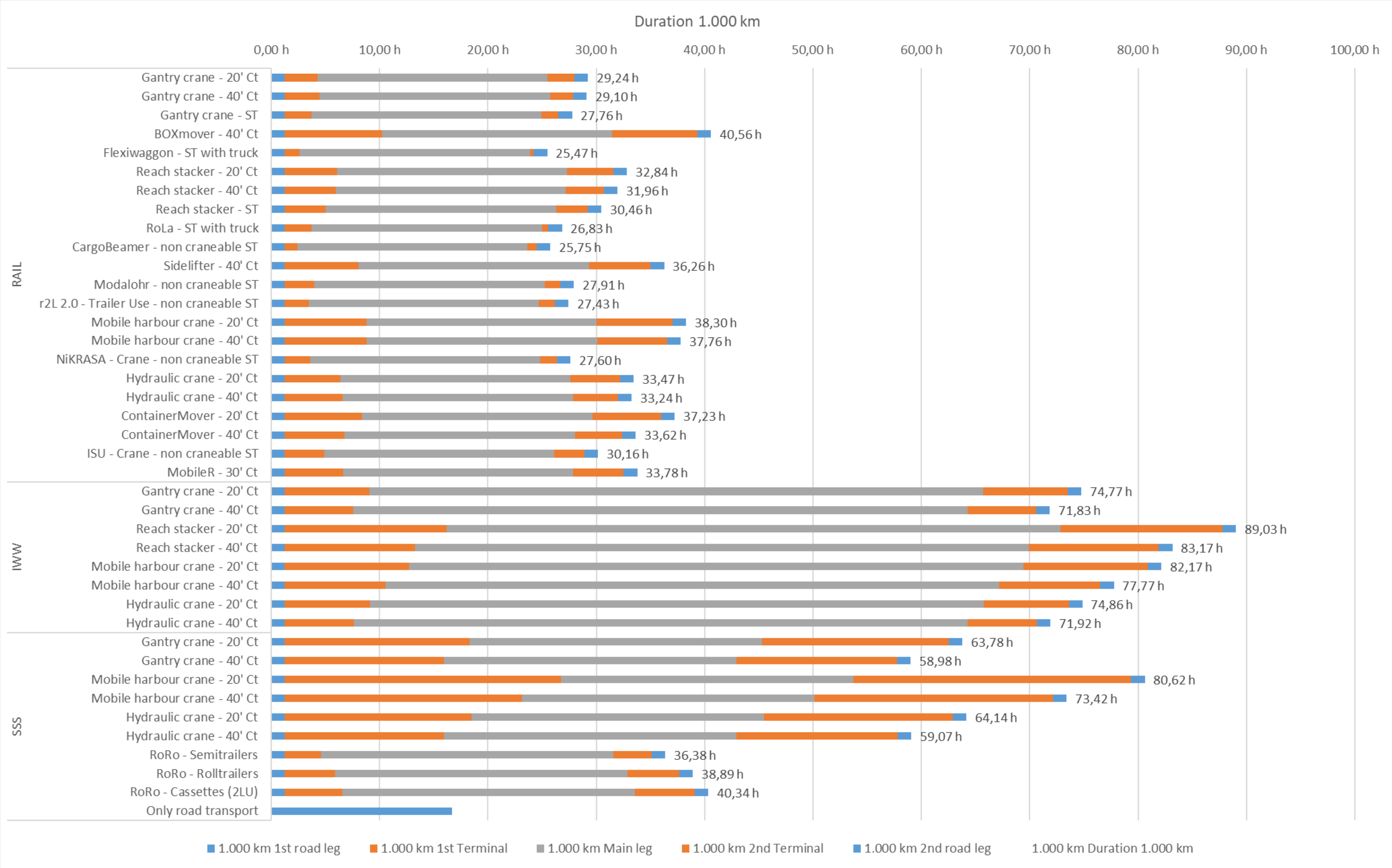


Figure 38: Total duration of the 1 000 km transport chain



As for the costs the provided durations were divided into equal intervals based on which the scoring is conducted. The basis for the scoring intervals is provided in Table 69.

Table 69: Delivery time scoring intervals

Basis for delivery time intervals					
		Min.	**Max.**	**Δ**	**Interval width**
Transport distance	**600 km**	10 h	67.92 h	57.92 h	2.32 h
	1 000 km	16.67 h	89.03 h	72.37 h	2.89 h

For availability the results of Task 3.1 were used for the scoring. As the results of Task 3.1 often only show ranges in which the actual number of terminals is estimated to be, further assumptions were necessary to estimate an upper bound for the highest scoring interval. The highest range of terminals identified in Task 3.1 was 363 to 905 terminals for the reach stacker and container combination. As reach stacker terminals are likely to mostly serve rail-road intermodal transport, the 129 terminals found from the intermodal-map for IWW and SSS terminals were subtracted from the upper bound leaving a range of 363 to 776 terminals for the (likely) most widely available technology and loading unit combination. We then decided the use the middle value (rounded 570) of this range as the upper limit of our highest availability interval. With the lower limit being 0 and using the approach from the cost and delivery time criteria, the scoring intervals were calculated. The basis for the scoring intervals is shown in Table 70. The basis and the intervals are the same for both the 600 km and the 1 000 km transport chains.

Table 70: Available number of terminals scoring intervals

Basis for availability intervals					
		Min.	**Max.**	**Δ**	**Interval width**
Transport distance	**600 km**	0	570	570	22.8
	1 000 km	0	570	570	22.8

Because the analysis of the data for Task 3.1 did not allow any reliable conclusions to be drawn as to how many of the terminals found serve which modes of transport and therefore no reliable figures were available, the final scoring for the technologies which serve different modes of transport was done based on our own judgement and expertise.

For the last criterion, network coverage, we used the results from Task 3.4. Here, the TEN-T Corridors, or sections of them, on which the technology and loading unit combinations are deployed were identified. Because the results from Task 3.4 are qualitative and not quantitative, the scoring of points for this criterion was not based on calculated intervals as for the other criteria, but based on publicly available sources about current use cases and our own expert assessment. As for availability, the scores are the same for both the 600 km and the 1 000 km transport distance

For the availability and network coverage criteria road-only will not be part of building the scoring scale but will then be scored with the highest possible score for these criteria. If road were included for creating the scoring scale, it would not be possible to differentiate the intermodal technologies against this.

With the procedure described above for all four criteria, the technology and loading unit combinations were scored. The results of the scoring procedure for all technology and loading unit combinations are shown in Table 71 for the 600 km transport chain and in Table

72 for the 1 000 km transport chain. Both tables include the individual scores per criterion, the sub scores for the costs and time criteria, the sub scores for the availability and network coverage criteria as well as the total score for competitiveness for all technology and loading unit combinations.

Table 71: Weighted scoring model competitiveness for 600 km transport

Mode	Tranship-ment Technology	Loading unit	Criteria and assigned weight: Comparative costs	Delivery time	Sub Score	Availability	Network coverage	Sub Score	Total score
			45%	25%		15%	15%		100%
Rail	Gantry Crane	20' Ct	24	22	**23.29**	24	25	**24.50**	**23.65**
		40' Ct	21	22	**21.36**	24	25	**24.50**	**22.3**
		St (craneable)	21	22	**21.36**	12	25	**18.50**	**20.5**
	BOXmover	40' Ct	16	17	**16.36**	1	1	**1.00**	**11.75**
	Flexiwaggon	St with truck	7	23	**12.71**	1	1	**1.00**	**9.2**
	Reach stacker	20' Ct	21	20	**20.64**	25	25	**25.00**	**21.95**
		40' Ct	17	20	**18.07**	25	25	**25.00**	**20.15**
		St (craneable)	17	21	**18.43**	13	25	**19.00**	**18.6**
	RoLa	St with truck	1	23	**8.86**	1	1	**1.00**	**6.5**
	CargoBeamer	St (non-craneable)	15	23	**17.86**	1	3	**2.00**	**13.1**
	Sidelifter	40' Ct	18	18	**18.00**	1	1	**1.00**	**12.9**
	Modalohr	St (non-craneable)	15	22	**17.50**	1	3	**2.00**	**12.85**
	r2l 2.0 trailer-use	St (non-craneable)	19	22	**20.07**	1	4	**2.50**	**14.8**
	Mobile harbour crane	20' Ct	16	18	**16.71**	2	8	**5.00**	**13.2**
		40' Ct	10	18	**12.86**	2	8	**5.00**	**10.5**
	NiKRASA - crane	St (non-craneable)	20	22	**20.71**	1	3	**2.00**	**15.1**
	Hydraulic crane	20' Container	20	20	**20.00**	1	1	**1.00**	**14.3**
		40' Ct	15	20	**16.79**	1	1	**1.00**	**12.05**
	Container-Mover	20' Ct	22	18	**20.57**	1	1	**1.00**	**14.7**
		40' Ct	18	20	**18.71**	1	1	**1.00**	**13.4**
	ISU	St (non-craneable)	14	21	**16.50**	1	1	**1.00**	**11.85**
	Mobiler	30' Ct	20	20	**20.00**	1	1	**1.00**	**14.3**
IWW	Gantry crane	20' Ct	20	9	**16.07**	6	23	**14.50**	**15.6**
		40' Ct	19	10	**15.79**	6	23	**14.50**	**15.4**
	Reach stacker	20' Ct	11	3	**7.50**	1	8	**4.50**	**7.05**
		40' Ct	10	5	**7.57**	1	8	**4.50**	**7.1**
	Mobile harbour crane	20' Ct	14	6	**11.14**	3	13	**8.00**	**10.2**
		40' Ct	13	8	**11.21**	3	13	**8.00**	**10.25**
	Hydraulic crane	20' Ct	19	9	**15.43**	1	1	**1.00**	**11.1**
		40' Ct	19	10	**15.14**	1	1	**1.00**	**11.35**
SSS	Gantry crane	20' Ct	25	8	**18.93**	14	25	**19.50**	**19.1**
		40' Ct	24	10	**19.00**	14	25	**19.50**	**19.15**
	Mobile harbour crane	20' Ct	20	1	**13.21**	2	10	**6.00**	**11.05**
		40' Ct	19	4	**13.64**	2	10	**6.00**	**11.35**
		20' Ct	24	8	**18.29**	1	1	**1.00**	**13.1**

Mode	Transhipment Technology	Loading unit	Criteria and assigned weight						Total score
			Comparative costs	Delivery time	Sub Score	Availability	Network coverage	Sub Score	
			45%	25%		15%	15%		100%
	Hydraulic crane	40' Ct	23	10	**18.36**	1	1	**1.00**	**13.15**
	RoRo	St (non-craneable)	11	20	**14.21**	9	25	**17.00**	**15.05**
	RoRo - Rolltrailers	40' Ct	8	19	**11.93**	9	20	**14.50**	**12.7**
	RoRo - Cassettes	40' Ct	16	18	**16.71**	9	20	**14.50**	**16.05**
Road	None	St with truck	25	25	**25.00**	25	25	**25.00**	**25**

The comparative costs have been discussed in detail in chapter 5.1 and because the scoring here follows the same patterns and assumptions, we will not repeat the deep dive at this point.

When looking at the delivery times and the points scored, it is noticeable that the differences can most notably be observed between the modes of transport. The rail technology and loading unit combinations are mostly faster than the IWW and SSS ones. One explanation for this are the assumed average speeds per mode transport with rail having a higher average transport speed than IWW and SSS. The fastest delivery time is achieved in road-only transport which also has the fastest average speed of all modes of transport.

The number of loading units on the train, barge or ship also has an influence, because a larger number of loading units in most cases leads to a longer total loading time. In the comparison between IWW and SSS vertical technologies, SSS vertical technologies have significantly longer transhipment times due to the higher number of loading units, however IWW has considerably longer transport durations because it is only traveling at about half the speed. Both effects almost cancel each other out, resulting in very similar results for this criterion for both modes of transport.

Having the same scoring intervals for all modes of transport enables the comparison between the different modes of transport but leads to a lower informative value when comparing technologies for the same transport mode. When comparing the delivery times of the Flexiwaggon and the BOXmover technologies in Figure 37 it can be seen, that the Flexiwagon has the fastest delivery time overall and is almost twice as fast as the BOXmover, which has the slowest rail delivery time. However, in the scoring in Table 71 they are only six points apart due to the generally high speed of rail compared to the other modes of transport. Within the rail technologies generally, the technologies transhipping semi-trailers or full vehicles have fast delivery times compared to those transhipping containers. While in the case of vertical transhipment of semi-trailers (craneable and non-craneable) this can be explained by the lower number of loading units per train and the sequential transhipment of the loading units. For the horizontal transhipment technologies for semi-trailers and full vehicles the explanation is different. These technologies can achieve a very fast transhipment time by enabling the simultaneous or nearly simultaneous transhipment of loading units. Nearly simultaneous transhipment is used in this case to describe the transhipment with the RoLa technology, where all trucks drive into the train directly behind each other and each additional truck (i.e. each loading unit) only adds seconds rather than minutes to the total transhipment duration.

Within the cluster of SSS technologies the RoRo technology combined with different loading units stands out, because it can achieve delivery times comparable to the slower rail technologies. This is due to the lower number of loading units transported on each main leg trip but also due to the loading units being transhipped more simultaneously. This follows the same explanation provided previously for the difference between sequential vertical transhipment and (nearly) simultaneous horizontal transhipment for the rail mode of transport.

Regarding the criteria for availability and network coverage, it should be noted that only the status quo was used for the scoring, and factors such as the ease or flexibility of rolling out a particular technology were not taken into account. For the availability criterion the gantry crane and for rail also the reach-stacker technologies transhipping containers achieve the highest scores per mode of transport. These technologies have been in use for a much longer time, are dominating the market and the number of available terminals is accordingly many times larger than for the other technologies.

Most of the identified terminals for task 3.1 have rail access, which is why the same technologies have a higher score for rail than for the other modes of transport. As there are less geographical prerequisites for rail than for IWW or SSS terminals, which require the availability of shippable rivers (IWW) or coastal access (SSS), this is a plausible assumption.

Although there is a high correlation between the availability and the network coverage criteria, the scores for network coverage are equal or higher than the availability score for each technology and loading unit combination. Even though the total number of terminals for the younger technology and loading unit combinations is much smaller, these terminals are usually placed in or near the dense parts of the TEN-T core network corridors in central Europe and in most cases are not packed in one place and can thereby cover relatively long stretches of multiple corridors.

Another issue came up when scoring the gantry crane technology for IWW and SSS as well as the RoRo and semi-trailer combination for SSS. Due to the geographical prerequisites for these modes of transport there are large parts of the TEN-T core network corridors which are not suitable for transport using these modes of transport. We therefore decided to score these technologies under the assumption, that they are used in terminals on most parts of the core network where they can reasonably be deployed.

In operational practice the competitiveness scores per technology and loading unit combination and per mode of transport are likely to vary depending on the geographical region observed. This influences all four criteria. As has previously been explained, cost elements along the transport chain, like personnel, electricity, diesel or terminal building costs can vary greatly depending on the European country.

For the total delivery time, geographical differences are to be expected, especially for rail, since the train speeds that can be realized depend on general environmental conditions, which can vary greatly from region to region and even from route to route.

The availability per country as well as the network coverage for the less common technology and loading unit combinations would likely show the strongest divergence between different geographical regions because certain technology providers focused their initial main expansion on single countries and are not yet widely available outside of these countries. Examples are Modalohr with a focus on France, ContainerMover with a focus on Switzerland or Mobiler and ISU with a focus on Austria. These regional differences will not be taken into account in the following analyses and evaluations; instead, the focus will be entirely on the general European level.

All these described effects and assumptions lead to the sub and the total competitiveness scores shown in the last column of Table 71 for the 600 km transport chain.

Table 72: Weighted scoring model competitiveness for 1 000 km transport

Mode	Transhipment Technology	Loading unit	Criteria and assigned weight						Total score
			Comparative costs	Delivery time	Sub Score	Availability	Network coverage	Sub Score	
			45%	25%		15%	15%		100%
Rail	Gantry Crane	20’ Ct	23	21	**22.29**	24	25	**24.50**	**22.95**
		40’ Ct	21	21	**21.00**	24	25	**24.50**	**22.05**
		St (craneable)	19	22	**20.07**	12	25	**18.50**	**19.6**
	BOXmover	40’ Ct	18	17	**17.64**	1	1	**1.00**	**12.65**
	Flexiwaggon	St with truck	4	22	**10.43**	1	1	**1.00**	**7.6**
	Reach stacker	20’ Ct	22	20	**21.29**	25	25	**25.00**	**22.4**
		40’ Ct	19	20	**19.36**	25	25	**25.00**	**21.05**
		St (craneable)	18	21	**19.07**	13	25	**19.00**	**19.05**
	RoLa	St with truck	1	22	**8.50**	1	1	**1.00**	**6.25**
	CargoBeamer	St (non-craneable)	15	22	**17.50**	1	3	**2.00**	**12.85**
	Sidelifter	40’ Ct	19	19	**19.00**	1	1	**1.00**	**13.6**
	Modalohr	St (non-craneable)	16	22	**18.14**	1	3	**2.00**	**13.3**
	r2l 2.0 trailer-use	St (non-craneable)	17	22	**18.79**	1	4	**2.50**	**13.9**
	Mobile harbour crane	20’ Ct	19	18	**18.64**	2	8	**5.00**	**14.55**
		40’ Ct	15	18	**16.07**	2	8	**5.00**	**12.75**
	NiKRASA - crane	St (non-craneable)	18	22	**19.43**	1	3	**2.00**	**14.2**
	Hydraulic crane	20’ Container	21	20	**20.64**	1	1	**1.00**	**14.75**
		40’ Ct	18	20	**18.71**	1	1	**1.00**	**13.4**
	Container-Mover	20’ Ct	23	18	**21.21**	1	1	**1.00**	**15.15**
		40’ Ct	19	20	**19.36**	1	1	**1.00**	**13.85**
	ISU	St (non-craneable)	16	21	**17.79**	1	1	**1.00**	**12.75**
	Mobiler	30’ Ct	21	20	**20.64**	1	1	**1.00**	**14.75**
IWW	Gantry crane	20’ Ct	22	5	**15.93**	6	23	**14.50**	**15.5**
		40’ Ct	21	6	**15.64**	6	23	**14.50**	**15.3**
	Reach stacker	20’ Ct	17	1	**11.29**	1	8	**4.50**	**9.25**
		40’ Ct	16	3	**11.36**	1	8	**4.50**	**9.3**
	Mobile harbour crane	20’ Ct	19	3	**13.29**	3	13	**8.00**	**11.7**
		40’ Ct	18	4	**13.00**	3	13	**8.00**	**11.5**
	Hydraulic crane	20’ Ct	21	5	**15.29**	1	1	**1.00**	**11**
		40’ Ct	20	6	**15.00**	1	1	**1.00**	**10.8**
SSS	Gantry crane	20’ Ct	25	9	**19.29**	14	25	**19.50**	**19.35**
		40’ Ct	25	11	**20.00**	14	25	**19.50**	**19.85**
	Mobile harbour crane	20’ Ct	23	3	**15.86**	2	10	**6.00**	**12.9**
		40’ Ct	23	6	**16.93**	2	10	**6.00**	**13.65**
	Hydraulic crane	20’ Ct	25	9	**19.29**	1	1	**1.00**	**13.8**
		40’ Ct	25	11	**20.00**	1	1	**1.00**	**14.3**
	RoRo	St (non-craneable)	13	19	**15.14**	9	25	**17.00**	**15.7**
	RoRo - Rolltrailers	40’ Ct	12	18	**14.14**	9	20	**14.50**	**14.25**

Mode	Tranship-ment Technology	Loading unit	Criteria and assigned weight						Total score
			Comparative costs	Delivery time	Sub Score	Availability	Network coverage	Sub Score	
			45%	25%		15%	15%		100%
	RoRo - Cassettes	40’ Ct	20	17	**18.93**	9	20	**14.50**	**17.6**
Road	None	St with truck	16	25	**19.21**	25	25	**25.00**	**20.95**

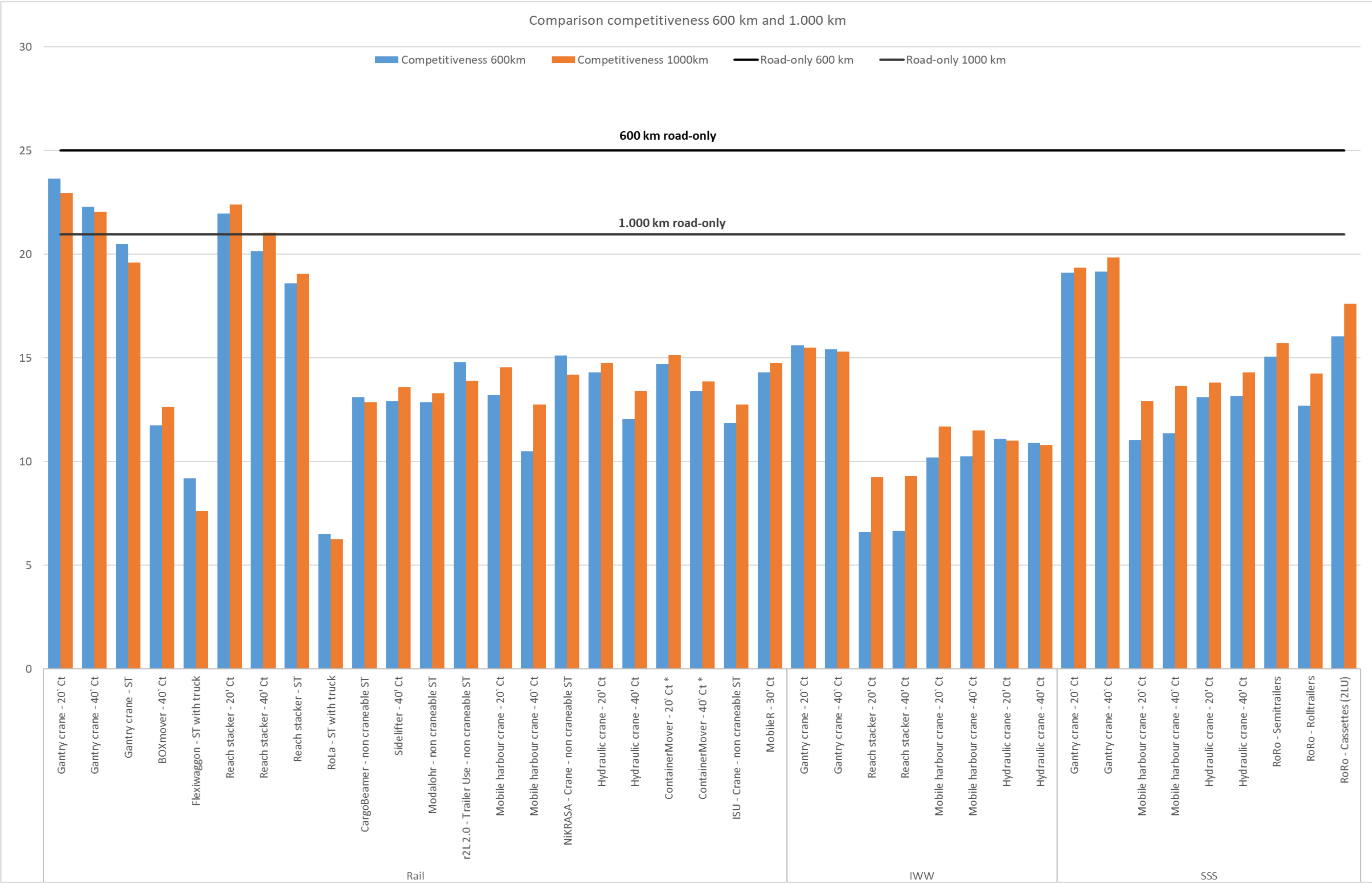
For the competitiveness scoring of the 1 000 km transport shown in Table 72 most of the explanations and arguments made for the 600 km transport still apply, and we will therefore focus on what is different. For the costs criterion a detailed analysis was provided in chapter5.1.

For the delivery time score the road-only alternative remains the fastest entry also for the 1 000 km transport chain due to the highest average speed and no transhipments. Only minor changes of plus or minus one point can be observed for the rail technologies with most of them scoring the same because the main leg speed is the closest to the average road transport speed. For IWW all technology and loading unit combinations reduce their delivery time score. This is a result of the slow barge speed. Due to the longer main leg the gap in delivery time between IWW and the other modes of transport widens. For SSS the vertical transhipment technologies can increase their score. As they previously had a similar total delivery time to IWW, the increase in main leg distance now leads to a better score than IWW due to faster speed of the ship compared to the barge. For the SSS RoRo technologies this effect cannot be observed as they already had a better score due to their faster transhipment times.

As was previously described, the criteria availability and network coverage are not influenced by the total transport distance and therefore the scores remain the same for all technology and loading unit combinations.

Figure 39 shows the competitiveness score for all technology and loading unit combinations for both the 600 km and the 1 000 km distance.

Figure 39: Comparison of the competitiveness score per combination between the 600 km and 1 000 km transport distance



As can be seen, the main leg distance does not have a large impact on the competitiveness score for most technology and loading unit combinations. One reason for this is, that two of the criteria, availability and network coverage, which together account for 30% of the allocated weight, are independent of the main leg distance.

The largest impact can be observed on the competitiveness of the road-only transport which decreases with an increase in transport distance due to no longer having the lowest comparative costs. However, although most of the intermodal technology and loading unit combinations have lower comparative costs for the 1 000 km distance, only four technology and loading unit combinations, the gantry and the reach-stacker for both container sizes and for rail, achieve a higher competitiveness score, due to the road-only alternative still having the fastest delivery time as well as being scored highest for availability and network coverage.

For the intermodal technology and loading unit combinations the picture is mixed, with the competitiveness being increased over the longer transport distance for some combinations but being reduced for others. Especially the SSS technologies increase their competitiveness which is due to the lowest per unit transport costs on the main leg of all modes of transport as well as the total delivery time improving compared to the IWW delivery time.

The highest competitiveness is achieved by the gantry crane rail technology for all types of loading units which also previously had the highest competitiveness score amongst the intermodal technology and loading unit combinations. However, the competitiveness score decreased from the 600 km to the 1 000 km transport chain due to the gaps towards the leading technology and loading unit combinations, the gantry crane SSS for the cost criterion and the road-only transport for the delivery time criterion, widening. It does however still score high in all four criteria and can now score even above the road-only alternative achieving the highest overall competitiveness score and not only amongst the intermodal technology and loading unit combinations.

5.3 Potential for modal shift by 2030 taking into account the competitiveness of the technology and today's network limitations

Determining the modal shift potential per technology and loading unit combination is impossible due to the insufficient available data about the current terminal handling capacity and capacity utilization from the sources utilized for task 3. As an alternate approach is needed, this task was carried out in two steps:

- calculation of the potential for modal shift per mode of transport by 2030 in tkm of road transport;
- the suitability of a technology and loading unit combination for modal shift based on the competitiveness of the technology, today's network limitations and the compatibility with other technology and loading unit combinations.

Calculation of the potential for modal shift by 2030 in tkm of road transport

Within the European Green Deal (EGD) and Sustainable and Smart Mobility Strategy (SSMS), the EU sets wide milestones and policy objects for the period from 2021 to 2030. To achieve its climate goals, among other things, it includes milestones to raise the shares of rail freight, inland waterways (IWW) and short sea shipping (SSS), as follows:

- rail freight traffic shall grow by 50% until 2030;
- transport on inland waterways and short sea shipping shall grow by 25% until 2030.

The last figures of the transport performance, which is the unit of measurement in tkm, of all those three modes were available for 2019. Thus, we applied the planned growth of the EGD and SSMS on this particular year, to reach a potential for modal shift by 2030. In 2019, the transport performance of the EU 27 countries counted to about 406 billion tkm on rail, 140 billion tkm on inland waterways and 979 billion tkm on short sea shipping. Applying the milestones from the EGD and SSMS on these transport performances in that particular year, a modal shift potential for rail of 203 billion tkm, for IWW of 35 billion tkm and for SSS of almost 245 billion tkm as is shown in Table 73.

Table 73: Transport performance for rail, IWW and SSS in 2019, envisaged growth and transport performance 2030, EU-27 countries

Mode	2019	growth by		2030
	billion tkm	%	billion tkm	billion tkm
Rail	406.4	50%	203.2	609.6
IWW	139.7	25%	34.9	174.6
SSS	978.8		244.7	1 223.5
Total	**1 524.9**		**482.8**	**2 007.7**

Source: EU transport in figures - Statistical pocketbook 2021, KombiConsult calculations

In total this accounts to almost 483 billion tkm of modal shift potential from road to other modes of transport such as rail, IWW or SSS by 2030.

To determine the transport performance for the intermodal transport by 2030, we applied the same growth figures to the current intermodal share of each mode, assuming that it would grow in the same way. This a rather conservative approach because multiple studies over the past years have estimated that the intermodal market segment will grow faster than the overall market. However, as no definite figures for this additional growth of the intermodal market could be identified, the equal growth target for all market segments was opted for. For rail, the “2020 Report on Combined Transport in Europe” does not include information on tkm in 2019, but it includes information on tonnes in 2019 for international and national intermodal transport. As it also states average distances for international and national intermodal transport, we multiplied those average distances with the tonnes and received a total of 181 billion tkm in 2019 for intermodal transport on rail. For inland waterways and short sea shipping, Eurostat states the shares of intermodal transport for those modes. With these shares, we receive 14 billion tkm for inland waterways and about 291 billion tkm for short sea shipping as concerns the intermodal transport performance of these modes. Applying the envisaged growth from the EGD and SSMS on these transport performances in that particular year, it would mean that the intermodal transport performance on rail would grow by about 91 billion tkm, IWW by about 4 billion tkm and SSS by about 73 billion tkm (see Table 74).

Table 74: Intermodal transport performance for rail, IWW and SSS 2019, envisaged growth and transport performance in 2030, EU-27 countries

Mode	2019	growth by		2030
	billion tkm	%	billion tkm	billion tkm
Rail	181.1	50%	90.6	271.7
IWW	14.0	25%	3.5	17.47
SSS	290.7		72.7	363.4
Total	**485.8**		**166.8**	**652.6**

Source: Source: 2020 Report on Combined Transport, Eurostat, KombiConsult calculations

Thus, in total, the modal shift potential for rail, IWW and SSS is 166.8 billion tkm based on the EGD and SSMS milestones, if the intermodal share grows by the same rate as total freight for these modes.

To meet this goal will also require appropriate infrastructure to be developed.

To compare these figures with the calculated capacity of the transhipment technologies, we applied the following methodology:

- converting transport performance (tkm) into transport volume (tonnes) with average numbers on km per mode (status 2019).
- Converting transport volume from tonnes into loading units with average numbers on tonnes per loading unit (status 2019).
- Converting transport volume (loading units) into handling volume (loading units). As the figures represent mainly EU intra transport, we assume that for each transport of one loading unit two handlings are needed on each side of the transport chain (factor two).

Table 75: Intermodal transport performance / volume and handling volume for rail, IWW and SSS 2019, in 2030, EU-27 countries

Mode	Transport performance / volume					Handling volume
	billion tkm	Ø ~ km	million t	Ø t / LU	million LU	million LU
Rail	271.7	670	405.5	18.5	21.9	43.8
IWW	17.1	220	77.7	16.0	4.9	9.8
SSS	363.4	540	673.0	15.1	44.6	89.2
Total	**652.2**		**1 156.2**		**71.4**	**142.8**

Source: 2020 Report on Combined Transport, Eurostat, KombiConsult calculations

Thus, a total handling capacity of 142.8 million loading units for the intermodal transport of rail, inland waterways and short sea shipping is needed in 2030 to reach the milestones of the EGD and SSMS.

In chapter 4.2 todays terminal handling capacity was analysed. However, since only incomplete data in low quality was available, only a wide range of possible terminal handling capacity per technology and loading unit combination could be provided here. Furthermore, the values cannot simply be added up, as the technologies are not necessarily mutually exclusive, and capacity used for one type of loading unit likely limits the capacity available for other types. To provide a very rough estimate for the available total terminal handling capacity, the lower bound values and the upper bound values for the different technologies are added up. For the technologies capable of transhipping different types of loading units, the handling capacity for the LU-type mostly transhipped with the technology is used. Technologies which can only be used with other listed technologies, i.e. the technologies used for enabling the vertical transhipment of non-craneable semi-trailers, the handling capacity is ignored because it is already included in the vertical transhipment technologies.

Using this approach, the resulting range for the possible current terminal handling capacity in the EU is between 90 million transhipments to 167 million transhipments. In chapter 4.2, it was already explained in detail that there are several factors impacting the accuracy of this assessment. These factors are likely to lead to an overestimation of the current terminal handling capacity.

The determined necessary terminal handling capacity of 143 million handlings to realize the 2030 modal shift milestones falls within the upper third of the calculated range for today's possible terminal handling capacity. When then considering, that the calculated range is likely overestimating the available terminal handling capacity, it is reasonable to assume that additional terminal handling capacity will be necessary to realize the 2030 milestones.

To determine the suitability for modal shift of the different technology and loading unit combinations, we are again using a weighted scoring model, this time with three differently weighted criteria but otherwise following the same approach and framework conditions described in 5.2 for scoring and weighting the criteria. In this task road-only transport will not be scored because this task is concerned with shifting transport volumes away from road-only transport.

Two of the three criteria, competitiveness and network limitations, were pre-determined by DG MOVE and the other criterion, compatibility, was added by us to take into account further characteristics of the technology.

Following the three previously used principles for the allocation of weight to the criteria the following weighting was decided upon:

- Competitiveness: 50%
  The competitiveness score per technology and loading combination was determined in task 5.2 and considers the costs, delivery time, availability and network coverage. The score used here will be the one determined for the 600 km transport distance because the shorter main leg distance leads to a larger impact of the transhipment on the total values for cost and delivery time and is thereby better suited for the comparison of the different technologies. The weight of 50% was assigned to this criterion.
- Network limitations: 30%
  This criterion assesses the potential network limitations for using specific technology and loading unit combinations on the TEN-T core network corridors. For network limitations, which were already analysed throughout tasks 3.5 to 3.9, it was agreed with DG MOVE to focus on the issue of loading gauges for rail-road intermodal transport. Due to the necessary compliance between the technology and loading unit combination and the railway line, having too large a loading gauge profile can negatively impact or prevent a technology and loading unit combination from being deployed. Removing loading gauge restrictions can be a very costly and time-consuming undertaking and while we expect progress to be made, there will likely still be many such limitations on the TEN-T core network corridors by 2030. We decided to allocate a weight of 30% to this criterion.
- Compatibility: 20%
  This criterion assesses the compatibility of the technology and loading unit combinations with each other. Technologies which can easily be combined with

other technologies in the same transport chain are at an advantage. The more flexible terminals for a technology and loading unit combination can be integrated into a heterogenous terminal network the easier and faster it can be deployed and scaled up in operations. This criterion was assigned a weight of 20%.

The scoring for the competitiveness criterion was done based on the competitiveness calculated and discussed in detail in 5.2. The calculated competitiveness scores for all technology and loading unit combinations were used as the basis for determining the scoring intervals following the approach using the minimum and maximum values and 25 equally sized scoring intervals explained in chapter 5.2. The road-only score is left out when preparing the scoring scale for this model because road-only transport will not be analysed in this task. The basis for the scoring scale is shown in below.

Table 76: Competitiveness scoring intervals

Basis for Competitiveness intervals				
	Min.	**Max.**	**∆**	**Interval width**
Value	6.50	23.65	17.15	0.69

For the network limitations criterion. the scoring procedure is dependent on the mode of transport of the specific technology and loading unit combination. For rail we looked at the minimum necessary loading gauge on route per rail wagon and loading unit combination (2 550 wide boxes/2 600 mm wide Semi-Trailers) as shown in Table 28. The scoring was then conducted according to loading gauge intervals determined on the basis shown in Table 77. These intervals are evenly sized between the P 330 and the P 408 loading gauge requirement.

Table 77: Loading gauge for rail wagon and loading unit combination scoring intervals

Basis for Network Limitations intervals				
	Min.	**Max.**	**∆**	**Interval width**
Value	330	408	78	3.12

For IWW and SSS the score for network limitations was set to 25 for all technology and loading unit combinations. Network limitations for IWW and SSS were not part of the respective tasks 3.5 to 3.9. Furthermore, for both modes of transport we are looking at relatively small barge or ship sizes which are assumed to be able to travel on all relevant shipping lines.

The compatibility criterion scoring is again dependent on the mode of transport. For IWW all analysed technologies and loading units are compatible with each other and therefore receive a score of 25 for this criterion.

For rail, the considerations were more complex due to the wide variety of different technologies and loading unit types. We therefore decided to implement a model, in which points were awarded for two types of compatibility. The results of the compatibility assessment are shown in Table 79. The first type is the compatibility of a train being loaded with one specific technology and type of loading unit (not size, in order to not count containers multiple times for different sizes) to be unloaded in a terminal of another technology and type of loading unit combination. Each compatible technology and type of loading unit combination where the train could be unloaded, awarded one point. This is shown in the rows for each technology and type of loading unit combinations. The second is the compatibility of the terminal with trains loaded by other technology and type of loading unit combinations. Again, each compatibility with another technology and type of loading unit combination awarded one point. The results for this type of compatibility are shown in the columns. By summing up the results of the row and the column for the same technology and type of loading unit combination, the total sum for the technology and loading unit combinations compatibilities are calculated. These points are then again used as the basis for determining the scoring intervals as shown in Table 78.

Table 78: Compatibility scoring intervals

Basis for Compatibility intervals				
	Min.	**Max.**	**Δ**	**Interval width**
Value	1	17	16	0.64

In SSS two main clusters can be identified, one being the vertical crane technologies and one the horizontal transhipment RoRo technologies. The vertical transhipment technologies in SSS are all compatible with each other, but not with the RoRo technologies, whereas for RoRo only semi-trailers can be transhipped in all RoRo terminals but not roll-trailers and cassettes as these require additional terminal equipment. None of the RoRo technologies is compatible with the vertical crane technologies. These compatibilities were scored the same way as for the rail mode of transport. The allocated compatibility points were then standardized to the scale of the rail technologies by multiplying them with a factor of the maximum rail points divided by the maximum SSS points to score them on the same scale as the rail technologies.

When checking the compatibilities, we adhered strictly to the model terminals described for each technology and loading unit combination. Therefore, even if a technology and loading unit combination can be made compatible with new ones with a small additional effort, this combination will be checked as non-compatible in this analysis.

Table 79: Compatibility between different transhipment technology and loading unit combinations rail

		Gantry Crane		BOXmover	Flexi-wagon	Reachstacker		RoLa	CargoBeamer	Sidelifter	Modalohr	r2l 2.0 trailer-use	Mobile Harbour crane	NiKRASA - crane	Hydraulic crane	Container-Mover	ISU	Mobiler	Total rows
		Ct	ST (craneable)	40' Ct	ST with truck	Ct	ST (craneable)	ST with truck	ST (non-craneable)	40' Ct	ST (non-craneable)	ST (non-craneable)	Ct	ST (non-craneable)	Ct	Ct	ST (non-craneable)	30' Ct	
Gantry Crane	Ct		1	1	0	1	1	0	0	1	0	1	1	1	1	0	1	0	10
	ST (craneable)	0		0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	3
BOXmover	40' Ct	1	1		0	1	1	0	0	1	0	1	1	1	1	0	1	0	10
Flexiwagon	ST with truck	1	1	1		1	1	1	0	1	1	1	1	1	1	1	1	1	15
Reach Stacker	Ct	1	1	1	0		1	0	0	1	0	1	1	1	1	0	1	0	10
	ST (craneable)	0	1	0	0	0		0	0	0	0	1	0	1	0	0	0	0	3
RoLa	ST with truck	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
CargoBeamer	ST (non-craneable)	0	1	0	0	0	1	0		0	0	1	0	1	0	0	0	0	4
Sidelifter	40' Ct	1	1	1	0	1	1	0	0		0	1	1	1	1	0	1	0	10
Modalohr	ST (non-craneable)	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
r2l 2.0 trailer-use	ST (non-craneable)	0	1	0	0	0	1	0	0	0	0		0	1	0	0	0	0	3
Mobile Harbour Crane	Ct	1	1	1	0	1	1	0	0	1	0	1		1	1	0	1	0	10
NiKRASA - crane	ST (non-craneable)	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
Hydraulic Crane	Ct	1	1	1	0	1	1	0	0	1	0	1	1	1		0	1	0	10
ContainerMover	Ct	1	1	1	0	1	1	0	0	1	0	1	1	1	1		1	0	11
ISU	ST (non-craneable)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Mobiler	30' Ct	0	1	0	0	0	1	0	0	0	0	1	0	1	0	0	0		4
Total columns		7	12	7	0	7	12	1	0	7	1	12	7	13	7	1	8	1	

Based on the described criteria and procedure for the suitability for modal shift the technology and loading unit combinations are then scored. The results are shown in Table 80 in the standard order and in sorted by score per mode of transport.

Table 80: Weighted scoring model Suitability for modal shift

Mode	Transhipment Technology	Loading unit	Criteria and assigned weight			Total score
			Competitiveness	Network limitations	Compatibility	
			50%	30%	20%	100%
Rail	Gantry Crane	20' Container	25	25	25	**25**
		40' Container	24	25	25	**24.5**
		Semi-trailer (craneable)	21	5	22	**16.4**
	BOXmover	40' Container	8	25	25	**16.5**
	Flexiwaggon	Semi-trailer with truck	4	6	22	**8.2**
	Reach stacker	20' Container	23	25	25	**24**
		40' Container	20	25	25	**22.5**
		Semi-trailer (craneable)	18	5	22	**14.9**
	RoLa	Semi-trailer with truck	1	1	1	**1**
	CargoBeamer	Semi-trailer (non-craneable)	10	8	5	**8.4**
	Sidelifter	40' Container	10	25	25	**17.5**
	Modalohr	Semi-trailer (non-craneable)	10	7	1	**7.3**
	r2l 2.0 trailer-use	Semi-trailer (non-craneable)	13	3	22	**11.8**
	Mobile harbour crane	20' Container	10	25	25	**17.5**
		40' Container	6	25	25	**15.5**
	NiKRASA - crane	Semi-trailer (non-craneable)	13	5	19	**11.8**
	Hydraulic crane	20' Container	12	25	25	**18.5**
		40' Container	9	25	25	**17**
	ContainerMover	20' Container	12	21	18	**15.9**
		40' Container	11	21	18	**15.4**
	ISU	Semi-trailer (non-craneable)	8	5	11	**7.7**
	Mobiler	30' Container	12	25	7	**14.9**
IWW	Gantry crane	20' Container	14	25	25	**19.5**
		40' Container	13	25	25	**19**
	Reach stacker	20' Container	1	25	25	**13**
		40' Container	1	25	25	**13**
	Mobile harbour crane	20' Container	6	25	25	**15.5**
		40' Container	6	25	25	**15.5**
	Hydraulic crane	20' Container	7	25	25	**16**
		40' Container	8	25	25	**16.5**
SSS	Gantry crane	20' Container	19	25	25	**22**
		40' Container	19	25	25	**22**
	Mobile harbour crane	20' Container	7	25	25	**16**
		40' Container	8	25	25	**16.5**
	Hydraulic crane	20' Container	10	25	25	**17.5**
		40' Container	10	25	25	**17.5**

Mode	Transhipment Technology	Loading unit	Criteria and assigned weight			Total score
			Competitiveness	Network limitations	Compatibility	
			50%	30%	20%	100%
	RoRo	Semi-trailer (non-craneable)	13	25	12	**16.4**
	RoRo - Rolltrailers	40' Container	10	25	6	**13.7**
	RoRo - Cassettes	40' Container	14	25	6	**15.7**

Table 81: Weighted scoring model Suitability for modal shift

Mode	Transhipment Technology	Loading unit	Criteria and assigned weight			Total score
			Competitiveness	Network limitations	Compatibility	
			50%	30%	20%	100%
Rail	Gantry Crane	20' Ct	25	25	25	**25**
Rail	Gantry Crane	40' Ct	24	25	25	**24.5**
Rail	Reach stacker	20' Ct	23	25	25	**24**
Rail	Reach stacker	40' Ct	20	25	25	**22.5**
Rail	Hydraulic crane	20' Ct	12	25	25	**18.5**
Rail	Sidelifter	40' Ct	10	25	25	**17.5**
Rail	Mobile harbour crane	20' Ct	10	25	25	**17.5**
Rail	Hydraulic crane	40' Ct	9	25	25	**17**
Rail	BOXmover	40' Ct	8	25	25	**16.5**
Rail	Gantry Crane	ST (craneable)	21	5	22	**16.4**
Rail	ContainerMover	20' Ct	12	21	18	**15.9**
Rail	Mobile harbour crane	40' Ct	6	25	25	**15.5**
Rail	ContainerMover	40' Ct	11	21	18	**15.4**
Rail	Reach stacker	ST (craneable)	18	5	22	**14.9**
Rail	Mobiler	30' Ct	12	25	7	**14.9**
Rail	r2l 2.0 trailer-use	ST (non-craneable)	13	3	22	**11.8**
Rail	NiKRASA - crane	ST (non-craneable)	13	5	19	**11.8**
Rail	CargoBeamer	ST (non-craneable)	10	8	5	**8.4**
Rail	Flexiwagon	ST with truck	4	6	22	**8.2**
Rail	ISU	ST (non-craneable)	8	5	11	**7.7**
Rail	Modalohr	ST (non-craneable)	10	7	1	**7.3**
Rail	RoLa	ST with truck	1	1	1	**1**
IWW	Gantry Crane	20' Ct	14	25	25	**19.5**
IWW	Gantry Crane	40' Ct	13	25	25	**19**
IWW	Hydraulic crane	20' Ct	7	25	25	**16**
IWW	Hydraulic crane	40' Ct	7	25	25	**16**
IWW	Mobile harbour crane	20' Ct	6	25	25	**15.5**
IWW	Mobile harbour crane	40' Ct	6	25	25	**15.5**
IWW	Reach stacker	20' Ct	1	25	25	**13**
IWW	Reach stacker	40' Ct	1	25	25	**13**
S	Gantry Crane	20' Ct	19	25	25	**22**

Mode	Transhipment Technology	Loading unit	Criteria and assigned weight			Total score
			Competitiveness	Network limitations	Compatibility	
			50%	30%	20%	100%
	Gantry Crane	40’ Ct	19	25	25	**22**
	Hydraulic crane	20’ Ct	10	25	25	**17.5**
	Hydraulic crane	40’ Ct	10	25	25	**17.5**
	Mobile harbour crane	40’ Ct	8	25	25	**16.5**
	RoRo	ST (non-craneable)	13	25	12	**16.4**
	Mobile harbour crane	20’ Ct	7	25	25	**16**
	RoRo - Cassettes	40’ Ct	14	25	6	**15.7**
	RoRo - Rolltrailers	40’ Ct	10	25	6	**13.7**

The competitiveness criteria have been discussed in detail in 5.2 and will not be discussed here again.

With regard to the network limitations for rail, it can be seen that for the same type of loading unit they are mostly the same. Whereas the container technologies receive the highest score, the technologies for transhipping semi-trailers and full vehicles are scoring in the single digits. The Flexiwaggon for full vehicles and the horizontal transhipment technologies for non-craneable semi-trailers, CargoBeamer and Modalohr, are scoring higher than the other semi-trailer and full vehicle technologies. For these technologies the score is higher than for their counterparts transhipping the same types of loading units because the specialized wagons noticeable reduce the loading profile for the wagon and loading unit combination.

The ContainerMover as well as the r2l 2.0 technologies are using additional equipment on the main leg which increases the loading profile of the wagon and loading unit combination, this increase is sufficient to impact their scoring and they are scoring lower than the other technologies transhipping the same types of loading units onto standard wagons.

For network limitations all IWW and SSS technology and loading unit combinations scored a five, which also means that these modes have a clear advantage in this criterion compared to rail.

When looking at the score for the compatibility criterion it can be noticed that most rail technologies received a high score in the twenties. The vertical rail transhipment technologies except for two, which require additional specialized terminal equipment, received the highest scores and are mostly compatible with each other. However also some horizontal technologies achieve a high compatibility score. These are the horizontal container technologies BOXmover and Sidelifter which are also fully compatible with vertical container technologies, and the Flexiwaggon, which doesn’t require a complex or specialized terminal but can be loaded or unloaded almost anywhere on its own. Although the Flexiwaggon has a high compatibility with other terminals, the assumed Flexiwaggon terminal itself cannot be used for trains loaded by another technology, as it lacks any kind of transhipment equipment. Still, this is enough for a high score due to no other rail technology achieving significantly more compatibility points. For NiKRASA and ISU the terminals are using specialized terminal equipment required for loading and unloading the train. Although the terminals itself are also suited to unload trains loaded with certain other technologies, NiKRASA and ISU trains cannot be handled in any other terminal, thereby reducing the compatibility compared to other vertical transhipment technologies for semi-trailers. The opposite is the case for the ContainerMover and the Mobiler technologies. For these technologies the terminal is unable to handle trains from other technologies (except the Flexiwaggon) due to technology requiring specialized loading units or adapters on the train, however the trains can be handled by other container terminal technologies. The lowest scores are received by the remaining horizontal transhipment technologies. For the CargoBeamer technology, the train can be handled by other technologies for the vertical transhipment of craneable and non-craneable semi-trailers (except the ISU technology) but the terminal is incompatible with all other technologies. For Rola and Modalohr the terminal can be used also by the Flexiwaggon, however the trains themselves cannot be handled by terminals for other technologies.

All IWW technologies are fully compatible with each other for the chosen barge size and receive a score of five and for SSS a differentiation must be made between the vertical technologies and the horizontal RoRo technologies. The crane technologies are all fully compatible with each other within our model parameters but are unable to handle the RoRo technologies. For RoRo, semi-trailers can be handled in all terminals, but the semi-trailer terminal is unable to handle roll-trailers or cassettes without additional equipment. For the roll-trailer and cassette technologies this in turn means, that the corresponding RoRo terminals can also handle semi-trailers, but the roll-trailers and cassettes cannot be handled in any other terminal, thereby reducing compatibility.

Because the total potential for modal shift as well as the scoring for two of the criteria already differentiates between the modes of transport, it is reasonable to also conduct the discussion of the resulting score of suitability for modal shift based on the modes of transport.

For the rail mode of transport, from the technology and loading unit perspective container technologies generally achieved a higher suitability score than technologies for other types of loading units due to their high scores for network limitations and compatibility and at least average scores for competitiveness.

Between craneable and non-craneable semi-trailer technologies the craneable semi-trailer technologies achieve higher suitability scores. This is mainly a result of higher competitiveness and compatibility scores. The higher competitiveness score implies that even though the craneable semi-trailer is slightly more expensive and a little heavier than the non-craneable variant, this does not have an overall negative impact on the intermodal transport chain but can be over-compensated by other positive effects. As they score low in the network limitations criterion and are unable to be used for transports on routes with a lower loading gauge. In these cases, it might be suitable to deploy lower loading gauge horizontal technologies even if they achieved an overall lower score.

When discussing the advantageousness of different loading unit types, it is important to point back to chapter 5.1 where we discussed in-depth the impact of our model assumptions on the comparison between different loading unit types and based on this also some resulting shortcomings when transferring the results to real world transport decisions.

For IWW only the competitiveness score is different for the technology and loading unit combinations and both other criteria are the same. This results in the gantry crane having the highest competitiveness score and thereby also the highest suitability for modal shift. However, all technologies are fully compatible with each other and none scored badly, therefore they all might be viable depending on the right circumstances, for example smaller terminals where a gantry crane could not be used to its full capacity.

SSS is similar to IWW for the vertical crane technologies and follows the same arguments. For RoRo the semi-trailer variant shows the highest suitability whereas the roll-trailer and cassette variants for containers fall short to both RoRo the semi-trailer as well as the crane technologies used for containers. The cassette scores higher than the roll-trailer technology. It is however important to note that this study considered double stacked cassettes and whether this is feasible or not is dependent on external circumstances, especially whether the deployed ship allows for this type of transport. The advantageous technologies for short sea container transport are therefore the vertical container technologies, with RoRo coming under consideration when these are either not available or feasible, for example due to low container transport volumes.

5.4 Potential for saving external costs by 2030 based on potential for modal shift

In 5.3 the potential for modal shift per mode of transport by intermodal transport chains in tkm of road-only transport was determined based on the European milestones to raise the share of rail, IWW and SSS by 2030 to achieve its climate goals. These modal shift potentials are now evaluated for their external cost savings if they are achieved with a certain technology and loading unit combination.

For each technology and loading unit combinations the external costs of the 600km and 1 000 km transport chain were determined based on the Handbook on external costs in transport and the considerations described in chapter 3.2.3 – part External costs.

The external costs were determined based on the total weight of the train, barge, ship or road vehicle, instead of only the loaded goods weight, in order to account for differences in transport equipment weight between the different technology and loading unit combinations which would otherwise be ignored.

In the same chapter the determined road-only costs for a 600 km and 1 000 km were calculated with the same approach. By calculating the difference between the external costs for each technology and loading unit combination and road-only transport for the same transport distance and dividing the result by the loaded goods weight and the transport distance the external cost savings potential per tkm of intermodal transport compared to road-only transport can be determined for each technology and loading unit combination.

By then multiplying the external cost saving potentials per tkm for each technology and loading unit combination with the potential for modal shift of the respective mode of transport, the total potential for saving external costs by 2030 can be calculated. The results are shown in Figure 40.

As can be seen, the potential for saving external costs is mainly dependent on the mode of transport and consequently the potential for modal shift per mode of transport. Because the modal shift potential for IWW is small compared to rail and SSS, also the potential external cost savings by 2030 are smaller than for the other modes. For IWW there are only small differences between the technologies regarding their external cost savings potential.

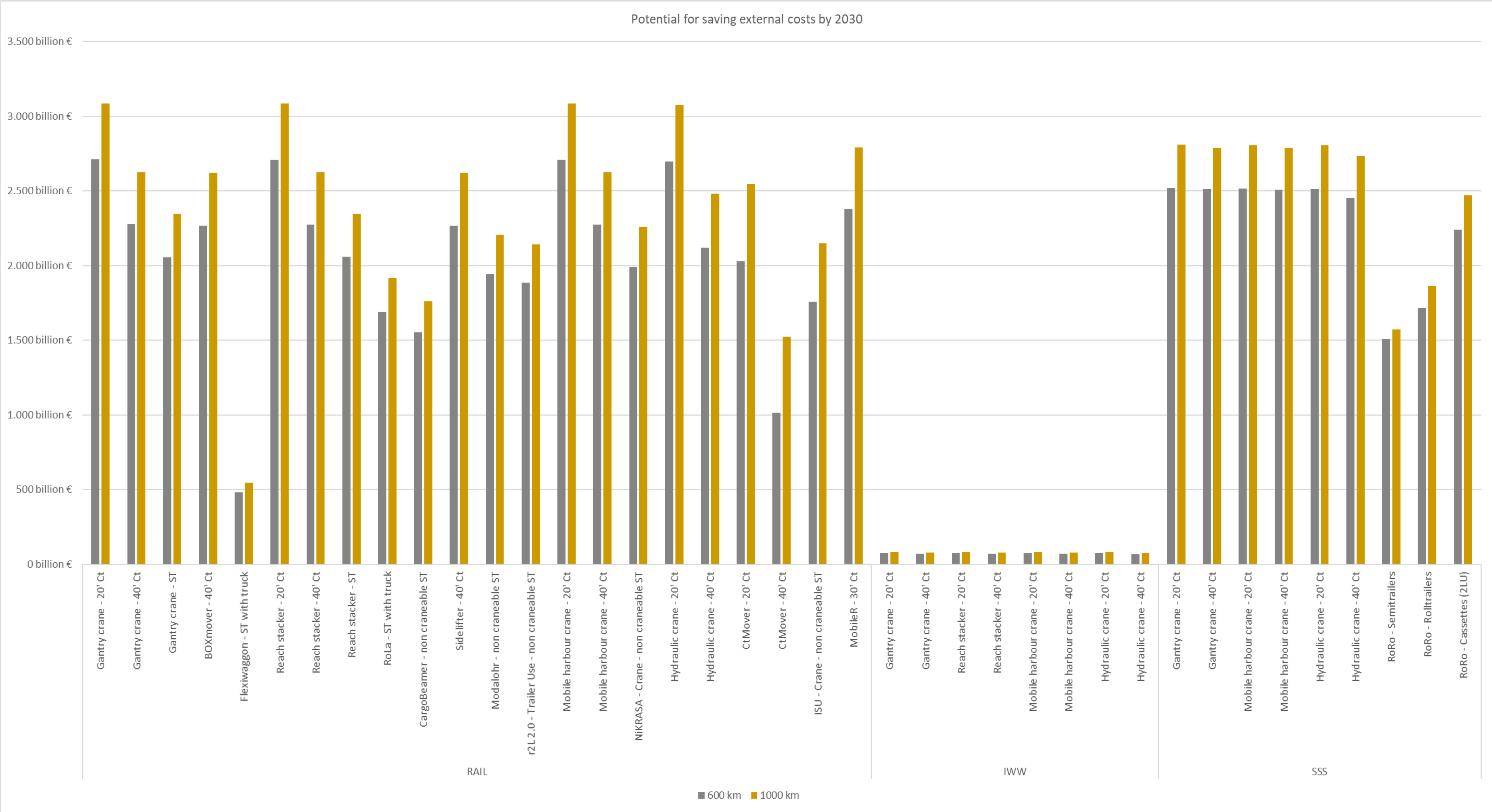
Generally, for all technology and loading unit combinations and modes of transport the external costs of transhipment are magnitudes lower than the external costs of transport on the road leg as well as on the main leg. Differences between the technologies for one mode of transport are therefore mainly caused by a different number of loading units on the main leg means of transport and thereby the transport efficiency. One other effect impacts the ContainerMover and the Hydraulic crane technologies. Because these technologies can only handle lighter loading units than are assumed for the other technologies, even though this slightly increases the number of loading units, the total transport performance per main leg transport is lower and therefore fewer external costs are saved per tkm compared to road-only transport.

For all technology and loading unit combinations the longer 1 000 km transport distance increases the external cost savings potential due to the increased share of the main leg transport distance.

For IWW the loading unit capacity of the barge is similar for all technologies, therefore no big differences can be observed.

For SSS and rail the same as for IWW can be observed for the vertical crane technology and container combinations which are all similar in loading unit capacity. Only the hydraulic crane has a slightly lower external costs savings potential caused by the lower loaded goods weight per loading unit as already explained.

Figure 40: potential for saving external costs by 2030 per technology and loading unit combination



The lower loaded goods weight is also noticeable for the ContainerMover technology which has a lower external cost savings potential than any other container technology for rail.

For all other technology and loading unit combinations the external cost savings potential correlates to the number of loading unit spots on the main leg means of transport. This is especially noticeable for the RoRo variants where either 166 semi-trailers, 192 40' containers on roll-trailers or 384 40' containers on double stacked cassettes can be transported on the same ship.

5.5 Comparative costs taking into account also external costs

This task evaluates the comparative costs of the technology and loading unit combinations taking into account also the external costs incurred during transport and transhipment for one loading unit. To this end the external costs, as previously determined based on the Handbook on external costs in transport and shown in the fact sheets for each technology and loading unit combination, are added to the comparative costs shown and analysed in chapter 5.1. The external costs were determined based on the total weight of the train, barge, ship or road vehicle, instead of only the loaded goods weight, in order to account for differences in transport equipment weight between the different technology and loading unit combinations which would otherwise be ignored.

The results for the 600 km transport chain are shown in Figure 41. Each technology and loading unit combination has its own column, of which the lower blue part represents the previously shown comparative system costs and the upper green part the added external costs. The horizontal black line provides the comparative road-only costs, and the grey line provides the road-only costs incl. the external costs of. The results for the 1 000 km transport chain are shown in a similar way in Figure 42. Here the lower orange part of the columns represents the previously shown comparative system costs and the upper blue part the added external costs per technology and loading unit combination. The horizontal yellow line provides the comparative road-only costs, and the horizontal orange line provides the road-only costs incl. the external costs.

When taking the external costs into consideration, only seven technology and loading unit combinations have higher comparative costs than the road-only transport for the 600 km transport chain. These are technology and loading unit combinations which already without external costs had high comparative costs and were above most other technology and loading unit combinations as well as road-only transport. The other technology and loading unit combinations which also showed higher comparative costs (excl. external costs) than road-only transport now fall below road-only transport when including external costs.

For the comparison of the technologies with each other, the other findings for the comparative costs analysis without external costs can be confirmed as well. Smaller and less complex loading units still show lower comparative costs than larger and more complex loading units for comparable technologies which, as explained, is due to the more efficient capacity utilization for the assumed standard loaded goods weight of 20 t per loading unit.

In the comparison between the technologies used for all the different modes of transport SSS still offers the lowest comparative costs per loading unit with rail being second and IWW offering the highest comparative costs for all six technology and loading unit combinations used on all modes of transport.

Figure 41: Total system costs incl. external costs for the 600 km model transport chain per LU

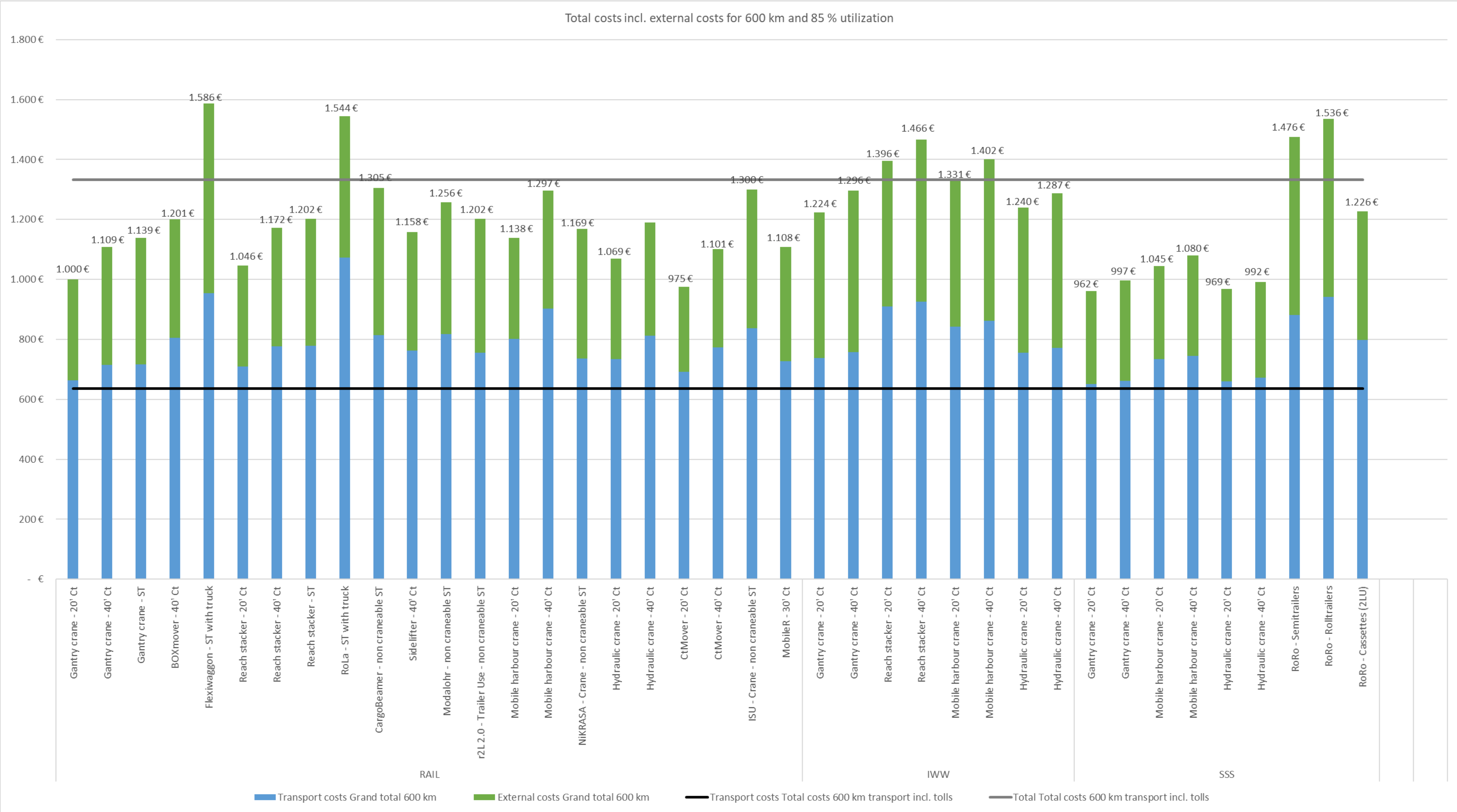
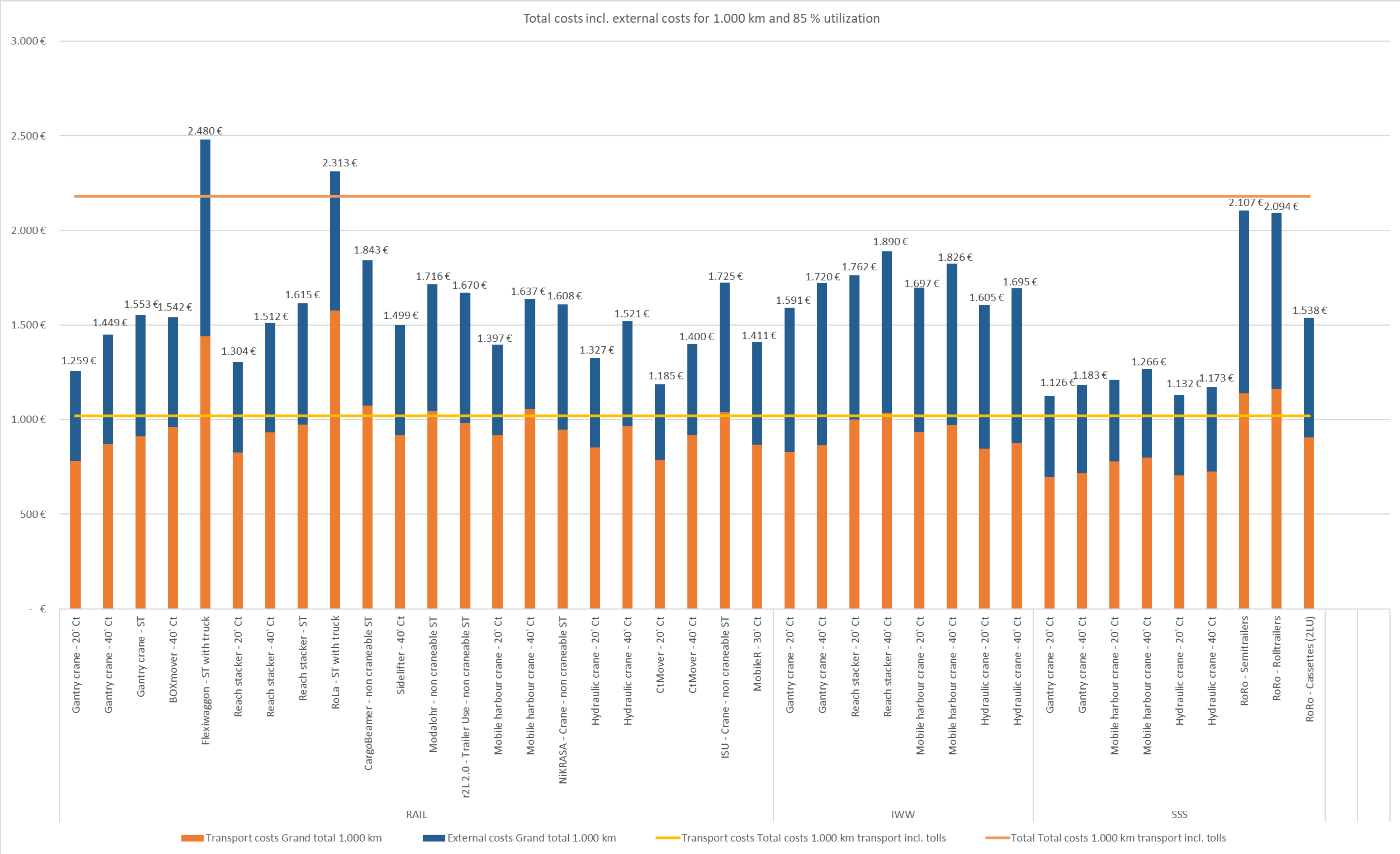


Figure 42: Total system costs incl. ~~external costs for the 1 000 km model transport chain per LU~~



The ContainerMover technology with 20’ containers now showing the lowest overall comparative costs for rail technologies is due to the previously explained lower max. transhipment weight of the technology. For this reason, more loading units are transported per train and the transport as well as external costs are distributed over more loading units lowering the per unit costs.

For all entries the external costs of the 600 km intermodal transport chain are lower than the external costs of the road-only alternative.

When looking at the 1 000 km transport comparative costs including external costs, only the technologies for accompanied intermodal transport still show higher comparative costs than road-only transport. All other technology and loading unit combinations have lower comparative costs incl. external costs than road-only transport with some technologies even being only slightly above the road-only comparative costs excl. external costs.

6. GLOSSARY

Combined Transport (CT) is intermodal transport where the major part of the journey is by rail, inland waterways or sea and any initial and/or final leg carried out by road is as short as possible.[77].

Intermodal transport is movement of goods (in one and the same loading unit or a vehicle) by successive modes of transport without handling of the goods themselves when changing modes. Vehicle can be a road or rail vehicle or a vessel. It is hence a type of multimodal transport.[78]

Multimodal transport is carriage of goods by at least two different modes of transport.[79]

Horizontal transhipment describes a transhipment process during which the transhipped loading unit is not lifted up or is lifted only a small amount to release it from the transport locks. Horizontal transhipment technologies can usually be used under the overhead line (catenary).

Vertical transhipment on the other hand describes a transhipment process during which the loading unit is subjected to a high vertical lift in order to be moved between the different modes of transport. These technologies cannot be used under the overhead line (catenary).

Accompanied intermodal transport describes a form of transport where the loading unit is transported by rail, inland waterway or sea and is accompanied by the tractor unit and the road vehicle driver.

Unaccompanied intermodal transport describes the transport of loading units on rail, inland waterway or sea without the accompanying driver and usually also without the tractor unit.

(European) **Technical Readiness Levels** (TRL) describe on a scale ranging from 1 to 9 the technical readiness of a certain technology, with 1 representing the lowest and 9 the highest TRL.

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[77] REFIT Ex-Post Evaluation of the CT Directive 92/106/EEC in 2016; https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2016)140&lang=de

[78] Ibidem

[79] Ibidem

7. Annexes

7.1 Annex 1: Technology fact sheets

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1 FACT SHEET FOR "GANTRY CRANE (WITH/WITHOUT CANTILEVER)"

1.1 Fact sheet for "Gantry Crane (with/without cantilever) – Rail/Road"

Picture of the technology:

Source: www.kuenz.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

A gantry crane consists of the crane system, the trolley, the rail system and the lifting equipment.
The crane system consists of two legs that are connected via a crossbeam and form a gantry. There is a fixed leg and a swinging leg to compensate for temperature-related deformations. The legs usually run-on tracks along the working area under the gantry. A gantry crane version with rubber wheels is also available. If the crossbeam extends beyond the supports, this is called a cantilever and thus increases the working area.
Other components are the trolley, which travels along the crossbeam, and the rail system on which the crane travels. The trolley consists of the lifting mechanism on which the spreader for picking up the loading unit is suspended from steel cables, and the crane operator's cabin which enables the crane operator to control the crane.
In addition to this standard crane, other elements can be added in some cases and elements described can be omitted. For example, a crane operator's cabin can be omitted if the crane is remote-controlled or operates automatically.
In the case of the spreader, a distinction must be made as to which loading units it is to handle. If it is only intended for containers, a simple spreader is sufficient that moves into the corner castings of the loading units with the help of twist locks, locks them and then the loading unit is lifted. After the loading unit has been set down, the twist locks are unlocked and the spreader is removed from the loading unit. If semi-trailers or swap bodies without corner castings are to be handled, grappler arms are required that grip the loading units from the side at their grappler pockets.

Process:

- Crane moves to the loading unit (storage) or loading unit is moved under the crane (Semi-trailer);
- crane moves over the loading unit with the trolley and lowers the spreader;
- spreader grips the loading unit or locks the twist locks;
- trolley lifts the loading unit;
- crane moves to destination;
- trolley lowers spreader with loading unit;

- spreader is opened or unlocked;
- spreader is lifted and crane moves to next order.

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network	

Indicative qualitative assessment:

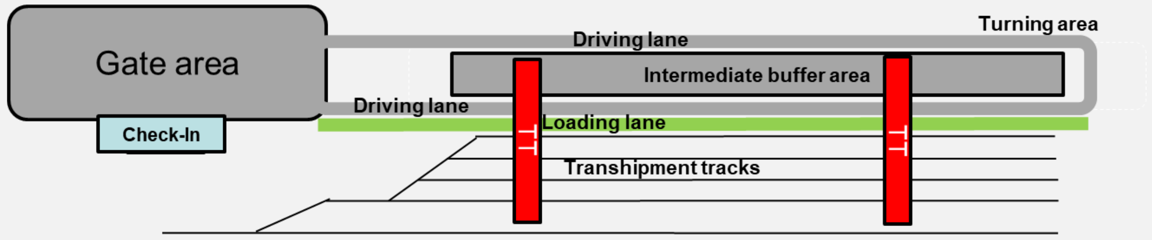
Strengths	Weaknesses and limitations
• Standardised system and compatible with common craneable loading units; • fast transhipment rate; • automation and digitalisation easy to implement; • remote control is more employee-friendly (more interesting for employee recruitment); • large working area is covered, which is used very efficiently (a lot of storage area and transhipment area in relation to the traffic area of the crane (crane track)); • compact storage area under crane, which can be used to 100%; • efficient technology for consumption and transhipment speed; • low life cycle costs; • long service life.	• High investment costs; • large area is necessary to take advantage of; • further terminal infrastructure necessary; • mostly fixed on rails.

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	41 t

1.1.1 Fact Sheet "Gantry Crane (with/without cantilever) – Rail/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Loco, Sggrss 80' rail wagons or similar

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 20' containers on Sggrss 80' wagons with no further special equipment (assuming 85% load factor)	64 (54)
For 40' containers on Sggrss 80' wagons with no further special equipment (assuming 85% load factor)	50 (43)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,0 min
	Handling equipment driver	2,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	2,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		

Transhipment of LU:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	20’: 63,2 min 40’: 98,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	20’: 73,2 min 40’: 108,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	2,0 min
	Truck driver	4,0 min
Handover duration per LU:	**Total LU**	4,0 min
Check-out: The truck drives to the exit and checks out of the terminal		

Drive from drop-off/parking:		Truck driver	2 min
Check-out duration per LU:		**Total LU**	2 min
Total time for the transhipment of one LU:	**Loading**	• All process steps: 11 min • Only Transhipment: 4 min	
	Unloading	• All process steps: 8 min • Only Transhipment: 4 min	
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min	
	Unloading	• 6 min	
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20'-Container: 108 min • 40'-Container: 86 min	
	Unloading	• 20'-Container: 108 min • 40'-Container: 86 min	
Total time for loading /unloading one train (incl. headway):	**Loading**	• 20'-Container: 181 min • 40'-Container: 195 min	
	Unloading	• 20'-Container: 148 min • 40'-Container: 126 min	
Trains that can be handled in an 8-hour shift:		• 20'-Container: 1,94 • 40'-Container: 2,44	

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	162 min 162 min 486 min 216 min 0 min 0 min 30 min 30 min 63 min 10 min 1.159 min	129 min 129 min 387 min 172 min 0 min 0 min 30 min 30 min 99 min 10 min 986 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km.	Train driver: Train dispatcher:	675 min 338 min	675 min 338 min

Duration: 675 min			
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	0 min 0 min 324 min 216 min 0 min 30 min 0 min 30 min 0 min 10 min 610 min	0 min 0 min 258 min 172 min 0 min 30 min 0 min 30 min 0 min 10 min 500 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	29,24 h	29,10 h
	600 km	19,24 h	19,10 h
Total working hours transport chain	**1.000 km**	208 h	173 h
	600 km	193 h	158 h
Total working hours per LU	**1.000 km**	3,85 h	4,03 h
	600 km	3,57 h	3,68 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	740,0 m	2,6 m	3	90 €/m²	5.772 m²	519.480 €
Intermediate buffer area (non-stackable)	0,0 m	0,0 m	0	80 €/m²	- m²	- €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	- m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €

Transhipment track	740,0 m	4,7 m	4	1.000 €/m	13.912 m²	2.960.000 €
Terminal switch	30,0 m	5,0 m	3	62.500 €/unit	450 m²	187.500 €
Buffer stop	15,0 m	4,7 m	4	12.000 €/unit	282 m²	48.000 €
Crane tracks	740,0 m	3,0 m	2	1.250 €/m	4.440 m²	1.850.000 €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	0	90 €/m²	- m²	- €
Total area complete terminal					39.486 m²	
Structural engineering (50 €/m²)						1.974.300 €
Earthworks and civil engineering (100 €/m²)						3.948.600 €
Building costs terminal						12.748.855 €
Planning costs 20%						2.549.771 €
Total building costs complete terminal						15.298.626 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						7.098.562 €
Maximum value based on European construction cost index						22.241.142 €
Depreciation time terminal (years)					25	
Terminal building costs per year						1.033.786 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Gantry crane	3.550.000 €	2	7.100.000 €	25
Spreader	100.000 €	2	200.000 €	10

Equipment costs terminal	**Investment costs**	7.300.000 €
	Planning costs (20%)	1.460.000 €
	Total	8.760.000 €
Total equipment costs terminal per year		605.330 €

Initial investment costs complete terminal and equipment incl. planning costs	24.058.626 €
Total investment costs complete terminal and equipment per year	1.639.115 €

1.1.1.1 Fact Sheet "Gantry Crane (with/without cantilever) – Rail/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	105.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	637.443 €
Gantry crane	2,8	198.800 €
Spreader	2,8	5.600 €
Total maintenance costs per year		841.843 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	43.435 kWh	5.429 €
Gantry Crane	Electricity	2,5 kWh	525.000 kWh	65.625 €
Total energy costs per year				71.054 €

Terminal energy costs range in EU	
Minimum value electricity costs	33.317 €
Maximum value electricity costs	103.012 €
Minimum value diesel costs	-
Maximum value diesel costs	-
Minimum value total energy costs	33.317 €
Maximum value diesel energy costs	103.012 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €

Total terminal personnel costs per year	644.750 €
Terminal personnel costs range in EU	
Minimum value personnel costs	139.653 €
Maximum value personnel costs	1.040.445 €

Total area costs (5,00 €/m² per year)	197.430 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 394.860 €

Total costs per year	3.394.192 €

Cost per transhipment for total terminal investment		15,61 €
Operational costs per transhipment	**Personnel costs**	6,14 €
	Energy costs	0,68 €
	Maintenance costs	8,02 €
	Total	14,83 €
Ground costs per transhipment		1,88 €
Total costs for one transhipment		32,33 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		16,91 €
Maximum value total costs transhipment		45,36 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Sggrss 80' wagon	85.000 €	16	1.360.000 €	40	15,73 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					6.360.000 €
Total investment costs per operating hour					73,54 €
Main leg equipment maintenance costs					

Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Sggrss 80' wagons	7	96.000 €	20,00 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			82,50 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.389 kWh	173,68 €
Total energy costs per operating hour				173,68 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption

Consumer	Energy type	Consumption per 100 km	Consumption per hour	Costs per operating hour
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	4.717 €	87,35 €
First transhipment	1.746 €	32,33 €
450 km main leg	6.196 €	114,75 €
850 km main leg	11.210 €	207,59 €
Second transhipment	1.746 €	32,33 €
Second road leg	4.575 €	84,72 €
LU costs transport chain 600 km main leg	89 €	1,65 €
LU costs transport chain 1.000 km main leg	136 €	2,51 €
Intermodal organizational costs 600 km main leg (25%)	4.767,11 €	88,28 €
Intermodal organizational costs 1.000 km main leg (25%)	6.031,99 €	111,70 €
Grand total 600 km	19.068 €	441,40 €
Grand total 1.000 km	24.128 €	558,52 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	410,56 €
Maximum value costs range 600 km transport in EU	467,47 €
Minimum value costs range 1.000 km transport in EU	527,68 €
Maximum value costs range 1.000 km transport in EU	584,59 €

External costs			
		Total	**Per LU**

First road leg	**75 km**	4.778 €	88,49 €
First transhipment		4 €	0,07 €
Main leg	**450 km**	8.597 €	159,21 €
	850 km	16.239 €	300,72 €
Second transhipment		4 €	0,07 €
Second road leg	**75 km**	4.778 €	88,49 €
Full transport chain per LU	**600 km**	18.154 €	336,33 €
	1.000 km	25.795 €	477,84 €

1.1.1.2 Fact Sheet "Gantry Crane (with/without cantilever) – Rail/Road – 40' Container"

Total terminal handling capacity per year (transhipments)	105.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	637.443 €
Gantry crane	2,8	198.800 €
Spreader	2,8	5.600 €
Total maintenance costs per year		841.843 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	43.435 kWh	5.429 €
Gantry Crane	Electricity	2,5 kWh	525.000 kWh	65.625 €
Total energy costs per year				71.054 €

Terminal energy costs range in EU	
Minimum value electricity costs	33.317 €
Maximum value electricity costs	103.012 €
Minimum value diesel costs	-
Maximum value diesel costs	-
Minimum value total energy costs	33.317 €
Maximum value diesel energy costs	103.012 €

Terminal personnel

Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				644.750 €
Terminal personnel costs range in EU				
Minimum value personnel costs				139.653 €
Maximum value personnel costs				1.040.445 €

Total area costs (5,00 €/m² per year)	197.430 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 394.860 €

Total costs per year	3.394.192 €

Cost per transhipment for total terminal investment		15,61 €
Operational costs per transhipment	Personnel costs	6,14 €
	Energy costs	0,68 €
	Maintenance costs	8,02 €
	Total	14,83 €
Ground costs per transhipment		1,88 €
Total costs for one transhipment		32,33 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		16,91 €
Maximum value total costs transhipment		45,36 €

Loading unit investments and costs:				
Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Sggrss 80' wagon	85.000 €	25	2.125.000 €	40	24,57 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.125.000 €
Total investment costs per operating hour					82,39 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Sggrss 80' wagons	7	150.000 €	31,25 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			93,75 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.451 kWh	181,34 €
Total energy costs per operating hour				181,34 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €

Reasonable fleet size (truck/semi-trailer ratio)	Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

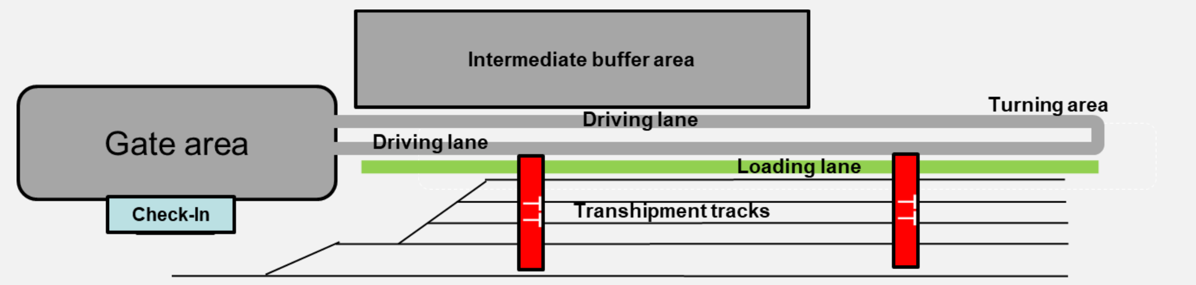
Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	3.756 €	87,35 €
First transhipment	1.390 €	32,33 €
450 km main leg	6.651 €	154,67 €
850 km main leg	11.941 €	277,71 €
Second transhipment	1.390 €	32,33 €
Second road leg	3.643 €	84,72 €
LU costs transport chain 600 km main leg	99 €	2,30 €
LU costs transport chain 1.000 km main leg	148 €	3,43 €
Intermodal organizational costs 600 km main leg (25%)	4.232,06 €	98,42 €
Intermodal organizational costs 1.000 km main leg (25%)	5.566,96 €	129,46 €
Grand total 600 km	16.928 €	492,10 €
Grand total 1.000 km	22.268 €	647,32 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	461,27 €
Maximum value costs range 600 km transport in EU	518,17 €
Minimum value costs range 1.000 km transport in EU	616,49 €
Maximum value costs range 1.000 km transport in EU	673,40 €

External costs			
		Total	Per LU
First road leg	75 km	3.980 €	92,57 €
First transhipment		3 €	0,07 €
Main leg	450 km	8.976 €	208,75 €
	850 km	16.955 €	394,31 €
Second transhipment		3 €	0,07 €
Second road leg	75 km	3.980 €	92,57 €
Full transport chain per LU	600 km	16.937 €	394,03 €
	1.000 km	24.916 €	579,59 €

1.1.2 Fact Sheet “Gantry Crane (with/without cantilever) – Rail/Road – Semi-trailer”

Description of our model terminal:



Necessary road leg equipment:	Truck
Necessary main leg equipment:	Loco, T3000e rail wagons or similar

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For Semi-trailer craneable on T3000e wagons with no further special equipment (assuming 85% load factor)	42 (36)

Detailed description of the transhipment process:		
Process steps loading main leg	Involved personnel	Time

Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5,0 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	3,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	8,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	3,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	3,0 min
Transhipment duration per LU:	**Total LU**	3,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	82,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	92,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		

Transhipment:	Handling equipment driver	3,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	3,0 min
Transhipment duration per LU:	**Total LU**	3,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	5,0 min
Handover of loading unit to truck:	Handling equipment driver	0,0 min
	Truck driver	5,0 min
Handover duration per LU:	**Total LU**	10,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 18 min • Only Transhipment: 3 min
	Unloading	• All process steps: 15 min • Only Transhipment: 3 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min
	Unloading	• 7 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 54 min
	Unloading	• 54 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 147 min
	Unloading	• 94 min
Trains that can be handled in an 8-hour shift:		• 3,89

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:**
		Semi-trailer
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min

First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	108 min 108 min 432 min 108 min 108 min 108 min 30 min 30 min 83 min 10 min 1.125 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	0 min 0 min 252 min 108 min 180 min 30 min 108 min 30 min 0 min 10 min 718 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	27,76 h
	600 km	17,76 h
Total working hours transport chain	**1.000 km**	160 h
	600 km	145 h
Total working hours per LU	**1.000 km**	4,46 h
	600 km	4,04 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				

Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	0	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	740,0 m	32,0 m	1	80 €/m²	23.680 m²	1.894.400 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	4	1.000 €/m	13.912 m²	2.960.000 €
Terminal switch	30,0 m	5,0 m	3	62.500 €/unit	450 m²	187.500 €
Buffer stop	15,0 m	4,7 m	4	12.000 €/unit	282 m²	48.000 €
Crane tracks	740,0 m	4,7 m	2	1.250 €/m	6.956 m²	1.850.000 €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	0	90 €/m²	m²	- €
Total area complete terminal					59.910 m²	
Structural engineering (50 €/m²)						2.995.500 €
Earthworks and civil engineering (100 €/m²)						5.991.000 €
Building costs terminal						17.187.375 €
Planning costs 20%						3.437.475 €
Total building costs complete terminal						20.624.850 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						9.569.930 €
Maximum value based on European construction cost index						29.984.407 €
Depreciation time terminal (years)					25	
Terminal building costs per year						1.393.699 €
Terminal equipment						

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Gantry crane	3.550.000 €	2	7.100.000 €	25
Spreader with gripper arms	150.000 €	2	300.000 €	10
Terminal truck	150.000 €	4	600.000 €	5
Equipment costs terminal	**Investment costs**		8.000.000 €	
	Planning costs (20%)		1.600.000 €	
	Total		9.600.000 €	
Total equipment costs terminal per year			778.513 €	

Initial investment costs complete terminal and equipment incl. planning costs	30.224.850 €
Total investment costs complete terminal and equipment per year	2.172.212 €

Total terminal handling capacity per year (transhipments)	140.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	859.369 €
Gantry crane	2,8	198.800 €
Spreader with gripper arms	2,8	8.400 €
Terminal truck	2,8	16.800 €
Total maintenance costs per year		1.083.369 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	65.901 kWh	8.238 €
Gantry Crane	Electricity	2,5 kWh	350.000 kWh	43.750 €
Terminal truck	Diesel	1,2 l	168.000 l	188.160 €
Total energy costs per year				240.148 €

Terminal energy costs range in EU	
Minimum value electricity costs	24.377 €
Maximum value electricity costs	75.370 €
Minimum value diesel costs	154.981 €

Maximum value diesel costs	229.933 €
Minimum value total energy costs	179.358 €
Maximum value diesel energy costs	305.303 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1,5	5	26.500 €	132.500 €
Gate agent	1,5	5	33.000 €	165.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	3,5	11,5	32.000 €	368.000 €
Instructor “Groundsman”	2,5	8,5	31.000 €	263.500 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				1.303.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				282.338 €
Maximum value personnel costs				2.103.482 €

Total area costs (5,00 €/m² per year)	299.550 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 599.100 €

Total costs per year	5.098.778 €

Cost per transhipment for total terminal investment		15,52 €
Operational costs per transhipment	**Personnel costs**	9,31 €
	Energy costs	1,72 €
	Maintenance costs	7,74 €
	Total	18,76 €
Ground costs per transhipment		2,14 €
Total costs for one transhipment		36,42 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		18,24 €

Maximum value total costs transhipment	51,78 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
Semi-trailer craneable	27.000 €	11	810,00 €	0,81 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
T3000e	140.000 €	21	2.940.000 €	40	34,00 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.940.000 €
Total investment costs per operating hour					91,82 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
T3000e	5	146.790 €	30,58 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			93,08 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.428 kWh	178,53 €
Total energy costs per operating hour				178,53 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)	**600 km**		1:3,0
	1.000 km		1:4,2

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	3.156 €	87,66 €
First transhipment	1.311 €	36,42 €
450 km main leg	6.673 €	185,35 €
850 km main leg	12.023 €	333,97 €
Second transhipment	1.311 €	36,42 €
Second road leg	3.003 €	83,42 €

LU costs transport chain 600 km main leg	520 €	14,45 €
LU costs transport chain 1.000 km main leg	798 €	22,17 €
Intermodal organizational costs 600 km main leg (25%)	3.993,55 €	110,93 €
Intermodal organizational costs 1.000 km main leg (25%)	5.400,52 €	150,01 €
Grand total 600 km	15.974 €	554,66 €
Grand total 1.000 km	21.602 €	750,07 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		518,29 €
Maximum value costs range 600 km transport in EU		585,38 €
Minimum value costs range 1.000 km transport in EU		713,70 €
Maximum value costs range 1.000 km transport in EU		780,79 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	3.185 €	88,49 €
First transhipment		14 €	0,40 €
Main leg	**450 km**	8.837 €	245,48 €
	850 km	16.693 €	463,68 €
Second transhipment		14 €	0,40 €
Second road leg	**75 km**	3.185 €	88,49 €
Full transport chain per LU	**600 km**	15.208 €	423,25 €
	1.000 km	23.063 €	641,45 €

1.2 Fact sheet for "Gantry Crane (with/without cantilever) – IWW/Road"

Picture of the technology:

Source: www.kuenz.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

A gantry crane consists of the crane system, the trolley, the rail system and the lifting equipment. The crane system consists of two legs that are connected via a crossbeam and form a gantry. There is a fixed leg and a swinging leg to compensate for temperature-related deformations. The legs usually run-on tracks along the working area under the gantry. A gantry crane version with rubber wheels is also available. If the crossbeam extends beyond the supports, this is called a cantilever and thus increases the working area.

Other components are the trolley, which travels along the crossbeam, and the rail system on which the crane travels. The trolley consists of the lifting mechanism on which the spreader for picking up the loading unit is suspended from steel cables, and the crane operator's cabin which enables the crane operator to control the crane.

In addition to this standard crane, other elements can be added in some cases and elements described can be omitted. For example, a crane operator's cabin can be omitted if the crane is remote-controlled or operates automatically.

In the case of the spreader, a distinction must be made as to which loading units it is to handle. If it is only intended for containers, a simple spreader is sufficient that moves into the corner castings of the loading units with the help of twist locks, locks them and then the loading unit is lifted. After the loading unit has been set down, the twist locks are unlocked and the spreader is removed from the loading unit. If semi-trailers or swap bodies without corner castings are to be handled, grappler arms are required that grip the loading units from the side at their grappler pockets.

Process:

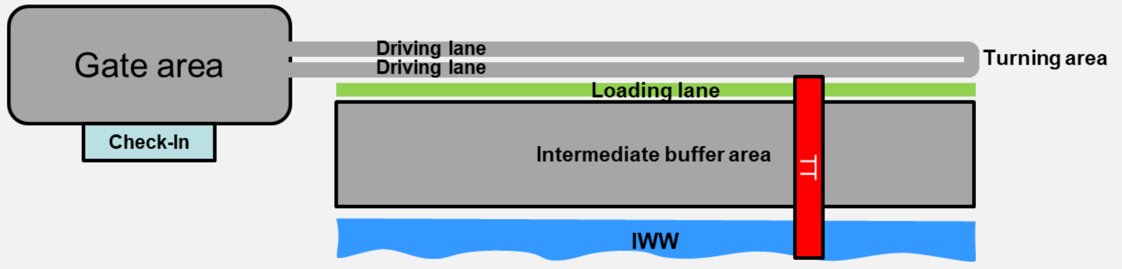
- Crane moves to the loading unit (storage) or loading unit is moved under the crane (Semi-trailer);
- crane moves over the loading unit with the trolley and lowers the spreader;

- spreader grips the loading unit or locks the twist locks;
- trolley lifts the loading unit;
- crane moves to destination;
- trolley lowers spreader with loading unit;
- spreader is opened or unlocked;
- spreader is lifted and crane moves to next order.

<table>
<tr><td rowspan="2">Classification</td><td>☐ Horizontal</td><td>☒ Vertical</td></tr>
<tr><td>☐ Accompanied</td><td>☒ Unaccompanied</td></tr>
<tr><td>Connected modes of transport</td><td>☒ Rail
☒ Inland waterway</td><td>☒ Short Sea
☒ Road</td></tr>
<tr><td>Technical readiness level and prevalence of the technology:</td><td colspan="2">TRL 9: Widespread technology, dense European network</td></tr>
<tr><td colspan="3">Indicative qualitative assessment:</td></tr>
<tr><td>Strengths</td><td colspan="2">Weaknesses and limitations</td></tr>
<tr><td>• Standardised system and compatible with common craneable loading units;
• fast transhipment rate;
• automation and digitalisation easy to implement;
• remote control is more employee-friendly (more interesting for employee recruitment);
• large working area is covered, which is used very efficiently (a lot of storage area and transhipment area in relation to the traffic area of the crane (crane track));
• compact storage area under crane, which can be used to 100%;
• efficient technology for consumption and transhipment speed;
• low life cycle costs;
• long service life.</td><td colspan="2">• High investment costs;
• large area is necessary to take advantage of;
• further terminal infrastructure necessary;
• mostly fixed on rails.</td></tr>
<tr><td colspan="3">Transhipable loading units:</td></tr>
<tr><td>Type of loading unit</td><td colspan="2">Sizes, exceptions and limitations</td></tr>
<tr><td>• ISO container</td><td colspan="2">• All</td></tr>
<tr><td>• Inland container</td><td colspan="2">• All craneable</td></tr>
<tr><td>• Swap body</td><td colspan="2">• All craneable</td></tr>
<tr><td>• Semi-trailer</td><td colspan="2">• Yes; top lift or with grappler pockets</td></tr>
<tr><td>• Complete road vehicle</td><td colspan="2">• Not possible</td></tr>
<tr><td colspan="2">Transhipable max. weight (loaded goods plus loading unit weight):</td><td>41 t</td></tr>
</table>

1.2.1 Fact Sheet "Gantry Crane (with/without cantilever) – IWW/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Barges (110 m, 2.800 t, 200 TEU)

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 20' containers on barge with no further special equipment (assuming 85% load factor)	126 (107)
For 40' containers on barge with no further special equipment (assuming 85% load factor)	100 (85)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,0 min
	Handling equipment driver	2,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	2,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		

Transhipment of LU:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	30 min
Further procedures for departure:	non	0 min
Departure:	Crew	25 min
Departure duration:	**Total**	40 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	25 min
Further arrival procedures:	non	0 min
Terminal check-in:	Groundsman ship	30 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	2,0 min
	Truck driver	4,0 min
Handover duration per LU:	**Total LU**	4,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 11 min • Only Transhipment: 4 min
	Unloading	• All process steps: 8 min • Only Transhipment: 4 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one ship (excl. headway):	**Loading**	• 20'-Container: 428 min • 40'-Container: 340 min
	Unloading	• 20'-Container: 428 min • 40'-Container: 340 min
Total time for loading /unloading one ship (incl. headway):	**Loading**	• 20'-Container: 468 min • 40'-Container: 380 min
	Unloading	• 20'-Container: 468 min • 40'-Container: 380 min
Trains that can be handled in an 8-hour shift:		• 20'-Container: 0,49 • 40'-Container: 0,62

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full ship: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	321 min 321 min 963 min 428 min 0 min 0 min 30 min 30 min 25 min 2118 min	255 min 255 min 765 min 340 min 0 min 0 min 31 min 30 min 25 min 1701 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 3.400 min**	Crew:	3.400 min	3.400 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 1.800 min**	Crew:	1.800 min	1.800 min
Second transhipment full ship: The LU is transhipped using the transhipment	Checker Gate agent Truck driver	0 min 0 min 642 min	0 min 0 min 510 min

technology as described in detail above.	Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	428 min 0 min 30 min 0 min 0 min 25 min 1125 min	340 min 0 min 31 min 0 min 0 min 25 min 906 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	74,77 h	71,83 h
	600 km	48,10 h	45,17 h
Total working hours transport chain	**1.000 km**	514 h	444 h
	600 km	434 h	364 h
Total working hours per LU	**1.000 km**	4,80 h	5,22 h
	600 km	4,05 h	4,28 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	240,0 m	3,5 m	2	80 €/m²	1.680 m²	134.400 €
Loading lane	240,0 m	3,5 m	1	80 €/m²	840 m²	67.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	240,0 m	2,6 m	4	90 €/m²	2.496 m²	224.640 €
Inland port quay per metre	240,0 m	10,0 m	1	45.000 €/m	2.400 m²	10.800.000 €
Crane tracks	240,0 m	3,0 m	2	1.250 €/m	1.440 m²	600.000 €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	0	90 €/m²	m²	- €
Total area complete terminal					15.481 m²	

<table>
<tr><td>Structural engineering (50 €/m²)</td><td colspan="4">774.050 €</td></tr>
<tr><td>Earthworks and civil engineering (100 €/m²)</td><td colspan="4">1.548.100 €</td></tr>
<tr><td>Building costs terminal</td><td colspan="4">14.675.265 €</td></tr>
<tr><td>Planning costs 20%</td><td colspan="4">2.935.053 €</td></tr>
<tr><td>Total building costs complete terminal</td><td colspan="4">17.610.318 €</td></tr>
<tr><td colspan="5">Terminal building costs range in EU</td></tr>
<tr><td>Minimum value based on European construction cost index</td><td colspan="4">8.171.188 €</td></tr>
<tr><td>Maximum value based on European construction cost index</td><td colspan="4">25.601.880 €</td></tr>
<tr><td>Depreciation time terminal (years)</td><td colspan="4">25</td></tr>
<tr><td>Terminal building costs per year</td><td colspan="4">1.189.995,58 €</td></tr>
<tr><td colspan="5">Terminal equipment</td></tr>
<tr><td>Equipment</td><td>Unit costs</td><td>Number of units (#)</td><td>Total costs</td><td>Depreciation time (years)</td></tr>
<tr><td>Gantry crane</td><td>3.550.000 €</td><td>1</td><td>3.550.000 €</td><td>25</td></tr>
<tr><td>Spreader</td><td>100.000 €</td><td>1</td><td>100.000 €</td><td>10</td></tr>
<tr><td rowspan="3">Equipment costs terminal</td><td colspan="2">Investment costs</td><td colspan="2">3.650.000 €</td></tr>
<tr><td colspan="2">Planning costs (20%)</td><td colspan="2">730.000 €</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">4.380.000 €</td></tr>
<tr><td>Total equipment costs terminal per year</td><td colspan="4">302.665 €</td></tr>
</table>

Initial investment costs complete terminal and equipment incl. planning costs	21.990.318 €
Total investment costs complete terminal and equipment per year	1.492.660 €

1.2.1.1 Fact Sheet "Gantry Crane (with/without cantilever) – IWW/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	52.500

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	733.763 €
Gantry crane	2,8	99.400
Spreader	2,8	2.800 €
Total maintenance costs per year		835.963 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	17.029 kWh	2.129 €
Gantry Crane	Electricity	2,5 kWh	262.500 kWh	32.813 €
Total energy costs per year				34.941 €

Terminal energy costs range in EU	
Minimum value electricity costs	16.384 €
Maximum value electricity costs	50.656 €
Minimum value diesel costs	-
Maximum value diesel costs	-
Minimum value total energy costs	16.384 €
Maximum value diesel energy costs	50.656 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	33.000 €	66.000 €
Gate agent	1	3,5	35.000 €	122.500 €
Handling equipment driver	0	0	32.000 €	- €
Terminal truck driver	0	0	31.000 €	- €
Instructor "Groundsman"	1	3,5	37.000 €	129.500 €
Dispatcher	0,5	2	26.500 €	53.000 €

Total terminal personnel costs per year	371.000 €
Terminal personnel costs range in EU	
Minimum value personnel costs	80.359 €
Maximum value personnel costs	598.690 €

Total area costs (5,00 €/m² per year)	77.405 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 154.810 €

Total costs per year	2.811.970 €

Cost per transhipment for total terminal investment		28,43 €
Operational costs per transhipment	**Personnel costs**	7,07 €
	Energy costs	0,67 €
	Maintenance costs	15,92 €
	Total	23,66 €
Ground costs per transhipment		1,47 €
Total costs for one transhipment		53,56 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		30,96 €
Maximum value total costs transhipment		72,57 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €

Total main leg investment costs	3.000.000 €
Total investment costs per operating hour	38,72 €

Main leg equipment maintenance costs

Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour

Barge (110 m)	2,7	80.000 €		16,67 €
Total maintenance costs per operating hour				16,67 €
Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Barge (110 m)	Gas oil	0,006	233 l	167,42 €
Total energy costs per operating hour				167,42 €
Other operational costs main leg				
Cost type	**Costs per km**		**Costs per operating hour**	
Inland shipping tax	0,00 €		0 €	
Total other operational costs per operating hour			0 €	
Personnel costs main leg				
Function			**Costs per operating hour**	
Crew			60,40 €	

Road leg investments				
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**	
Truck	100.000 €	9	3,83 €	
Chassis	26.000 €	11	0,85 €	
Total road leg investment costs			126.000 €	
Total investment costs per operating hour			4,68 €	
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant	
Road leg equipment maintenance costs				
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**	
Truck	10%	10.000,00 €	2,86 €	
Chassis	10%	2.600,00 €	0,74 €	
Total maintenance costs per operating hour			3,60 €	
Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				
Cost type	**Costs per km**	**Costs per leg**		

Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	9.346 €	87,35 €
First transhipment	5.731 €	53,56 €
450 km main leg	13.778 €	128,77 €
850 km main leg	21.330 €	199,35 €
Second transhipment	5.731 €	53,56 €
Second road leg	9.065 €	84,72 €
LU costs transport chain 600 km main leg	442 €	4,13 €
LU costs transport chain 1.000 km main leg	687 €	6,42 €
Intermodal organizational costs 600 km main leg (25%)	11.023,34 €	103,02 €
Intermodal organizational costs 1.000 km main leg (25%)	12.972,64 €	121,24 €
Grand total 600 km	44.093 €	515,11 €
Grand total 1.000 km	51.891 €	606,20 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	469,90 €
Maximum value costs range 600 km transport in EU	553,14 €
Minimum value costs range 1.000 km transport in EU	560,99 €
Maximum value costs range 1.000 km transport in EU	644,22 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	2.525 €	23,60 €
First transhipment		8 €	0,07 €
Main leg	**450 km**	33.135 €	309,67 €
	850 km	62.588 €	584,93 €
Second transhipment		8 €	0,07 €

Second road leg	**75 km**	2.525 €	23,60 €
Full transport chain per LU	**600 km**	38.184 €	357,01 €
	1.000 km	67.637 €	632,27 €

1.2.1.2 Fact Sheet “Gantry Crane (with/without cantilever) – IWW/Road – 40’ Container”

Total terminal handling capacity per year (transhipments)	52.500

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	733.763 €
Gantry crane	2,8	99.400 €
Spreader	2,8	2.800 €
Total maintenance costs per year		835.963 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	17.029 kWh	2.129 €
Gantry Crane	Electricity	2,5 kWh	262.500 kWh	32.813 €
Total energy costs per year				34.941 €

Terminal energy costs range in EU	
Minimum value electricity costs	16.384 €
Maximum value electricity costs	50.656 €
Minimum value diesel costs	- €
Maximum value diesel costs	- €
Minimum value total energy costs	16.384 €
Maximum value diesel energy costs	50.656 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	1	3,5	35.000 €	122.500 €

Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0	0	31.000 €	- €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				371.000 €
Terminal personnel costs range in EU				
Minimum value personnel costs				80.359 €
Maximum value personnel costs				598.690 €

Total area costs (5,00 €/m² per year)	77.405 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 154.810 €

Total costs per year	2.811.970 €

Cost per transhipment for total terminal investment		28,43 €
Operational costs per transhipment	**Personnel costs**	7,07 €
	Energy costs	0,67 €
	Maintenance costs	15,92 €
	Total	23,66 €
Ground costs per transhipment		1,47 €
Total costs for one transhipment		53,56 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		30,96 €
Maximum value total costs transhipment		72,57 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40' Container	3.000 €	12	90 €	0,09 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €
Total main leg investment costs					3.000.000 €

Total investment costs per operating hour	38,72 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Barge (110 m)	2,7	80.000 €	16,67 €
Total maintenance costs per operating hour			16,67 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Barge (110 m)	Gas oil	0,006	211 l	152,19 €
Total energy costs per operating hour				152,19 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Inland shipping tax	0,00 €	0 €
Total other operational costs per operating hour		0 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	60,40 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption

Consumer	Energy type	Consumption per 100 km	Consumption per hour	Costs per operating hour
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				
Cost type	**Costs per km**		**Costs per leg**	
Tolls	0,187 €		11,22 €	
Personnel costs road leg				
Function			**Costs per operating hour**	
Truck driver			22,11 €	
Truck dispatcher			24,32 €	

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	7.425 €	87,35 €
First transhipment	4.553 €	53,56 €
450 km main leg	12.135 €	142,77 €
850 km main leg	19.281 €	226,84 €
Second transhipment	4.553 €	53,56 €
Second road leg	7.201 €	84,72 €
LU costs transport chain 600 km main leg	462 €	5,43 €
LU costs transport chain 1.000 km main leg	734 €	8,64 €
Intermodal organizational costs 600 km main leg (25%)	9.082,02 €	106,85 €
Intermodal organizational costs 1.000 km main leg (25%)	10.936,69 €	128,67 €
Grand total 600 km	36.328 €	534,24 €
Grand total 1.000 km	43.747 €	643,33 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	489,03 €
Maximum value costs range 600 km transport in EU	598,13 €
Minimum value costs range 1.000 km transport in EU	643,33 €
Maximum value costs range 1.000 km transport in EU	681,36 €

External costs			
		Total	**Per LU**

First road leg	**75 km**	2.098 €	24,68 €
First transhipment		6 €	0,07 €
Main leg	**450 km**	30.122 €	354,37 €
	850 km	56.896 €	669,37 €
Second transhipment		6 €	0,07 €
Second road leg	**75 km**	2.098 €	24,68 €
Full transport chain per LU	**600 km**	34.318 €	403,88 €
	1.000 km	61.093 €	718,88 €

2 Fact sheet for "Gantry Crane (with/without cantilever) – SSS/Road"

Picture of the technology:

Source: www.kuenz.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

A gantry crane consists of the crane system, the trolley, the rail system and the lifting equipment. The crane system consists of two legs that are connected via a crossbeam and form a gantry. There is a fixed leg and a swinging leg to compensate for temperature-related deformations. The legs usually run-on tracks along the working area under the gantry. A gantry crane version with rubber wheels is also available. If the crossbeam extends beyond the supports, this is called a cantilever and thus increases the working area.
Other components are the trolley, which travels along the crossbeam, and the rail system on which the crane travels. The trolley consists of the lifting mechanism on which the spreader for picking up the loading unit is suspended from steel cables, and the crane operator's cabin which enables the crane operator to control the crane.
In addition to this standard crane, other elements can be added in some cases and elements described can be omitted. For example, a crane operator's cabin can be omitted if the crane is remote-controlled or operates automatically.
In the case of the spreader, a distinction must be made as to which loading units it is to handle. If it is only intended for containers, a simple spreader is sufficient that moves into the corner castings of the loading units with the help of twist locks, locks them and then the loading unit is lifted. After the loading unit has been set down, the twist locks are unlocked and the spreader is removed from the loading unit. If semi-trailers or swap bodies without corner castings are to be handled, grappler arms are required that grip the loading units from the side at their grappler pockets.

Process:

- Crane moves to the loading unit (storage) or loading unit is moved under the crane (Semi-trailer);
- crane moves over the loading unit with the trolley and lowers the spreader;
- spreader grips the loading unit or locks the twist locks;
- trolley lifts the loading unit;

- crane moves to destination;
- trolley lowers spreader with loading unit;
- spreader is opened or unlocked;
- spreader is lifted and crane moves to next order.

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network	

Indicative qualitative assessment:

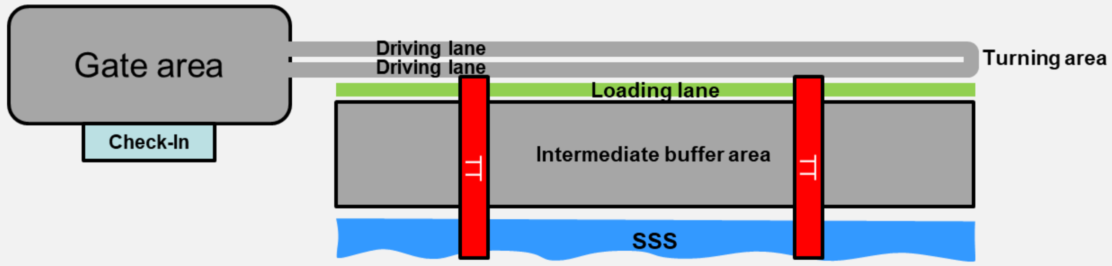
Strengths	Weaknesses and limitations
• Standardised system and compatible with common craneable loading units; • fast transhipment rate; • automation and digitalisation easy to implement; • remote control is more employee-friendly (more interesting for employee recruitment); • large working area is covered, which is used very efficiently (a lot of storage area and transhipment area in relation to the traffic area of the crane (crane track)); • compact storage area under crane, which can be used to 100%; • efficient technology for consumption and transhipment speed; • low life cycle costs; • long service life.	• High investment costs; • large area is necessary to take advantage of; • further terminal infrastructure necessary; • mostly fixed on rails.

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	41 t

2.1.1 Fact Sheet "Gantry Crane (with/without cantilever) – SSS/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Short sea container ships (1.000 TEU)

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:

For 20' containers on barge with no further special equipment (assuming 85% load factor)	585 (497)
For 40' containers on barge with no further special equipment (assuming 85% load factor)	500 (425)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,0 min
	Handling equipment driver	2,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	2,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		

Transhipment of LU:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	10 min
Further procedures for departure:	Crew	20 min
Departure:	Crew	10 min
Departure duration:	**Total**	30 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	10 min
Further arrival procedures:	Crew	20 min
Terminal check-in:	Groundsman ship	20 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	2,0 min
	Truck driver	4,0 min
Handover duration per LU:	**Total LU**	4,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 11 min • Only Transhipment: 4 min
	Unloading	• All process steps: 8 min • Only Transhipment: 4 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20'-Container: 994 min • 40'-Container: 850 min
	Unloading	• 20'-Container: 994 min • 40'-Container: 850 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 20'-Container: 1.024 min • 40'-Container: 880 min
	Unloading	• 20'-Container: 1.034 min • 40'-Container: 890 min
Trains that can be handled in an 8-hour shift:		• 20'-Container: 0,21 • 40'-Container: 0,25

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	1.491 min 1.491 min 4.473 min 1.988 min 0 min 0 min 30 min 50 min 240 min 9.763 min	1.275 min 1.275 min 3.825 min 1.700 min 0 min 0 min 30 min 50 min 240 min 8.395 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.619 min**	Crew:	1.619 min	1.619 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 857 min**	Crew:	857 min	857 min
Second transhipment full train: The LU is transhipped using the transhipment	Checker Gate agent Truck driver	0 min 0 min 2.982 min	0 min 0 min 2.550 min

technology as described in detail above.	Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	1.988 min 0 min 30 min 0 min 100 min 240 min 5.340 min	1.700 min 0 min 30 min 0 min 100 min 240 min 4.620 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	63,78 h	58,98 h
	600 km	51,09 h	46,29 h
Total working hours transport chain	**1.000 km**	1.814 h	1.584 h
	600 km	1.712 h	1.482 h
Total working hours per LU	**1.000 km**	3,65 h	3,73 h
	600 km	3,44 h	3,49 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	240,0 m	3,5 m	2	80 €/m²	1.680 m²	134.400 €
Loading lane	240,0 m	3,5 m	1	80 €/m²	840 m²	67.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	240,0 m	2,6 m	4	90 €/m²	2.496 m²	224.640 €
Inland port quay per metre	320,0 m	10,0 m	1	75.000 €/m	3.200 m²	24.000.000 €
Crane tracks	240,0 m	3,0 m	2	1.250 €/m	1.440 m²	600.000 €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	0	90 €/m²	m²	- €
Total area complete terminal					16.281 m²	

Structural engineering (50 €/m²)				814.050 €
Earthworks and civil engineering (100 €/m²)				1.628.100 €
Building costs terminal				27.995.265 €
Planning costs 20%				4.199.290 €
Total building costs complete terminal				32.194.555 €
Terminal building costs range in EU				
Minimum value based on European construction cost index				14.938.273 €
Maximum value based on European construction cost index				46.804.444 €
Depreciation time terminal (years)				25
Terminal building costs per year				2.175.507,42 €
Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Gantry crane	3.550.000 €	2	7.100.000 €	25
Spreader	100.000 €	2	200.000 €	10
Equipment costs terminal	**Investment costs**			7.300.000 €
	Planning costs (20%)			1.460.000 €
	Total			8.760.000 €
Total equipment costs terminal per year				605.330 €

Initial investment costs complete terminal and equipment incl. planning costs	40.954.555 €
Total investment costs complete terminal and equipment per year	2.780.837 €

2.1.1.1 Fact Sheet "Gantry Crane (with/without cantilever) – SSS/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	105.000

Terminal maintenance costs		
	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	1.399.763 €
Gantry crane	2,8	198.800 €
Spreader	2,8	5.600 €
Total maintenance costs per year		1.604.163 €

Terminal energy consumption				
Consumer	Energy type	Consumption per transhipment	Consumption per year	Energy costs per year
Infrastructure	Electricity	-	17.909 kWh	2.239 €
Gantry Crane	Electricity	2,5 kWh	525.000 kWh	65.625 €
Total energy costs per year				67.864 €

Terminal energy costs range in EU	
Minimum value electricity costs	31.821 €
Maximum value electricity costs	98.386 €
Minimum value diesel costs	- €
Maximum value diesel costs	- €
Minimum value total energy costs	31.821,26 €
Maximum value diesel energy costs	98.386,05 €

Terminal personnel				
Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	0	0	37.000 €	- €

Total terminal personnel costs per year	561.750 €
Terminal personnel costs range in EU	
Minimum value personnel costs	121.675 €
Maximum value personnel costs	906.506 €

Total area costs (5,00 €/m² per year)	81.405 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 162.810 €

Total costs per year	5.096.019 €

Cost per transhipment for total terminal investment		26,48 €
Operational costs per transhipment	**Personnel costs**	5,35 €
	Energy costs	0,65 €
	Maintenance costs	15,28 €
	Total	21,27 €
Ground costs per transhipment		0,78 €
Total costs for one transhipment		48,53 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		29,03 €
Maximum value total costs transhipment		64,90 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Short Sea Container Ship	20.000.000 €	1	20.000.000 €	25	281,56 €
Total main leg investment costs					20.000.000 €
Total investment costs per operating hour					281,56 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**

Short Sea Container Ship	2,2	430.647 €	89,72 €
Total maintenance costs per operating hour			89,72 €

Main leg energy consumption				
Consumer	**Energy type**	**Energy consumption per t/h**	**Energy consumption per 450 km transport (ton)**	**Energy consumption per 850 km transport (ton)**
Short Sea Container Ship	Gas oil	1,75	25	47

Other operational costs main leg	
Cost type	**Costs**
Port	1.494 €
Total other operational costs per operating hour	1.494 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport	Total	
	Total	**Per LU**
First road leg	43.412 €	87,35 €
First transhipment	24.121 €	48,53 €
450 km main leg	34.588 €	69,59 €
850 km main leg	52.228 €	105,09 €
Second transhipment	24.121 €	48,53 €
Second road leg	42.105 €	84,72 €
LU costs transport chain 600 km main leg	2.181 €	4,39 €
LU costs transport chain 1.000 km main leg	2.723 €	5,48 €
Intermodal organizational costs 600 km main leg (25%)	42.632,06 €	85,78 €
Intermodal organizational costs 1.000 km main leg (25%)	47.177,62 €	94,92 €
Grand total 600 km	170.528 €	428,89 €
Grand total 1.000 km	188.710 €	474,62 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	389,88 €
Maximum value costs range 600 km transport in EU	461,63 €
Minimum value costs range 1.000 km transport in EU	435,61 €
Maximum value costs range 1.000 km transport in EU	507,36 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	43.977 €	88,49 €
First transhipment		34 €	0,07 €
Main leg	**450 km**	66.255 €	133,31 €
	850 km	125.149 €	251,81 €

Second transhipment		34 €	0,07 €
Second road leg	**75 km**	43.977 €	88,49 €
Full transport chain per LU	**600 km**	154.209 €	310,28 €
	1.000 km	213.103 €	428,78 €

2.1.1.2 Fact Sheet "Gantry Crane (with/without cantilever) – SSS/Road – 40' Container"

Total terminal handling capacity per year (transhipments)	105.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	1.399.763 €
Gantry crane	2,8	198.800 €
Spreader	2,8	5.600 €
Total maintenance costs per year		1.604.163 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	17.909 kWh	2.239 €
Gantry Crane	Electricity	2,5 kWh	525.000 kWh	65.625 €
Total energy costs per year				67.864 €

Terminal energy costs range in EU	
Minimum value electricity costs	31.821 €
Maximum value electricity costs	98.386 €
Minimum value diesel costs	- €
Maximum value diesel costs	- €
Minimum value total energy costs	31.821,26 €
Maximum value diesel energy costs	98.386,05 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €

Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				561.750 €
Terminal personnel costs range in EU				
Minimum value personnel costs				121.675 €
Maximum value personnel costs				906.506 €

Total area costs (5,00 €/m² per year)	81.405 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 162.810 €

Total costs per year	5.096.019 €

Cost per transhipment for total terminal investment		26,48 €
Operational costs per transhipment	**Personnel costs**	5,35 €
	Energy costs	0,65 €
	Maintenance costs	15,28 €
	Total	21,27 €
Ground costs per transhipment		0,78 €
Total costs for one transhipment		48,53 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		29,03 €
Maximum value total costs transhipment		64,90 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40' Container	3.000 €	12	90 €	0,09 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour

Short Sea Container Ship	20.000.000 €	1	20.000.000 €	25	281,56 €
Total main leg investment costs					20.000.000 €
Total investment costs per operating hour					281,56 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Short Sea Container Ship	2,2	430.647 €	89,72 €
Total maintenance costs per operating hour			89,72 €

Main leg energy consumption				
Consumer	**Energy type**	**Energy consumption per t/h**	**Energy consumption per 450 km transport (ton)**	**Energy consumption per 850 km transport (ton)**
Short Sea Container Ship	Gas oil	1,75	25	47

Other operational costs main leg	
Cost type	**Costs**
Port	1.494 €
Total other operational costs per operating hour	1.494 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €

Total maintenance costs per operating hour	3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €

Total energy costs per operating hour	22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	37.123 €	87,35 €
First transhipment	20.627 €	48,53 €
450 km main leg	32.806 €	77,19 €
850 km main leg	50.446 €	118,70 €
Second transhipment	20.627 €	48,53 €
Second road leg	36.006 €	84,72 €
LU costs transport chain 600 km main leg	2.366 €	5,57 €
LU costs transport chain 1.000 km main leg	3.015 €	7,09 €
Intermodal organizational costs 600 km main leg (25%)	37.388,32 €	87,97 €
Intermodal organizational costs 1.000 km main leg (25%)	41.960,60 €	98,73 €
Grand total 600 km	149.553 €	439,86 €
Grand total 1.000 km	167.842 €	493,65 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	400,85 €
Maximum value costs range 600 km transport in EU	472,60 €
Minimum value costs range 1.000 km transport in EU	454,64 €
Maximum value costs range 1.000 km transport in EU	526,39 €

External costs			
		Total	Per LU
First road leg	75 km	39.340 €	92,57 €
First transhipment		29 €	0,07 €
Main leg	450 km	63.362 €	149,09 €
	850 km	119.684 €	281,61 €
Second transhipment		29 €	0,07 €
Second road leg	75 km	39.340 €	92,57 €
Full transport chain per LU	600 km	142.043 €	334,35 €
	1.000 km	198.365 €	466,88 €

3 Fact sheet for "Reach stacker"

3.1 Fact sheet for "Reach stacker – Rail/Road"

Picture of the technology:

Source: Liebherr

Description of the transhipment technology and transhipment process (road → main leg):

A reach stacker is an industrial truck with variable reach that can lift and move intermodal loading units. Until today, only combustion engine powered primary drives are available. Reach stackers drive on six rubberised wheels, have a driver's cab and a lifting arm that reaches in front of the vehicle and can lift loading units with the help of a spreader. In addition to reach stackers for moving intermodal loading units in combined transport, there are also reach stackers designed only for empty loading units. These are much lighter and do not require high motorisation and power. In some cases, the lifting arm is replaced by a forklift mast because the load units are lighter.

- Reach stacker moves to the loading unit
- Spreader is positioned above the loading unit
- Spreader is locked or gripper arms are closed
- Reach stacker lifts the loading unit
- Reach stacker drives with loading unit to destination
- Reach stacker sets down the loading unit at the destination
- Spreader is opened or unlocked
- Spreader is lifted and reach stacker moves to next order

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network	
Indicative qualitative assessment:		

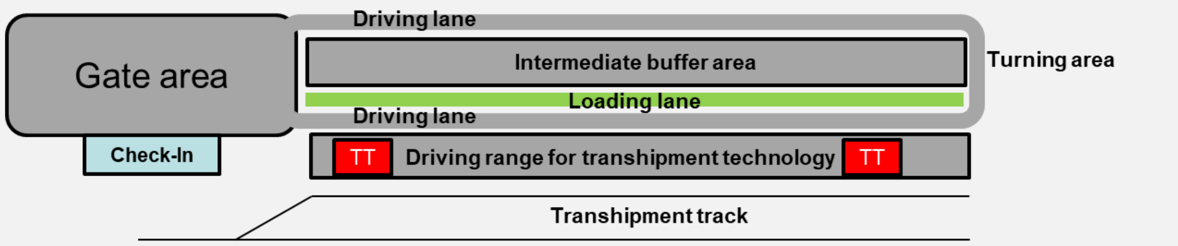
Strengths	**Weaknesses and limitations**
• Standardised system and compatible with common craneable loading units • Fast transhipment rate • Easy to implement: only traffic areas and one track necessary	• Large area for manoeuvring necessary • Further terminal infrastructure necessary • Automation and digitalisation not easy to implement

Transhipable loading units:

Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	40,5 t

3.1.1 Fact Sheet "Reach stacker – Rail/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Loco, Sggrss 80' rail wagons or similar
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 20' containers on Sggrss 80' wagons with no further special equipment (assuming 85% load factor)	64 (54)

For 40’ containers on Sggrss 80’ wagons with no further special equipment (assuming 85% load factor)	50 (43)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	4,0 min
	Handling equipment driver	4,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	4,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	4,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	4,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	20’: 63,2 min 40’: 98,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	20’: 73,2 min 40’: 108,8 min
Process steps unloading main leg	**Involved personnel**	**Time**

Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	4,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	4,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	4,0 min
	Truck driver	4,0 min
Handover duration per LU:	**Total LU**	4,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 15 min • Only Transhipment: 8 min
	Unloading	• All process steps: 10 min • Only Transhipment: 8 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 11 min
	Unloading	• 6 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20’-Container: 216 min • 40’-Container: 172 min
	Unloading	• 20’-Container: 216 min • 40’-Container: 172 min

Total time for loading /unloading one train (incl. headway):	**Loading**	• 20'-Container: 289 min • 40'-Container: 281 min
	Unloading	• 20'-Container: 256 min • 40'-Container: 212 min
Trains that can be handled in an 8-hour shift:		• 20'-Container: 0,77 • 40'-Container: 0,85

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	162 min 162 min 594 min 432 min 0 min 0 min 30 min 30 min 63 min 10 min 1.483 min	129 min 129 min 473 min 344 min 0 min 0 min 30 min 30 min 99 min 10 min 1.244 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	0 min 0 min 324 min 432 min 0 min 30 min 0 min 30 min 0 min 10 min 826 min	0 min 0 min 258 min 344 min 0 min 30 min 0 min 30 min 0 min 10 min 672 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min

Total duration transport chain	**1.000 km**	32,84 h	31,96 h
	600 km	22,84 h	21,96 h
Total working hours transport chain	**1.000 km**	217 h	181 h
	600 km	202 h	166 h
Total working hours per LU	**1.000 km**	4,02 h	4,20 h
	600 km	3,74 h	3,85 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	740,0 m	2,6 m	1	90 €/m²	1.924 m²	173.160 €
Intermediate buffer area (non-stackable)	0,0 m	0,0 m	-	80 €/m²	m²	- €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	30,0 m	5,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0,0 m	0,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	15,0 m	1	90 €/m²	11.100 m²	999.000 €
Total area complete terminal					28.203 m²	
Structural engineering (50 €/m²)					1.410.125 €	
Earthworks and civil engineering (100 €/m²)					2.820.250 €	

Building costs terminal				7.175.510 €
Planning costs 20%				1.435.102 €
Total building costs complete terminal				8.610.612 €
Terminal building costs range in EU				
Minimum value based on European construction cost index				3.995.324 €
Maximum value based on European construction cost index				12.518.108 €
Depreciation time terminal (years)				25
Terminal building costs per year				581.852 €
Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Reach stacker	480.000 €	2	960.000 €	5
Spreader	100.000 €	2	200.000 €	10
Equipment costs terminal	**Investment costs**			1.160.000 €
	Planning costs (20%)			232.000 €
	Total			1.392.000 €
Total equipment costs terminal per year				283.013 €

Initial investment costs complete terminal and equipment incl. planning costs	10.002.612 €
Total investment costs complete terminal and equipment per year	864.865 €

3.1.1.1 Fact Sheet “Reach stacker – Rail/Road – 20’ Container”

Total terminal handling capacity per year (transhipments)	41.599

Terminal maintenance costs				
	Percentage of investment (%)		**Total costs per year**	
Terminal Infrastructure	5		358.776 €	
Reach stacker	2,8		26.880 €	
Spreader	2,8		5.600 €	
Total maintenance costs per year			391.256 €	
Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	31.023 kWh	3.878 €

Reach stacker	Diesel	0,9 l	74.879 l	83.864 €
Total energy costs per year				87.742 €
Terminal energy costs range in EU				
Minimum value electricity costs				1.818 €
Maximum value electricity costs				5.622 €
Minimum value diesel costs				69.076 €
Maximum value diesel costs				102.483 €
Minimum value total energy costs				70.895 €
Maximum value diesel energy costs				108.105 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				555.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				120.321 €
Maximum value personnel costs				896.421 €

Total area costs (5,00 €/m² per year)	141.013 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 282.025 €

Total costs per year	2.040.375 €

Cost per transhipment for total terminal investment		20,79 €
Operational costs per transhipment	**Personnel costs**	13,35 €
	Energy costs	2,11 €

	Maintenance costs	9,41 €
	Total	24,87 €
Ground costs per transhipment		3,39 €
Total costs for one transhipment		49,05 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		23,65 €
Maximum value total costs transhipment		70,56 €

Loading unit investments and costs:				
Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
20’ Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Sggrss 80’ wagon	85.000 €	16	1.360.000 €	40	15,73 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					6.360.000 €
Total investment costs per operating hour					73,54 €

Main leg equipment maintenance costs			
Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Sggrss 80’ wagons	7	96.000 €	20,00 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			82,50 €

Main leg energy consumption				
Consumer	Energy type	Consumption in kWh per ton-km	Consumption per hour	Costs per operating hour(€)
Loco	Electricity	0,02	1.389 kWh	173,68 €
Total energy costs per operating hour				173,68 €

Other operational costs main leg		
Cost type	Costs per km	Costs per operating hour
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**

First road leg	4.811 €	89,10 €
First transhipment	2.649 €	49,05 €
450 km main leg	6.325 €	117,13 €
850 km main leg	11.338 €	209,97 €
Second transhipment	2.649 €	49,05 €
Second road leg	4.575 €	84,72 €
LU costs transport chain 600 km main leg	106 €	1,96 €
LU costs transport chain 1.000 km main leg	150 €	2,77 €
Intermodal organizational costs 600 km main leg (25%)	5.278,60 €	97,75 €
Intermodal organizational costs 1.000 km main leg (25%)	6.542,85 €	121,16 €
Grand total 600 km	21.114 €	488,76 €
Grand total 1.000 km	26.171 €	605,82 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	437,96 €
Maximum value costs range 600 km transport in EU	531,78 €
Minimum value costs range 1.000 km transport in EU	555,02 €
Maximum value costs range 1.000 km transport in EU	648,84 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	4.778 €	88,49 €
First transhipment		14 €	0,26 €
Main leg	**450 km**	8.597 €	159,21 €
	850 km	16.239 €	300,72 €
Second transhipment		14 €	0,26 €
Second road leg	**75 km**	4.778 €	88,49 €
Full transport chain per LU	**600 km**	18.154 €	336,70 €
	1.000 km	25.795 €	478,22 €

3.1.1.2 Fact Sheet “Reach stacker – Rail/Road – 40’ Container”

Total terminal handling capacity per year (transhipments)	36.648

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	358.776 €

Reach stacker	2,8			26.880 €
Spreader	2,8			5.600 €
Total maintenance costs per year				391.256 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	31.023 kWh	3.878 €
Reach stacker	Diesel	0,9 l	65.966 l	73.882 €
Total energy costs per year				77.760 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.818 €
Maximum value electricity costs	5.622 €
Minimum value diesel costs	60.854 €
Maximum value diesel costs	90.284 €
Minimum value total energy costs	62.672 €
Maximum value diesel energy costs	95.906 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				555.500 €

Terminal personnel costs range in EU	
Minimum value personnel costs	120.321 €
Maximum value personnel costs	896.421 €

Total area costs (5,00 €/m² per year)	141.013 €

Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 282.025 €

Total costs per year	2.030.393 €

Cost per transhipment for total terminal investment		23,60 €
Operational costs per transhipment	**Personnel costs**	15,16 €
	Energy costs	2,12 €
	Maintenance costs	10,68 €
	Total	27,96 €
Ground costs per transhipment		3,85 €
Total costs for one transhipment		55,40 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		26,62 €
Maximum value total costs transhipment		79,76 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40' Container	3.000 €	12	90 €	0,09 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Sggrss 80' wagon	85.000 €	25	2.125.000 €	40	24,57 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.125.000 €
Total investment costs per operating hour					82,39 €

Main leg equipment maintenance costs

Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Sggrss 80' wagons	7	150.000 €	31,25 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			93,75 €

Main leg energy consumption

Consumer	Energy type	Consumption in kWh per ton-km	Consumption per hour	Costs per operating hour(€)
Loco	Electricity	0,02	1.451 kWh	181,34 €
Total energy costs per operating hour				181,34 €
Other operational costs main leg				

Cost type	Costs per km	Costs per operating hour
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €
Personnel costs main leg		

Function	Costs per operating hour
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant
Road leg equipment maintenance costs			

Equipment	Percentage of investment (%)	Total per year	Costs per operating hour
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €
Road leg energy consumption			

Consumer	Energy type	Consumption per 100 km	Consumption per hour	Costs per operating hour
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				

Cost type	Costs per km	Costs per leg
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	3.831 €	89,10 €
First transhipment	2.382 €	55,40 €
450 km main leg	6.811 €	158,39 €
850 km main leg	12.101 €	281,43 €
Second transhipment	2.382 €	55,40 €
Second road leg	3.643 €	84,72 €
LU costs transport chain 600 km main leg	114 €	2,64 €
LU costs transport chain 1.000 km main leg	162 €	3,78 €
Intermodal organizational costs 600 km main leg (25%)	4.790,77 €	111,41 €
Intermodal organizational costs 1.000 km main leg (25%)	6.125,67 €	142,46 €
Grand total 600 km	19.163 €	557,07 €
Grand total 1.000 km	24.503 €	712,29 €

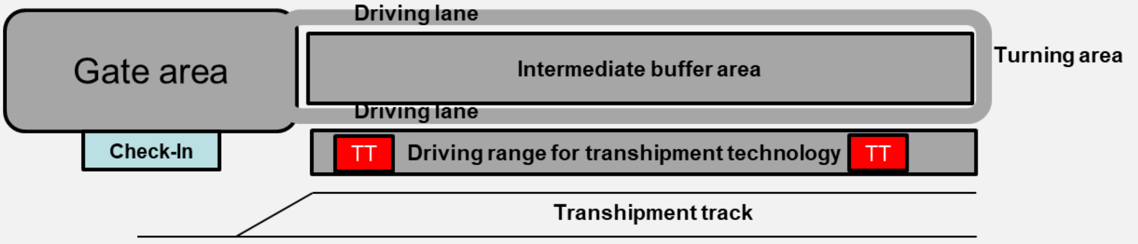
Costs range in EU	
Minimum value costs range 600 km transport in EU	499,50 €
Maximum value costs range 600 km transport in EU	605,78 €
Minimum value costs range 1.000 km transport in EU	654,72 €
Maximum value costs range 1.000 km transport in EU	761,00 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	3.980 €	92,57 €
First transhipment		11 €	0,26 €
Main leg	**450 km**	8.976 €	208,75 €
	850 km	16.955 €	394,31 €
Second transhipment		11 €	0,26 €
Second road leg	**75 km**	3.980 €	92,57 €

Full transport chain per LU	**600 km**	16.937 €	394,41 €
	1.000 km	24.916 €	579,97 €

3.1.2 Fact Sheet “Reach stacker – Rail/Road – Semi-trailer”

Description of our model terminal:



Necessary road leg equipment:	Truck
Necessary main leg equipment:	Loco, T3000e rail wagons or similar
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For Semi-trailer craneable on T3000e wagons with no further special equipment (assuming 85% load factor)	42 (36)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5,0 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min

Handover duration per LU:	**Total LU**	5,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	7,5 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	7,5 min
Transhipment duration per LU:	**Total LU**	7,5 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	82,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	92,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	7,5 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	7,5 min
Transhipment duration per LU:	**Total LU**	7,5 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	0,0 min
	Truck driver	5,0 min
Handover duration per LU:	**Total LU**	5,0 min

Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 20 min • Only Transhipment: 7,5 min
	Unloading	• All process steps: 15 min • Only Transhipment: 7,5 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min
	Unloading	• 7 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 135 min
	Unloading	• 135 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 228 min
	Unloading	• 175 min
Trains that can be handled in an 8-hour shift:		• 1,04

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:**
		Semi-trailer
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	108 min 108 min 432 min 270 min 0 min 270 min 30 min 30 min 83 min 10 min 1.341 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped	Checker Gate agent	0 min 0 min

using the transhipment technology as described in detail above.	Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	252 min 270 min 0 min 30 min 270 min 30 min 0 min 10 min 862 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	30,46 h
	600 km	20,46 h
Total working hours transport chain	**1.000 km**	166 h
	600 km	151 h
Total working hours per LU	**1.000 km**	4,62 h
	600 km	4,21 h

Costs and investments associated with the transhipment technology

Terminal infrastructure

Elements	Dimensions (m)		Number of units (#)	Unit costs	Total area	Total costs
	Length	Width				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	0,0 m	0,0 m	-	80 €/m²	m²	- €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	50.000 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	250,0 m	32,0 m	1	80 €/m²	8.000 m²	640.000 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	30,0 m	5,0 m	-	62.500 €/unit	m²	- €

Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0,0 m	0,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	15,0 m	1	90 €/m²	11.100 m²	999.000 €

Total area complete terminal	31.689 m²
Structural engineering (50 €/m²)	1.584.425 €
Earthworks and civil engineering (100 €/m²)	3.168.850 €
Building costs terminal	7.961.175 €
Planning costs 20%	1.592.235 €
Total building costs complete terminal	9.553.410 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	4.432.782 €
Maximum value based on European construction cost index	13.888.747 €
Depreciation time terminal (years)	25
Terminal building costs per year	645.560 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Reach stackere	480.000 €	2	960.000 €	5
Spreader with gripper arms	150.000 €	2	300.000 €	10

Equipment costs terminal	**Investment costs**	1.260.000 €
	Planning costs (20%)	252.000 €
	Total	1.512.000 €
Total equipment costs terminal per year		297.814 €

Initial investment costs complete terminal and equipment incl. planning costs	11.065.410 €
Total investment costs complete terminal and equipment per year	943.374 €

Total terminal handling capacity per year (transhipments)	37.537

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	398.059 €
Reach stacker	2,8	26.880 €
Spreader with gripper arms	2,8	8.400 €
Total maintenance costs per year		1.083.369 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	34.857 kWh	4.357 €
Reach stacker	Diesel	0,9 l	33.784 l	37.838 €
Total energy costs per year				42.195 €

Terminal energy costs range in EU	
Minimum value electricity costs	2.043 €
Maximum value electricity costs	6.317 €
Minimum value diesel costs	31.166 €
Maximum value diesel costs	46.238 €
Minimum value total energy costs	33.209 €
Maximum value diesel energy costs	52.555 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	1	3,5	31.000 €	108.500 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				602.000 €
Terminal personnel costs range in EU				

Minimum value personnel costs	130.393 €
Maximum value personnel costs	971.458 €

Total area costs (5,00 €/m² per year)	158.443 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 316.885 €

Total costs per year	2.179.350 €

Cost per transhipment for total terminal investment		25,13 €
Operational costs per transhipment	**Personnel costs**	16,04 €
	Energy costs	1,12 €
	Maintenance costs	11,54 €
	Total	28,71 €
Ground costs per transhipment		4,22 €
Total costs for one transhipment		58,06 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		27,56 €
Maximum value total costs transhipment		83,80 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
Semi-trailer craneable	27.000 €	11	810,00 €	0,81 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
T3000e	140.000 €	21	2.940.000 €	40	34,00 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.940.000 €
Total investment costs per operating hour					91,82 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
T3000e	5	146.790 €	30,58 €

Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			93,08 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.428 kWh	178,53 €
Total energy costs per operating hour				178,53 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)		**600 km**	1:3,0
		1.000 km	1:4,2

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport	Total	
	Total	**Per LU**
First road leg	3.156 €	87,66 €
First transhipment	2.090 €	58,06 €
450 km main leg	6.847 €	190,20 €
850 km main leg	12.197 €	338,81 €
Second transhipment	2.090 €	58,06 €
Second road leg	3.003 €	83,42 €
LU costs transport chain 600 km main leg	599 €	16,65 €
LU costs transport chain 1.000 km main leg	877 €	24,37 €
Intermodal organizational costs 600 km main leg (25%)	4.446,40 €	123,51 €
Intermodal organizational costs 1.000 km main leg (25%)	5.853,37 €	162,59 €
Grand total 600 km	17.786 €	617,56 €
Grand total 1.000 km	23.413 €	812,97 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	556,57 €
Maximum value costs range 600 km transport in EU	669,04 €
Minimum value costs range 1.000 km transport in EU	751,98 €
Maximum value costs range 1.000 km transport in EU	864,46 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	3.185 €	88,49 €
First transhipment		10 €	0,27 €
Main leg	**450 km**	8.837 €	245,48 €
	850 km	16.693 €	463,68 €

Second transhipment		10 €	0,27 €
Second road leg	**75 km**	3.185 €	88,49 €
Full transport chain per LU	**600 km**	15.208 €	422,98 €
	1.000 km	23.063 €	641,19 €

4 Fact sheet for “Reach stacker – IWW/Road”

Picture of the technology:

Source: Liebherr

Description of the transhipment technology and transhipment process (road → main leg):

A reach stacker is an industrial truck with variable reach that can lift and move intermodal loading units. Until today, only combustion engine powered primary drives are available. Reach stackers drive on six rubberised wheels, have a driver's cab and a lifting arm that reaches in front of the vehicle and can lift loading units with the help of a spreader. In addition to reach stackers for moving intermodal loading units in combined transport, there are also reach stackers designed only for empty loading units. These are much lighter and do not require high motorisation and power. In some cases, the lifting arm is replaced by a forklift mast because the load units are lighter.

- Reach stacker moves to the loading unit
- Spreader is positioned above the loading unit
- Spreader is locked or gripper arms are closed
- Reach stacker lifts the loading unit
- Reach stacker drives with loading unit to destination
- Reach stacker sets down the loading unit at the destination
- Spreader is opened or unlocked
- Spreader is lifted and reach stacker moves to next order

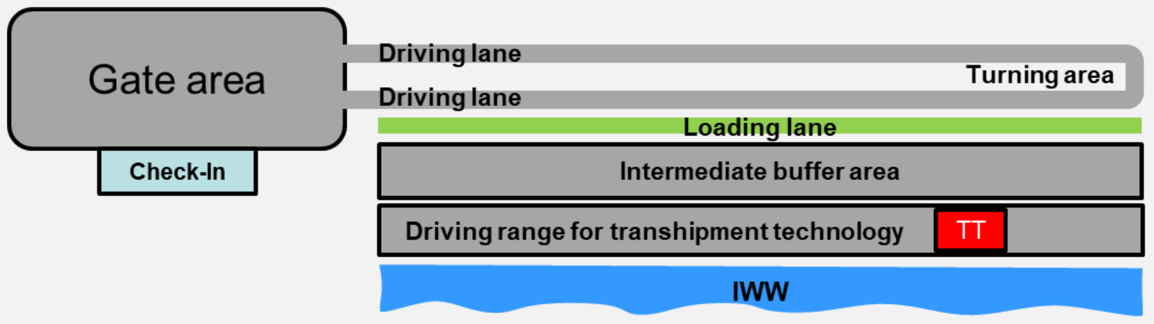
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network. Used rather rarely in the inland waterway sector.	

Indicative qualitative assessment:	
Strengths	**Weaknesses and limitations**
• Standardised system and compatible with common craneable loading units • Fast transhipment rate • Easy to implement: only traffic areas and one track necessary	• Large area for manoeuvring necessary • Further terminal infrastructure necessary • Automation and digitalisation not easy to implement

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	40,5 t

4.1.1 Fact Sheet "Gantry Crane (with/without cantilever) – IWW/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Barges (110 m, 2.800 t, 200 TEU)
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	

For 20' containers on barge with no further special equipment (assuming 85% load factor)	126 (107)
For 40' containers on barge with no further special equipment (assuming 85% load factor)	100 (85)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	4 min
	Handling equipment driver	4 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Handling equipment driver	0 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	4 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	4 min
	Terminal truck driver	0 min
	Truck driver	0 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	4 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	30 min
Further procedures for departure:	non	0 min
Departure:	Crew	25 min
Departure duration:	**Total**	40 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		

Arrival:	Crew	25 min
Further arrival procedures:	non	0 min
Terminal check-in:	Groundsman ship	30 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	4 min
	Terminal truck driver	0 min
	Truck driver	0 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	4 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	0 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	4 min
	Truck driver	4 min
Handover duration per LU:	**Total LU**	6 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 15 min • Only Transhipment: 8 min
	Unloading	• All process steps: 12 min • Only Transhipment: 8 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 11 min
	Unloading	• 6 min
Total time for loading /unloading one ship (excl. headway):	**Loading**	• 20'-Container: 856 min • 40'-Container: 680 min
	Unloading	• 20'-Container: 856 min • 40'-Container: 680 min
Total time for loading /unloading one ship (incl. headway):	**Loading**	• 20'-Container: 896 min • 40'-Container: 720 min
	Unloading	• 20'-Container: 896 min • 40'-Container: 720 min

Ships that can be handled in an 8-hour shift:	• 20'-Container: 0,25 • 40'-Container: 0,31

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full ship: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	321 min 321 min 1177 min 856 min 0 min 0 min 32 min 30 min 25 min 2762 min	255 min 255 min 935 min 680 min 0 min 0 min 33 min 30 min 25 min 2213 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 3.400 min**	Crew:	3.400 min	3.400 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 1.800 min**	Crew:	1.800 min	1.800 min
Second transhipment full ship: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	0 min 0 min 642 min 856 min 0 min 32 min 0 min 0 min 25 min 1555 min	0 min 0 min 510 min 680 min 0 min 33 min 0 min 0 min 25 min 1248 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	89,03 h	83,17 h
	600 km	62,37 h	56,50 h
Total working hours transport chain	**1.000 km**	532 h	458 h
	600 km	452 h	378 h
Total working hours per LU	**1.000 km**	4,97 h	5,39 h

	600 km	4,22 h	4,45 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60	1	80 €/m²	6.000 m²	480.000 €
Driving lane	240,0 m	3,5	2	80 €/m²	1.680 m²	134.400 €
Loading lane	240,0 m	3,5	1	80 €/m²	840 m²	67.200 €
Turning area	25,0 m	25	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	240,0 m	2,6	3	90 €/m²	1.872 m²	168.480 €
Inland port quay per metre	240,0 m	10	1	45.000 €/m	2.400 m²	10.800.000
Crane tracks	0,0 m	0	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	240,0 m	17	1	90 €/m²	4.080 m²	367.200 €
Total area complete terminal					17.497 m²	
Structural engineering (50 €/m²)					874.850 €	
Earthworks and civil engineering (100 €/m²)					1.749.700 €	
Building costs terminal					14.688.705 €	
Planning costs 20%					2.937.741 €	
Total building costs complete terminal					17.626.446 €	
Terminal building costs range in EU						
Minimum value based on European construction cost index					8.178.671 €	
Maximum value based on European construction cost index					25.625.327 €	
Depreciation time terminal (years)					25	
Terminal building costs per year					1.191.085,41 €	

Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**

Reach stacker	480.000 €	1	480.000 €	5
Spreader	100.000 €	1	100.000 €	10

Equipment costs terminal	**Investment costs**	580.000 €
	Planning costs (20%)	116.000 €
	Total	696.000 €
Total equipment costs terminal per year		141.507 €

Initial investment costs complete terminal and equipment incl. planning costs	18.322.446 €
Total investment costs complete terminal and equipment per year	1.332.592 €

4.1.1.1 Fact Sheet "Reach stacker – IWW/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	26.250

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	734.435 €
Reach stacker	2,8	13.440 €
Spreader	2,8	2.800 €
Total maintenance costs per year		750.675 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	19.247 kWh	2.129 €
Reach stacker	Diesel	0,9 kWh	47.250 l	52.920 €
Total energy costs per year				55.326 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.128 €
Maximum value electricity costs	3.488 €
Minimum value diesel costs	43.589 €
Maximum value diesel costs	64.669 €
Minimum value total energy costs	44.717 €
Maximum value diesel energy costs	68.157 €

Terminal personnel

Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0	0	31.000 €	- €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				371.000 €
Terminal personnel costs range in EU				
Minimum value personnel costs				80.359 €
Maximum value personnel costs				598.690 €

Total area costs (5,00 €/m² per year)	87.485 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 174.970 €

Total costs per year	2.597.078 €

Cost per transhipment for total terminal investment		50,77 €
Operational costs per transhipment	Personnel costs	14,13 €
	Energy costs	2,11 €
	Maintenance costs	28,60 €
	Total	44,84 €
Ground costs per transhipment		3,33 €
Total costs for one transhipment		98,94 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		56,92 €
Maximum value total costs transhipment		134,47 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €
Total main leg investment costs					3.000.000 €
Total investment costs per operating hour					38,72 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Barge (110 m)	2,7	80.000 €	16,67 €
Total maintenance costs per operating hour			16,67 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Barge (110 m)	Gas oil	0,006	233 l	167,42 €
Total energy costs per operating hour				167,42 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Inland shipping tax	0,00 €	0 €
Total other operational costs per operating hour		0 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	60,40 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €

Chassis	10%	2.600,00 €		0,74 €
Total maintenance costs per operating hour				3,60 €
Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				
Cost type	**Costs per km**		**Costs per leg**	
Tolls	0,187 €		11,22 €	
Personnel costs road leg				
Function			**Costs per operating hour**	
Truck driver			22,11 €	
Truck dispatcher			24,32 €	

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	9.534 €	89,10 €
First transhipment	10.586 €	98,94 €
450 km main leg	18.609 €	173,91 €
850 km main leg	26.161 €	244,49 €
Second transhipment	10.586 €	98,94 €
Second road leg	9.065 €	84,72 €
LU costs transport chain 600 km main leg	573 €	5,36 €
LU costs transport chain 1.000 km main leg	818 €	7,65 €
Intermodal organizational costs 600 km main leg (25%)	14.738,20 €	137,74 €
Intermodal organizational costs 1.000 km main leg (25%)	16.687,49 €	155,96 €
Grand total 600 km	58.953 €	688,70 €
Grand total 1.000 km	66.750 €	779,79 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		604,66 €
Maximum value costs range 600 km transport in EU		759,77 €
Minimum value costs range 1.000 km transport in EU		695,75 €
Maximum value costs range 1.000 km transport in EU		850,85 €

External costs			
		Total	Per LU
First road leg	75 km	2.525 €	23,60 €
First transhipment		28 €	0,26 €
Main leg	450 km	33.135 €	309,67 €
	850 km	62.588 €	584,93 €
Second transhipment		28 €	0,26 €
Second road leg	75 km	2.525 €	23,60 €
Full transport chain per LU	600 km	38.184 €	357,39 €
	1.000 km	67.637 €	632,65 €

4.1.1.2 Fact Sheet “Reach stacker – IWW/Road – 40’ Container”

Total terminal handling capacity per year (transhipments)	26.250

Terminal maintenance costs		
	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	734.435 €
Reach stacker	2,8	13.440 €
Spreader	2,8	2.800 €
Total maintenance costs per year		750.675 €

Terminal energy consumption				
Consumer	Energy type	Consumption per transhipment	Consumption per year	Energy costs per year
Infrastructure	Electricity	-	19.247 kWh	2.129 €
Reach stacker	Diesel	0,9 kWh	47.250 l	52.920 €
Total energy costs per year				55.326 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.128 €
Maximum value electricity costs	3.488 €
Minimum value diesel costs	43.589 €
Maximum value diesel costs	64.669 €
Minimum value total energy costs	44.717 €
Maximum value diesel energy costs	68.157 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0	0	31.000 €	- €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				371.000 €
Terminal personnel costs range in EU				
Minimum value personnel costs				80.359 €
Maximum value personnel costs				598.690 €

Total area costs (5,00 €/m² per year)	87.485 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 174.970 €

Total costs per year	2.597.078 €

Cost per transhipment for total terminal investment		50,77 €
Operational costs per transhipment	**Personnel costs**	14,13 €
	Energy costs	2,11 €
	Maintenance costs	28,60 €
	Total	44,84 €
Ground costs per transhipment		3,33 €
Total costs for one transhipment		98,94 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		56,92 €
Maximum value total costs transhipment		134,47 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**

40' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €
Total main leg investment costs					3.000.000 €
Total investment costs per operating hour					38,72 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Barge (110 m)	2,7	80.000 €	16,67 €
Total maintenance costs per operating hour			16,67 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Barge (110 m)	Gas oil	0,006	211 l	152,19 €
Total energy costs per operating hour				152,19 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Inland shipping tax	0,00 €	0 €
Total other operational costs per operating hour		0 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	60,40 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant
Road leg equipment maintenance costs			

Equipment	Percentage of investment (%)	Total per year	Costs per operating hour
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	7.573 €	89,10 €
First transhipment	8.410 €	98,94 €
450 km main leg	15.800 €	185,88 €
850 km main leg	22.946 €	269,96 €
Second transhipment	8.410 €	98,94 €
Second road leg	7.201 €	84,72 €
LU costs transport chain 600 km main leg	578 €	6,80 €
LU costs transport chain 1.000 km main leg	850 €	10,00 €
Intermodal organizational costs 600 km main leg (25%)	11.992,86 €	141,09 €
Intermodal organizational costs 1.000 km main leg (25%)	13.847,53 €	162,91 €
Grand total 600 km	47.971 €	705,46 €
Grand total 1.000 km	55.390 €	814,56 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		621,42 €

Maximum value costs range 600 km transport in EU	598,13 €
Minimum value costs range 1.000 km transport in EU	730,52 €
Maximum value costs range 1.000 km transport in EU	885,63 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	2.098 €	24,68 €
First transhipment		22 €	0,26 €
Main leg	**450 km**	30.122 €	354,37 €
	850 km	56.896 €	669,37 €
Second transhipment		22 €	0,26 €
Second road leg	**75 km**	2.098 €	24,68 €
Full transport chain per LU	**600 km**	34.318 €	404,26 €
	1.000 km	61.093 €	719,26 €

5 Fact sheet for "Hydraulic material handling crane"

5.1 Fact sheet for "Hydraulic material handling crane – Rail/Road"

Picture of the technology:

Source: www.sennebogen.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):
A hydraulic material handling crane (hydraulic crane) is mainly used in ports for handling mass and bulk goods. The crane resembles an excavator and the grab arm is moved exclusively hydraulically (without ropes). For the handling of intermodal loading units, a spreader must be coupled to the grab arm. The hydraulic material handling crane is mobile and can be used on various chassis. The crane can be moved for loading and unloading. Process: • Hydraulic crane moves to the transhipment place • The crane extends the support legs and starts the handling operation • Crane moves the Spreader to the loading unit. Spreader locks the twist locks • Crane lift the loading unit via spreader and hoist rope

- Crane moves the loading unit the destination
- Hoist rope lowers spreader with loading unit
- Spreader is opened or unlocked
- Spreader is lifted and crane moves to next order
- Spreader is lifted and reach stacker moves to next order

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network with other vertical handling systems. The focus of the technology is more on transhipment of conventional goods, but can also be used for transhipment of intermodal loading units. Currently, the technology is rarely used for intermodal tasks.	

Indicative qualitative assessment:

Strengths	Weaknesses and limitations
• Flexible use in the port • Can also be used for other goods, not only for intermodal loading units • due to hydraulic quick-change systems the change between various attachments (grabs/spreader) can be done without mechanics and in a few minutes • Using a material handling crane the cargo is not affected by wind the same way a rope spreader is. • Due to rigid fixation of the spreader to the material handling boom a more precise positioning is possible • The cycle speed of a material handler in comparison to a crane seriously faster • A material Handler is classed as an excavator which reduces the regular inspection costs • Operators for hydraulic material handlers are easier to find then crane operators • Energy Recovery Systems (Green Hybrid) support the lift and reduce energy consumption • hydraulic cabin elevation reduce time for climbing up to cabin	• High acquisition costs • Special structure needed to withstand the weight of the crane. • Acquisition costs need to be compared speed is considerably faster

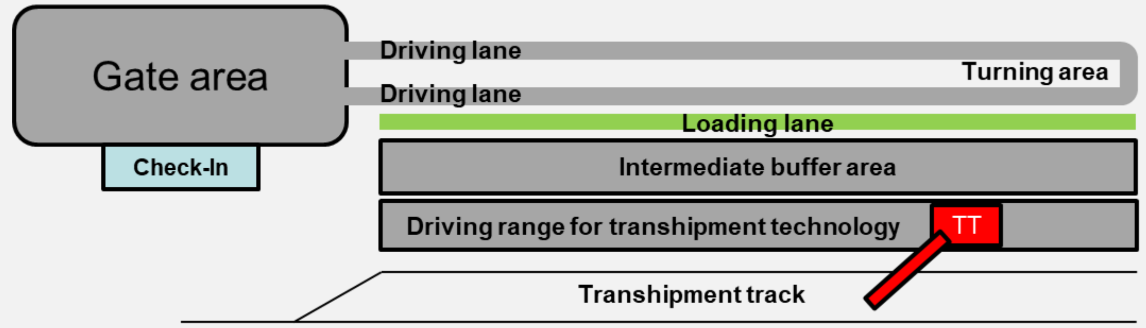
Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• All

• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets (Not used in practice)
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	22 t

5.1.1 Fact Sheet “Hydraulic material handling crane – Rail/Road – Containers”

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Loco, Sggrss 80’ rail wagons or similar

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 20’ containers on Sggrss 80’ wagons with no further special equipment (assuming 85% load factor)	64 (54)
For 40’ containers on Sggrss 80’ wagons with no further special equipment (assuming 85% load factor)	52 (44)

Detailed description of the transhipment process:

Process steps <u>loading</u> main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,0 min

	Handling equipment driver	1,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	2,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	3,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	1,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	1,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	20’: 63,2 min 40’: 102,4 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	20’: 73,2 min 40’: 112,4 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	1,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	1,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min

	Handling equipment driver	2,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	1,0 min
	Truck driver	4,0 min
Handover duration per LU:	**Total LU**	5,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2,0 min
Check-out duration per LU:	**Total LU**	2,0 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 11 min • Only Transhipment: 4 min
	Unloading	• All process steps: 8 min • Only Transhipment: 4 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20'-Container: 235 min • 40'-Container: 208 min
	Unloading	• 20'-Container: 235 min • 40'-Container: 208 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 20'-Container: 308 min • 40'-Container: 321 min
	Unloading	• 20'-Container: 275 min • 40'-Container: 248 min
Trains that can be handled in an 8-hour shift:		• 20'-Container: 0,72 • 40'-Container: 0,74

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train	162 min 162 min 486 min 216 min 0 min 0 min 30 min	132 min 132 min 396 min 176 min 0 min 0 min 30 min

	Groundsman train Visitor/Wagon inspector Train driver Total:	30 min 63 min 10 min 1.159 min	30 min 102 min 10 min 1.008 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	0 min 0 min 324 min 216 min 0 min 30 min 0 min 30 min 0 min 10 min 610 min	0 min 0 min 264 min 176 min 0 min 30 min 0 min 30 min 0 min 10 min 510 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	33,47 h	33,24 h
	600 km	23,47 h	23,24 h
Total working hours transport chain	**1.000 km**	208 h	177 h
	600 km	193 h	162 h
Total working hours per LU	**1.000 km**	3,85 h	4,02 h
	600 km	3,57 h	3,67 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €

Intermediate buffer area (stackable)	740,0 m	2,6 m	1	90 €/m²	1.924 m²	173.160 €
Intermediate buffer area (non-stackable)	0,0 m	0,0 m	-	80 €/m²	m²	- €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	30,0 m	5,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	740,0 m	3,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	15,0 m	1	90 €/m²	11.100 m²	999.000 €
Total area complete terminal					28.203 m²	
Structural engineering (50 €/m²)						1.410.125 €
Earthworks and civil engineering (100 €/m²)						2.820.250 €
Building costs terminal						7.175.510 €
Planning costs 20%						1.435.102 €
Total building costs complete terminal						8.610.612 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						3.995.324 €
Maximum value based on European construction cost index						12.518.108 €
Depreciation time terminal (years)					25	
Terminal building costs per year						581.852 €

Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Hydraulic crane	2.700.000 €	1	2.700.000 €	14
Spreader	100.000 €	1	100.000 €	10
Equipment costs terminal	**Investment costs**		2.800.000 €	

	Planning costs (20%)	560.000 €
	Total	3.360.000 €
Total equipment costs terminal per year		326.532 €

Initial investment costs complete terminal and equipment incl. planning costs	11.970.612 €
Total investment costs complete terminal and equipment per year	908.383 €

5.1.1.1 Fact Sheet "Hydraulic material handling crane – Rail/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	38.902

Terminal maintenance costs		
	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	358.776 €
Hydraulic crane	8	215.285 €
Spreader	2,8	2.800 €
Total maintenance costs per year		576.861 €

Terminal energy consumption				
Consumer	Energy type	Consumption per transhipment	Consumption per year	Energy costs per year
Infrastructure	Electricity	-	31.023 kWh	3.878 €
Hydraulic crane	Diesel	1,17 l	90.772 l	101.664 €
Total energy costs per year				105.542 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.818 €
Maximum value electricity costs	5.622 €
Minimum value diesel costs	83.738 €
Maximum value diesel costs	124.235 €
Minimum value total energy costs	85.556 €
Maximum value diesel energy costs	129.857 €

Terminal personnel				
Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	1	3,5	37.000 €	129.500 €

Total terminal personnel costs per year	568.750 €
Terminal personnel costs range in EU	
Minimum value personnel costs	123.191 €
Maximum value personnel costs	917.802 €

Total area costs (5,00 €/m² per year)	141.013 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 282.025 €

Total costs per year	2.300.548 €

Cost per transhipment for total terminal investment		23,35 €
Operational costs per transhipment	**Personnel costs**	14,62 €
	Energy costs	2,71 €
	Maintenance costs	14,83 €
	Total	32,16 €
Ground costs per transhipment		3,62 €
Total costs for one transhipment		59,14 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		31,03 €
Maximum value total costs transhipment		82,96 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Sggrss 80' wagon	85.000 €	16	1.360.000 €	40	15,73 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					6.360.000 €
Total investment costs per operating hour					73,54 €
Main leg equipment maintenance costs					

Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Sggrss 80' wagons	7	96.000 €	20,00 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			82,50 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.381 kWh	172,60 €
Total energy costs per operating hour				172,60 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption

Consumer	Energy type	Consumption per 100 km	Consumption per hour	Costs per operating hour
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	Per LU
First road leg	4.717 €	87,35 €
First transhipment	3.193 €	59,14 €
450 km main leg	6.335 €	117,31 €
850 km main leg	11.337 €	209,95 €
Second transhipment	3.193 €	59,14 €
Second road leg	4.575 €	84,72 €
LU costs transport chain 600 km main leg	109 €	2,02 €
LU costs transport chain 1.000 km main leg	153 €	2,83 €
Intermodal organizational costs 600 km main leg (25%)	5.530,47 €	102,42 €
Intermodal organizational costs 1.000 km main leg (25%)	6.792,02 €	125,78 €
Grand total 600 km	22.122 €	512,08 €
Grand total 1.000 km	27.168 €	628,89 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	455,87 €
Maximum value costs range 600 km transport in EU	559,72 €
Minimum value costs range 1.000 km transport in EU	572,68 €
Maximum value costs range 1.000 km transport in EU	676,53 €

External costs			
		Total	Per LU

First road leg	**75 km**	4.751 €	87,98 €
First transhipment		18 €	0,34 €
Main leg	**450 km**	8.544 €	158,22 €
	850 km	16.138 €	298,85 €
Second transhipment		18 €	0,34 €
Second road leg	**75 km**	4.751 €	87,98 €
Full transport chain per LU	**600 km**	18.045 €	334,84 €
	1.000 km	25.639 €	475,47 €

5.1.1.2 Fact Sheet "Hydraulic material handling crane – 40' Container"

Total terminal handling capacity per year (transhipments)	32.467

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	358.776 €
Hydraulic crane	8	215.285 €
Spreader	2,8	2.800 €
Total maintenance costs per year		576.861 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	31.023 kWh	3.878 €
Hydraulic crane	Diesel	1,17 l	75.755 l	84.846 €
Total energy costs per year				88.724 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.818 €
Maximum value electricity costs	5.622 €
Minimum value diesel costs	69.885 €
Maximum value diesel costs	103.683 €
Minimum value total energy costs	71.703 €
Maximum value diesel energy costs	109.305 €

Terminal personnel

Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				568.750 €
Terminal personnel costs range in EU				
Minimum value personnel costs				123.191 €
Maximum value personnel costs				917.802 €

Total area costs (5,00 €/m² per year)	141.013 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 282.025 €

Total costs per year	2.283.730 €

Cost per transhipment for total terminal investment		27,98 €
Operational costs per transhipment	**Personnel costs**	17,52 €
	Energy costs	2,73 €
	Maintenance costs	17,77 €
	Total	38,02 €
Ground costs per transhipment		4,34 €
Total costs for one transhipment		70,34 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		36,75 €
Maximum value total costs transhipment		98,77 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Sggrss 80' wagon	85.000 €	26	2.210.000 €	40	25,55 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.210.000 €
Total investment costs per operating hour					83,37 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Sggrss 80' wagons	7	156.000 €	32,50 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			95,00 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.429 kWh	178,60 €
Total energy costs per operating hour				178,60 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €

Reasonable fleet size (truck/semi-trailer ratio)				Not relevant
Road leg equipment maintenance costs				
Equipment	**Percentage of investment (%)**	**Total per year**		**Costs per operating hour**
Truck	10%	10.000,00 €		2,86 €
Chassis	10%	2.600,00 €		0,74 €
Total maintenance costs per operating hour				3,60 €
Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				
Cost type	**Costs per km**		**Costs per leg**	
Tolls	0,187 €		11,22 €	
Personnel costs road leg				
Function			**Costs per operating hour**	
Truck driver			22,11 €	
Truck dispatcher			24,32 €	

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	3.843 €	87,35 €
First transhipment	3.095 €	70,34 €
450 km main leg	6.899 €	156,80 €
850 km main leg	12.185 €	276,92 €
Second transhipment	3.095 €	70,34 €
Second road leg	3.728 €	84,72 €
LU costs transport chain 600 km main leg	123 €	2,79 €
LU costs transport chain 1.000 km main leg	173 €	3,93 €
Intermodal organizational costs 600 km main leg (25%)	5.195,72 €	118,08 €
Intermodal organizational costs 1.000 km main leg (25%)	6.529,63 €	148,40 €
Grand total 600 km	20.783 €	590,42 €
Grand total 1.000 km	26.119 €	742,00 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	523,25 €
Maximum value costs range 600 km transport in EU	647,27 €
Minimum value costs range 1.000 km transport in EU	674,83 €
Maximum value costs range 1.000 km transport in EU	798,85 €

External costs			
		Total	Per LU
First road leg	75 km	3.871 €	87,98 €
First transhipment		15 €	0,34 €
Main leg	450 km	8.841 €	200,93 €
	850 km	16.699 €	379,53 €
Second transhipment		15 €	0,34 €
Second road leg	75 km	3.871 €	87,98 €
Full transport chain per LU	600 km	16.583 €	377,55 €
	1.000 km	24.441 €	556,15 €

6 Fact sheet for "Hydraulic material handling crane – IWW/Road"

Picture of the technology:

Source: www.sennebogen.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

A hydraulic material handling crane (hydraulic crane) is mainly used in ports for handling mass and bulk goods. The crane resembles an excavator and the grab arm is moved exclusively hydraulically (without ropes). For the handling of intermodal loading units, a spreader must be coupled to the grab arm.
The hydraulic material handling crane is mobile and can be used on various chassis. The crane can be moved for loading and unloading.

Process:

- Hydraulic crane moves to the transhipment place
- The crane extends the support legs and starts the handling operation
- Crane moves the Spreader to the loading unit. Spreader locks the twist locks
- Crane lift the loading unit via spreader and hoist rope
- Crane moves the loading unit the destination
- Hoist rope lowers spreader with loading unit
- Spreader is opened or unlocked
- Spreader is lifted and crane moves to next order
- Spreader is lifted and reach stacker moves to next order

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network with other vertical handling systems. The focus of the technology is more on transhipment of conventional goods, but can also be used for transhipment of intermodal loading units. Currently, the technology is rarely used for intermodal tasks.	

Indicative qualitative assessment:

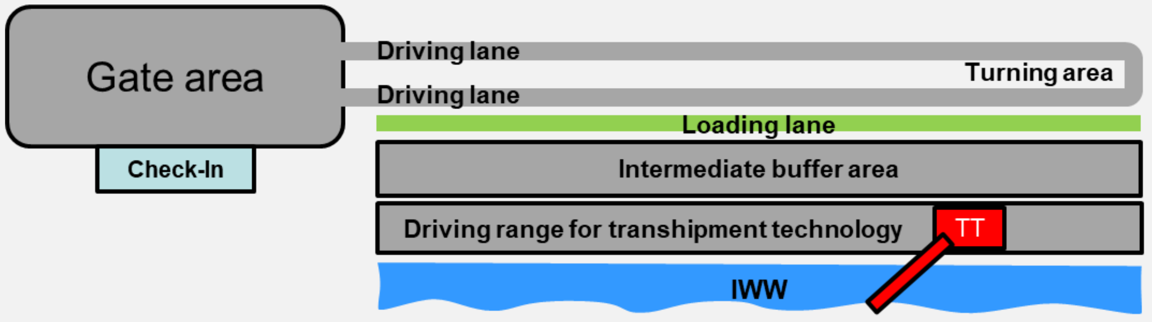
Strengths	Weaknesses and limitations
• Flexible use in the port • Can also be used for other goods, not only for intermodal loading units • due to hydraulic quick-change systems the change between various attachments (grabs/spreader) can be done without mechanics and in a few minutes • Using a material handling crane the cargo is not affected by wind the same way a rope spreader is. • Due to rigid fixation of the spreader to the material handling boom a more precise positioning is possible • The cycle speed of a material handler in comparison to a crane seriously faster • A material Handler is classed as an excavator which reduces the regular inspection costs • Operators for hydraulic material handlers are easier to find then crane operators • Energy Recovery Systems (Green Hybrid) support the lift and reduce energy consumption • hydraulic cabin elevation reduce time for climbing up to cabin	• High acquisition costs • Special structure needed to withstand the weight of the crane. • Acquisition costs need to be compared speed is considerably faster

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets (Not used in practice)

• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	22 t

6.1.1 Fact Sheet "Hydraulic material handling crane – IWW/Road – Containers"

Description of our model terminal:	
	
Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Barges (110 m, 2.800 t, 200 TEU)
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 20' containers on barge with no further special equipment (assuming 85% load factor)	126 (107)
For 40' containers on barge with no further special equipment (assuming 85% load factor)	100 (85)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3 min
Administrative check-in:	Truck driver	5 min
	Gate agent	3 min
Drive to drop-off/parking:	Truck driver	2 min
Check-in duration per LU:	**Total LU**	7 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2 min
	Handling equipment driver	1 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min

Preparing transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	3 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	1 min
	Terminal truck driver	0 min
	Truck driver	0 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	1 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	30 min
Further procedures for departure:	non	0 min
Departure:	Crew	25 min
Departure duration:	**Total**	40 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	25 min
Further arrival procedures:	non	0 min
Terminal check-in:	Groundsman ship	30 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	1 min
	Terminal truck driver	0 min
	Truck driver	0 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	1 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	1 min
	Truck driver	4 min
Handover duration per LU:	**Total LU**	5 min

Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 11 min • Only Transhipment: 4 min
	Unloading	• All process steps: 8 min • Only Transhipment: 4 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one ship (excl. headway):	**Loading**	• 20'-Container: 431 min • 40'-Container: 343 min
	Unloading	• 20'-Container: 431 min • 40'-Container: 343 min
Total time for loading /unloading one ship (incl. headway):	**Loading**	• 20'-Container: 471 min • 40'-Container: 383 min
	Unloading	• 20'-Container: 471 min • 40'-Container: 383 min
Ships that can be handled in an 8-hour shift:		• 20'-Container: 0,49 • 40'-Container: 0,62

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full ship: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	321 min 321 min 963 min 428 min 0 min 0 min 36 min 30 min 25 min 2.124 min	255 min 255 min 765 min 340 min 0 min 0 min 37 min 30 min 25 min 1.707 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 3.400 min**	Crew:	3.400 min	3.400 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km.	Crew:	1.800 min	1.800 min

Duration: 1.800 min			
Second transhipment full ship: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	0 min 0 min 642 min 428 min 0 min 36 min 0 min 0 min 25 min 1.131 min	0 min 0 min 510 min 340 min 0 min 37 min 0 min 0 min 25 min 912 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	74,86 h	71,92 h
	600 km	48,19 h	45,26 h
Total working hours transport chain	**1.000 km**	514 h	444 h
	600 km	434 h	364 h
Total working hours per LU	**1.000 km**	4,80 h	5,22 h
	600 km	4,06 h	4,28 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	240,0 m	3,5 m	2	80 €/m²	1.680 m²	134.400 €
Loading lane	240,0 m	3,5 m	1	80 €/m²	840 m²	67.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	240,0 m	2,6 m	4	90 €/m²	2.496 m²	224.640 €
Inland port quay per metre	240,0 m	10,0 m	1	45.000 €/m	2.400 m²	10.800.000
Crane tracks	240,0 m	3,0 m	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile	240,0 m	15,0 m	1	90 €/m²	3.600 m²	324.000 €

harbour crane/HMHC						

Total area complete terminal	17.641 m²
Structural engineering (50 €/m²)	882.050 €
Earthworks and civil engineering (100 €/m²)	1.764.100 €
Building costs terminal	14.723.265 €
Planning costs 20%	2.944.653 €
Total building costs complete terminal	17.667.918 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	8.197.914 €
Maximum value based on European construction cost index	25.685.619 €
Depreciation time terminal (years)	25
Terminal building costs per year	1.193.887,83 €

Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Hydraulic crane	2.700.000	1	2.700.000	9
Spreader	100.000 €	1	100.000 €	10

Equipment costs terminal	**Investment costs**	2.800.000 €
	Planning costs (20%)	560.000 €
	Total	3.360.000 €
Total equipment costs terminal per year		448.930 €

Initial investment costs complete terminal and equipment incl. planning costs	21.027.918 €
Total investment costs complete terminal and equipment per year	1.642.818 €

6.1.1.1 Fact Sheet "Hydraulic material handling crane – IWW/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	52.500

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	736.163 €
Hydraulic crane	8	215.285 €

Spreader	2,8	2.800 €
Total maintenance costs per year		954.248 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	19.405 kWh	2.426 €
Hydraulic Crane	Diesel	1,17 l	122.500 l	137.200 €
Total energy costs per year				139.626 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.137 €
Maximum value electricity costs	3.517 €
Minimum value diesel costs	113.007 €
Maximum value diesel costs	167.660 €
Minimum value total energy costs	114.145 €
Maximum value diesel energy costs	171.176 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	33.000 €	66.000 €
Gate agent	1	3,5	35.000 €	122.500 €
Handling equipment driver	0	0	32.000 €	- €
Terminal truck driver	0	0	31.000 €	- €
Instructor “Groundsman”	1	3,5	37.000 €	129.500 €
Dispatcher	0,5	2	26.500 €	53.000 €
Total terminal personnel costs per year				371.000 €

Terminal personnel costs range in EU	
Minimum value personnel costs	80.359 €
Maximum value personnel costs	598.690 €

Total area costs (5,00 €/m² per year)	88.205 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 176.410 €

Total costs per year	3.195.897 €

Cost per transhipment for total terminal investment		31,29 €
Operational costs per transhipment	**Personnel costs**	7,07 €
	Energy costs	2,66 €
	Maintenance costs	18,18 €
	Total	27,90 €
Ground costs per transhipment		1,68 €
Total costs for one transhipment		60,87 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		36,40 €
Maximum value total costs transhipment		81,69 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €
Total main leg investment costs					3.000.000 €
Total investment costs per operating hour					38,72 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Barge (110 m)	2,7	80.000 €	16,67 €
Total maintenance costs per operating hour			16,67 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Barge (110 m)	Gas oil	0,006	233 l	167,42 €
Total energy costs per operating hour				167,42 €
Other operational costs main leg				

Cost type	Costs per km	Costs per operating hour
Inland shipping tax	0,00 €	0 €
Total other operational costs per operating hour		0 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	60,40 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport

	Total	
	Total	Per LU
First road leg	9.346 €	87,35 €
First transhipment	6.514 €	60,87 €
450 km main leg	13.766 €	128,66 €
850 km main leg	21.294 €	199,01 €
Second transhipment	6.514 €	60,87 €
Second road leg	9.065 €	84,72 €
LU costs transport chain 600 km main leg	443 €	4,14 €
LU costs transport chain 1.000 km main leg	688 €	6,43 €
Intermodal organizational costs 600 km main leg (25%)	11.411,85 €	106,65 €
Intermodal organizational costs 1.000 km main leg (25%)	13.354,98 €	124,81 €
Grand total 600 km	45.647 €	533,26 €
Grand total 1.000 km	53.420 €	624,06 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	484,32 €
Maximum value costs range 600 km transport in EU	574,90 €
Minimum value costs range 1.000 km transport in EU	575,12 €
Maximum value costs range 1.000 km transport in EU	665,70 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	2.510 €	23,46 €
First transhipment		35 €	0,32 €
Main leg	**450 km**	32.952 €	307,96 €
	850 km	62.242 €	581,70 €
Second transhipment		35 €	0,32 €
Second road leg	**75 km**	2.510 €	23,46 €
Full transport chain per LU	**600 km**	37.972 €	355,53 €
	1.000 km	67.263 €	629,27 €

6.1.1.2 Fact Sheet “Hydraulic material handling crane – IWW/Road – 40’ Container”

Total terminal handling capacity per year (transhipments)	52.500

Terminal maintenance costs

	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	736.163 €
Hydraulic crane	8	215.285 €
Spreader	2,8	2.800 €
Total maintenance costs per year		954.248 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	19.405 kWh	2.426 €
Hydraulic Crane	Diesel	1,17 l	122.500 l	137.200 €
Total energy costs per year				139.626 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.137 €
Maximum value electricity costs	3.517 €
Minimum value diesel costs	113.007 €
Maximum value diesel costs	167.660 €
Minimum value total energy costs	114.145 €
Maximum value diesel energy costs	171.176 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0	0	31.000 €	- €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				371.000 €

Terminal personnel costs range in EU	
Minimum value personnel costs	80.359 €

Maximum value personnel costs	598.690 €

Total area costs (5,00 €/m² per year)	88.205 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 176.410 €

Total costs per year	3.195.897 €

Cost per transhipment for total terminal investment		31,29 €
Operational costs per transhipment	**Personnel costs**	7,07 €
	Energy costs	2,66 €
	Maintenance costs	18,18 €
	Total	27,90 €
Ground costs per transhipment		1,68 €
Total costs for one transhipment		60,87 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		36,40 €
Maximum value total costs transhipment		81,69 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40’ Container	3.000 €	12	90 €	0,09 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €
Total main leg investment costs					3.000.000 €
Total investment costs per operating hour					38,72 €

Main leg equipment maintenance costs

Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Barge (110 m)	2,7	80.000 €	16,67 €
Total maintenance costs per operating hour			16,67 €

Main leg energy consumption

Consumer	Energy type	Consumption in kWh per ton-km	Consumption per hour	Costs per operating hour(€)
Barge (110 m)	Gas oil	0,006	211 l	152,19 €
Total energy costs per operating hour				152,19 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Inland shipping tax	0,00 €	0 €
Total other operational costs per operating hour		0 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	60,40 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**

Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	7.425 €	87,35 €
First transhipment	5.174 €	60,87 €
450 km main leg	11.882 €	139,79 €
850 km main leg	18.852 €	221,78 €
Second transhipment	5.174 €	60,87 €
Second road leg	7.201 €	84,72 €
LU costs transport chain 600 km main leg	463 €	5,44 €
LU costs transport chain 1.000 km main leg	735 €	8,65 €
Intermodal organizational costs 600 km main leg (25%)	9.329,67 €	109,76 €
Intermodal organizational costs 1.000 km main leg (25%)	11.140,28 €	131,06 €
Grand total 600 km	37.319 €	548,80 €
Grand total 1.000 km	44.561 €	655,31 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	499,86 €
Maximum value costs range 600 km transport in EU	590,44 €
Minimum value costs range 1.000 km transport in EU	606,36 €
Maximum value costs range 1.000 km transport in EU	696,95 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	1.994 €	23,46 €
First transhipment		28 €	0,32 €
Main leg	**450 km**	28.814 €	338,98 €
	850 km	54.426 €	640,30 €
Second transhipment		28 €	0,32 €
Second road leg	**75 km**	1.994 €	23,46 €
Full transport chain per LU	**600 km**	32.802 €	386,55 €
	1.000 km	58.414 €	687,87 €

7 Fact sheet for "Hydraulic material handling crane – SSS/Road"

Picture of the technology:

Source: www.sennebogen.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

A hydraulic material handling crane (hydraulic crane) is mainly used in ports for handling mass and bulk goods. The crane resembles an excavator and the grab arm is moved exclusively hydraulically (without ropes). For the handling of intermodal loading units, a spreader must be coupled to the grab arm.
The hydraulic material handling crane is mobile and can be used on various chassis. The crane can be moved for loading and unloading.

Process:

- Hydraulic crane moves to the transhipment place
- The crane extends the support legs and starts the handling operation
- Crane moves the Spreader to the loading unit. Spreader locks the twist locks
- Crane lift the loading unit via spreader and hoist rope
- Crane moves the loading unit the destination
- Hoist rope lowers spreader with loading unit
- Spreader is opened or unlocked
- Spreader is lifted and crane moves to next order
- Spreader is lifted and reach stacker moves to next order

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network with other vertical handling systems. The focus of the technology is more on transhipment of conventional goods, but can also be used for transhipment of intermodal loading units. Currently, the technology is rarely used for intermodal tasks.	

Indicative qualitative assessment:

Strengths	Weaknesses and limitations
• Flexible use in the port • Can also be used for other goods, not only for intermodal loading units • due to hydraulic quick-change systems the change between various attachments (grabs/spreader) can be done without mechanics and in a few minutes • Using a material handling crane the cargo is not affected by wind the same way a rope spreader is. • Due to rigid fixation of the spreader to the material handling boom a more precise positioning is possible • The cycle speed of a material handler in comparison to a crane seriously faster • A material Handler is classed as an excavator which reduces the regular inspection costs • Operators for hydraulic material handlers are easier to find then crane operators • Energy Recovery Systems (Green Hybrid) support the lift and reduce energy consumption • hydraulic cabin elevation reduce time for climbing up to cabin	• High acquisition costs • Special structure needed to withstand the weight of the crane. • Acquisition costs need to be compared speed is considerably faster

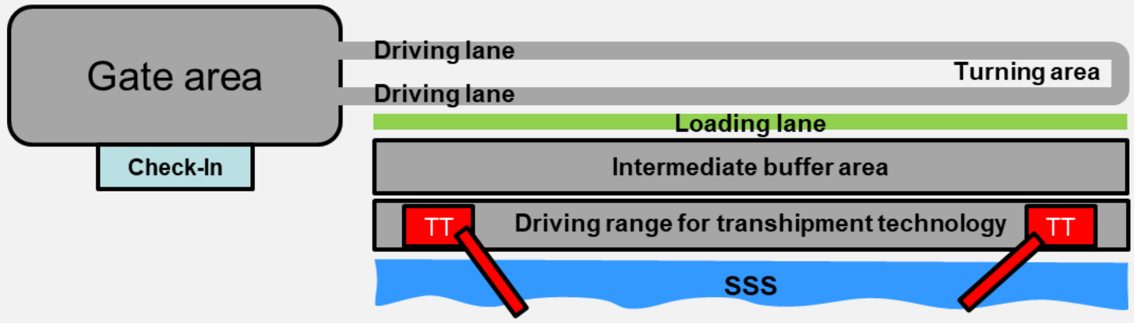
Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets (Not used in practice)

• Complete road vehicle	• Not possible	
Transhipable max. weight (loaded goods plus loading unit weight):		22 t

7.1.1 Fact Sheet "Hydraulic material handling crane – SSS/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Short sea container ships (1.000 TEU)

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:

For 20' containers on barge with no further special equipment (assuming 85% load factor)	590 (501)
For 40' containers on barge with no further special equipment (assuming 85% load factor)	500 (425)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3 min
Administrative check-in:	Truck driver	5 min
	Gate agent	3 min
Drive to drop-off/parking:	Truck driver	2 min
Check-in duration per LU:	**Total LU**	7 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2 min
	Handling equipment driver	1 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	3 min

LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	1 min
	Terminal truck driver	0 min
	Truck driver	0 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	1 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	10 min
Further procedures for departure:	Crew	20 min
Departure:	Crew	10 min
Departure duration:	**Total**	30 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	10 min
Further arrival procedures:	Crew	20 min
Terminal check-in:	Groundsman ship	20 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	1 min
	Terminal truck driver	0 min
	Truck driver	0 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	1 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	1 min
	Truck driver	4 min
Handover duration per LU:	**Total LU**	5 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 11 min • Only Transhipment: 4 min
	Unloading	• All process steps: 8 min • Only Transhipment: 4 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20'-Container: 1.005 min • 40'-Container: 853 min
	Unloading	• 20'-Container: 1.005 min • 40'-Container: 853 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 20'-Container: 1.035 min • 40'-Container: 883 min
	Unloading	• 20'-Container: 1.045 min • 40'-Container: 893 min
Trains that can be handled in an 8-hour shift:		• 20'-Container: 0,21 • 40'-Container: 0,25

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	1.503 min 1.503 min 4.509 min 2.004 min 0 min 0 min 30 min 50 min 240 min 9.839 min	1.275 min 1.275 min 3.825 min 1.700 min 0 min 0 min 30 min 50 min 240 min 8.395 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.619 min**	Crew:	1.619 min	1.619 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 857 min**	Crew:	857 min	857 min
Second transhipment full train: The LU is transhipped using the transhipment	Checker Gate agent Truck driver	0 min 0 min 3.006 min	0 min 0 min 2.550 min

technology as described in detail above.	Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	2.004 min 0 min 30 min 0 min 100 min 240 min 5.380 min	1.700 min 0 min 30 min 0 min 100 min 240 min 4.620 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	64,14 h	59,07 h
	600 km	51,44 h	46,38 h
Total working hours transport chain	**1.000 km**	1.826 h	1.584 h
	600 km	1.725 h	1.482 h
Total working hours per LU	**1.000 km**	3,65 h	3,73 h
	600 km	3,44 h	3,49 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60	1	80 €/m²	6.000 m²	480.000 €
Driving lane	240,0 m	3,5	2	80 €/m²	1.680 m²	134.400 €
Loading lane	240,0 m	3,5	1	80 €/m²	840 m²	67.200 €
Turning area	25,0 m	25	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	240,0 m	2,6	4	90 €/m²	2.496 m²	224.640 €
Inland port quay per metre	320,0 m	10	1	75.000 €/m	3.200 m²	24.000.000 €
Crane tracks	240,0 m	0	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	240,0 m	15	1	90 €/m²	3.600 m²	324.000 €
Total area complete terminal					18.441 m²	

Structural engineering (50 €/m²)				922.050 €
Earthworks and civil engineering (100 €/m²)				1.844.100 €
Building costs terminal				28.043.265 €
Planning costs 20%				4.206.490 €
Total building costs complete terminal				32.249.755 €
Terminal building costs range in EU				
Minimum value based on European construction cost index				14.963.886 €
Maximum value based on European construction cost index				46.884.693 €
Depreciation time terminal (years)				25
Terminal building costs per year				2.179.237 €
Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Hydraulic crane	2.700.000 €	2	5.600.000 €	9
Spreader	100.000 €	2	200.000 €	10
Equipment costs terminal	**Investment costs**			5.600.000 €
	Planning costs (20%)			1.120.000 €
	Total			6.720.000 €
Total equipment costs terminal per year				897.860 €

Initial investment costs complete terminal and equipment incl. planning costs	38.969.755 €
Total investment costs complete terminal and equipment per year	3.077.097 €

7.1.1.1 Fact Sheet "Hydraulic material handling crane – SSS/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	105.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	1.402.163 €
Hydraulic crane	6	162.645 €
Spreader	2,8	5.600 €
Total maintenance costs per year		1.570.408 €
Terminal energy consumption		

Consumer	Energy type	Consumption per transhipment	Consumption per year	Energy costs per year
Infrastructure	Electricity	-	20.285 kWh	2.536 €
Mobil harbour crane	Diesel	1,17 l	245.000 l	176.400 €
Total energy costs per year				178.936 €
Terminal energy costs range in EU				
Minimum value electricity costs				1.189 €
Maximum value electricity costs				3.676 €
Minimum value diesel costs				145.295 €
Maximum value diesel costs				215.563 €
Minimum value total energy costs				146.484 €
Maximum value diesel energy costs				219.239 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				561.750 €
Terminal personnel costs range in EU				
Minimum value personnel costs				121.675 €
Maximum value personnel costs				906.506 €

Total area costs (5,00 €/m² per year)	92.205 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 184.410 €

Total costs per year	5.480.396 €

Cost per transhipment for total terminal investment		29,31 €
Operational costs per transhipment	**Personnel costs**	5,35 €
	Energy costs	1,70 €
	Maintenance costs	14,96 €
	Total	22,01 €
Ground costs per transhipment		0,88 €
Total costs for one transhipment		52,19 €

Total transhipment costs range in EU	
Minimum value total costs transhipment	31,11 €
Maximum value total costs transhipment	70,04 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Short Sea Container Ship	20.000.000 €	1	20.000.000 €	25	281,56 €
Total main leg investment costs					20.000.000 €
Total investment costs per operating hour					281,56 €

Main leg equipment maintenance costs

Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Short Sea Container Ship	2,2	430.647 €	89,72 €
Total maintenance costs per operating hour			89,72 €

Main leg energy consumption

Consumer	Energy type	Energy consumption per t/h	Energy consumption per 450 km transport (ton)	Energy consumption per 850 km transport (ton)
Short Sea Container Ship	Gas oil	1,75	25	47

Other operational costs main leg

Cost type	Costs
Port	1.494 €
Total other operational costs per operating hour	1.494 €
Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant
Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport

	Total	
	Total	Per LU
First road leg	43.761 €	87,35 €
First transhipment	26.149 €	52,19 €
450 km main leg	34.720 €	69,30 €
850 km main leg	52.360 €	104,51 €
Second transhipment	26.149 €	52,19 €
Second road leg	42.444 €	84,72 €
LU costs transport chain 600 km main leg	2.214 €	4,42 €
LU costs transport chain 1.000 km main leg	2.761 €	5,51 €
Intermodal organizational costs 600 km main leg (25%)	43.859,54 €	87,54 €
Intermodal organizational costs 1.000 km main leg (25%)	48.406,19 €	96,62 €
Grand total 600 km	175.438 €	437,72 €
Grand total 1.000 km	193.625 €	483,10 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	395,55 €
Maximum value costs range 600 km transport in EU	440,92 €
Minimum value costs range 1.000 km transport in EU	411,12 €
Maximum value costs range 1.000 km transport in EU	518,78 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	44.075 €	87,98 €
First transhipment		160 €	0,32 €
Main leg	**450 km**	66.219 €	132,17 €
	850 km	125.081 €	249,66 €
Second transhipment		160 €	0,32 €
Second road leg	**75 km**	44.075 €	87,98 €
Full transport chain per LU	**600 km**	154.370 €	308,76 €
	1.000 km	213.232 €	426,25 €

7.1.1.2 Fact Sheet “Hydraulic material handling crane – SSS/Road – 40’ Container”

Total terminal handling capacity per year (transhipments)	105.000

Terminal maintenance costs

	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	1.402.163 €
Hydraulic crane	6	162.645 €
Spreader	2,8	5.600 €
Total maintenance costs per year		1.570.408 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	20.285 kWh	2.536 €
Mobil harbour crane	Diesel	1,17 l	245.000 l	176.400 €
Total energy costs per year				178.936 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.189 €
Maximum value electricity costs	3.676 €
Minimum value diesel costs	145.295 €
Maximum value diesel costs	215.563 €
Minimum value total energy costs	146.484 €
Maximum value diesel energy costs	219.239 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	1	3,5	31.000 €	108.500 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				561.750 €

Terminal personnel costs range in EU	
Minimum value personnel costs	121.675 €

Maximum value personnel costs	906.506 €

Total area costs (5,00 €/m² per year)	92.205 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 184.410 €

Total costs per year	5.480.396 €

Cost per transhipment for total terminal investment		29,31 €
Operational costs per transhipment	**Personnel costs**	5,35 €
	Energy costs	1,70 €
	Maintenance costs	14,96 €
	Total	22,01 €
Ground costs per transhipment		0,88 €
Total costs for one transhipment		52,19 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		31,11 €
Maximum value total costs transhipment		70,04 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
40’ Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Short Sea Container Ship	20.000.000 €	1	20.000.000 €	25	281,56 €
Total main leg investment costs					20.000.000 €
Total investment costs per operating hour					281,56 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Short Sea Container Ship	2,2	430.647 €	89,72 €
Total maintenance costs per operating hour			89,72 €

Main leg energy consumption				
Consumer	**Energy type**	**Energy consumption per t/h**	**Energy consumption per 450 km transport (ton)**	**Energy consumption per 850 km transport (ton)**
Short Sea Container Ship	Gas oil	1,75	25	47

Other operational costs main leg	
Cost type	**Costs**
Port	1.494 €
Total other operational costs per operating hour	1.494 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	37.123 €	87,35 €
First transhipment	22.183 €	52,19 €
450 km main leg	32.839 €	77,27 €
850 km main leg	50.479 €	118,77 €
Second transhipment	22.183 €	52,19 €
Second road leg	36.006 €	84,72 €
LU costs transport chain 600 km main leg	2.371 €	5,58 €
LU costs transport chain 1.000 km main leg	3.020 €	7,10 €
Intermodal organizational costs 600 km main leg (25%)	38.175,73 €	89,83 €
Intermodal organizational costs 1.000 km main leg (25%)	42.748,01 €	100,58 €
Grand total 600 km	152.703 €	449,13 €
Grand total 1.000 km	170.992 €	502,92 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		406,95 €
Maximum value costs range 600 km transport in EU		484,81 €
Minimum value costs range 1.000 km transport in EU		460,75 €
Maximum value costs range 1.000 km transport in EU		538,61 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	37.389 €	87,98 €
First transhipment		136 €	0,32 €
Main leg	**450 km**	60.953 €	143,42 €
	850 km	115.133 €	270,90 €
Second transhipment		136 €	0,32 €
Second road leg	**75 km**	37.389 €	87,98 €

Full transport chain per LU	**600 km**	135.731 €	320,01 €
	1.000 km	189.911 €	447,49 €

8 Fact sheet for "Mobile harbour crane"

8.1 Fact sheet for "Mobile harbour crane – Rail/Road"

Picture of the technology:

Source: Liebherr

Description of the transhipment technology and transhipment process (road → main leg):

A mobile harbour crane is a crane that can be used flexibly in the harbour area due to its rubberised wheels. It combines the performance of normal fixed or rail-mounted cranes with the advantage of being able to be used flexibly along transhipment tracks or quays. Due to the crane's mass, however, a corresponding area structure is necessary. In addition to handling bulk goods, this crane can also handle intermodal loading units with the help of a spreader.
Generally equipped with a hoist rope, wire ropes or chains, and sheaves, that can be used both to lift and lower cargo like intermodal loading units.
The mobile crane can be operated in two ways when transhipping from rail or waterway to road. One variant is to extend the crane at the place of its support legs and to carry out the transhipment from this place. Once the working area of the crane has been worked through, the train or ship is moved and the crane can work on the next section. With this variant, additional vehicles such as reach stackers are usually used. The second variant is after the working area has been completed, the crane moves to the next working area and carries out the handling there. Since the crane can only move slowly and the extension and retraction of the support legs is time-consuming, this variant is slow when handling between the modes of transport.

Process:

- Mobile Harbour Crane moves to the transhipment place
- The crane extends the support legs and starts the transhipment operation.
- Crane moves the Spreader to the loading unit. Spreader is locked or closed.
- Crane lift the loading unit via spreader and hoist rope

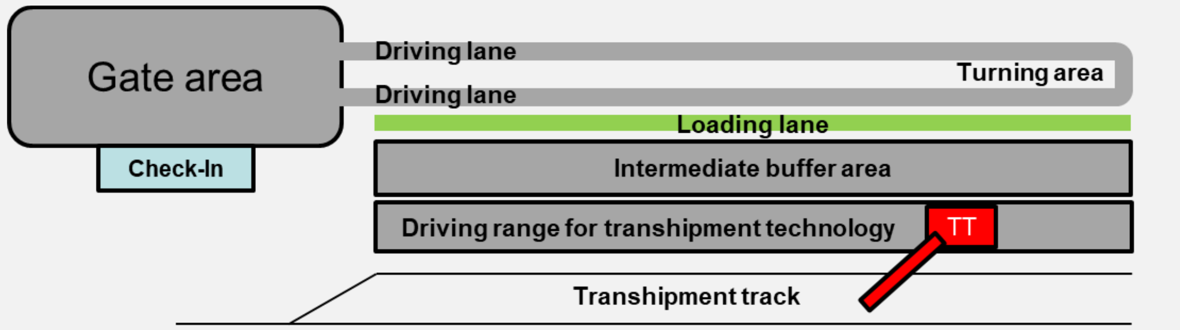
• Crane moves the loading unit to the destination • Hoist rope lowers spreader with loading unit • Spreader is opened or unlocked • Spreader is lifted and crane moves to next order		
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network with other vertical handling systems. The focus of the technology is more on transhipment of conventional goods, but can also be used for transhipment of intermodal loading units.	

Indicative qualitative assessment:	
Strengths	**Weaknesses and limitations**
• Flexible use in the port • Can also be used for other goods, not only for intermodal loading units	• High acquisition costs • Special structure needed to withstand the weight of the crane.

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets (Not used in practice)
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	84 t

8.1.1 Fact Sheet "Mobile harbour crane – Rail/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Loco, Sggrss 80’ rail wagons or similar

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 20’ containers on Sggrss 80’ wagons with no further special equipment (assuming 85% load factor)	64 (54)
For 40’ containers on Sggrss 80’ wagons with no further special equipment (assuming 85% load factor)	50 (43)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	2,0 min
Administrative check-in:	Truck driver	2,0 min
	Gate agent	0,0 min
Drive to drop-off/parking:	Truck driver	0,0 min
Check-in duration per LU:	**Total LU**	0,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,0 min
	Handling equipment driver	1,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	1,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	4,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	2,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
Departure: The departure on the main leg is prepared and executed.		

Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	20': 63,2 min 40': 98,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	20': 73,2 min 40': 108,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	2,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	2,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	2,0 min
	Truck driver	4,0 min
Handover duration per LU:	**Total LU**	4,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 13 min • Only Transhipment: 6 min
	Unloading	• All process steps: 8 min • Only Transhipment: 6 min

Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20'-Container: 380 min • 40'-Container: 364 min
	Unloading	• 20'-Container: 380 min • 40'-Container: 346 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 20'-Container: 453 min • 40'-Container: 455 min
	Unloading	• 20'-Container: 420 min • 40'-Container: 386 min
Trains that can be handled in an 8-hour shift:		• 20'-Container: 0,48 • 40'-Container: 0,50

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	162 min 162 min 486 min 324 min 0 min 108 min 30 min 30 min 63 min 10 min 1.375 min	129 min 129 min 387 min 258 min 0 min 86 min 30 min 30 min 99 min 10 min 1.158 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman	0 min 0 min 324 min 324 min 0 min 30 min 108 min	0 min 0 min 258 min 258 min 0 min 30 min 86 min

	Groundsman train Visitor/Wagon inspector Train driver Total:	30 min 0 min 10 min 826 min	30 min 0 min 10 min 672 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	38,30 h	37,76 h
	600 km	28,30 h	27,76 h
Total working hours transport chain	**1.000 km**	215 h	179 h
	600 km	200 h	164 h
Total working hours per LU	**1.000 km**	3,98 h	4,17 h
	600 km	3,71 h	3,82 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	7,0 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	2	80 €/m²	2.590 m²	207.200 €
Turning area	57,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	1.924 m²	173.160 €
Intermediate buffer area (non-stackable)	740,0 m	11,0 m	2	80 €/m²	m²	- €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	0,0 m	0,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0,0 m	0,0 m	-	1.250 €/m	m²	- €

Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	-	90 €/m²	11.100 m²	999.000 €

Total area complete terminal	28.203 m²
Structural engineering (50 €/m²)	1.410.125 €
Earthworks and civil engineering (100 €/m²)	2.820.250 €
Building costs terminal	7.175.510 €
Planning costs 20%	1.435.102 €
Total building costs complete terminal	8.610.612 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	3.995.324 €
Maximum value based on European construction cost index	12.518.108 €
Depreciation time terminal (years)	25
Terminal building costs per year	581.852 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Hydraulic crane	2.400.000 €	1	2.400.000 €	9
Spreader	100.000 €	1	100.000 €	10

Equipment costs terminal	**Investment costs**	2.500.000 €
	Planning costs (20%)	500.000 €
	Total	3.000.000 €
Total equipment costs terminal per year		400.693 €

Initial investment costs complete terminal and equipment incl. planning costs	11.610.612 €
Total investment costs complete terminal and equipment per year	982.545 €

8.1.1.1 Fact Sheet “Mobile harbour crane – Rail/Road – 20’ Container”

Total terminal handling capacity per year (transhipments)	25.973

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**

Terminal Infrastructure	5	358.776 €
Mobile harbour crane	7	168.000
Spreader	2,8	2.800 €
Total maintenance costs per year		529.576 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	31.023 kWh	3.878 €
Mobile harbour crane	Diesel	0,8 l	41.557 l	46.544 €
Total energy costs per year				50.422 €
Terminal energy costs range in EU				
Minimum value electricity costs				1.818 €
Maximum value electricity costs				5.622 €
Minimum value diesel costs				38.337 €
Maximum value diesel costs				56.878 €
Minimum value total energy costs				40.155 €
Maximum value diesel energy costs				62.500 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				479.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				103.860 €
Maximum value personnel costs				773.778 €

Total area costs (5,00 €/m² per year)	141.013 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 282.025 €

Total costs per year	2.175.002 €

Cost per transhipment for total terminal investment		45,74 €
Operational costs per transhipment	**Personnel costs**	22,32 €
	Energy costs	1,97 €
	Maintenance costs	24,65 €
	Total	48,95 €
Ground costs per transhipment		6,56 €
Total costs for one transhipment		101,26 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		52,28 €
Maximum value total costs transhipment		142,76 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
20’ Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Sggrss 80’ wagon	85.000 €	16	1.360.000 €	40	15,73 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					6.360.000 €
Total investment costs per operating hour					73,54 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Sggrss 80’ wagons	7	96.000 €	20,00 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			82,50 €

Main leg energy consumption

Consumer	Energy type	Consumption in kWh per ton-km	Consumption per hour	Costs per operating hour(€)
Loco	Electricity	0,02	1.389 kWh	173,68 €
Total energy costs per operating hour				173,68 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	4.717 €	87,35 €
First transhipment	4.539 €	84,05 €
450 km main leg	6.520 €	120,75 €
850 km main leg	11.534 €	213,58 €
Second transhipment	4.539 €	84,05 €
Second road leg	4.575 €	84,72 €
LU costs transport chain 600 km main leg	131 €	2,43 €
LU costs transport chain 1.000 km main leg	175 €	3,24 €
Intermodal organizational costs 600 km main leg (25%)	6.255,15 €	115,84 €
Intermodal organizational costs 1.000 km main leg (25%)	7.519,39 €	139,25 €
Grand total 600 km	25.021 €	579,18 €
Grand total 1.000 km	30.078 €	696,24 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	498,05 €
Maximum value costs range 600 km transport in EU	647,96 €
Minimum value costs range 1.000 km transport in EU	615,11 €
Maximum value costs range 1.000 km transport in EU	765,02 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	4.778 €	88,49 €
First transhipment		13 €	0,25 €
Main leg	**450 km**	8.597 €	159,21 €
	850 km	16.239 €	300,72 €
Second transhipment		13 €	0,25 €
Second road leg	**75 km**	4.778 €	88,49 €

Full transport chain per LU	**600 km**	18.154 €	336,67 €
	1.000 km	25.795 €	478,19 €

8.1.1.2 Fact Sheet “Mobile harbour crane – 40’ Container”

Total terminal handling capacity per year (transhipments)	21.480

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	358.776 €
Mobile harbour crane	7	168.000 €
Spreader	2,8	2.800 €
Total maintenance costs per year		529.576 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	31.023 kWh	3.878 €
Mobile harbour crane	Diesel	0,8 l	34.367 l	38.491 €
Total energy costs per year				42.369 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.818 €
Maximum value electricity costs	5.622 €
Minimum value diesel costs	31.704 €
Maximum value diesel costs	47.037 €
Minimum value total energy costs	33.522 €
Maximum value diesel energy costs	52.659 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €

Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				479.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				103.860 €
Maximum value personnel costs				773.778 €

Total area costs (5,00 €/m² per year)	141.013 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 282.025 €

Total costs per year	2.175.002 €

Cost per transhipment for total terminal investment		45,74 €
Operational costs per transhipment	**Personnel costs**	22,32 €
	Energy costs	1,97 €
	Maintenance costs	24,65 €
	Total	48,95 €
Ground costs per transhipment		6,56 €
Total costs for one transhipment		101,26 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		52,28 €
Maximum value total costs transhipment		142,76 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
40' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Sggrss 80' wagon	85.000 €	25	2.125.000 €	40	24,57 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.125.000 €

Total investment costs per operating hour				82,39 €
Main leg equipment maintenance costs				
Equipment	**Percentage of investment (%)**	**Costs per year**		**Costs per operating hour**
Sggrss 80' wagons	7	150.000 €		31,25 €
Loco	6	300.000 €		62,50 €
Total maintenance costs per operating hour				93,75 €
Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.451 kWh	181,34 €
Total energy costs per operating hour				181,34 €
Other operational costs main leg				
Cost type	**Costs per km**			**Costs per operating hour**
Track access	3,00 €			120 €
Total other operational costs per operating hour				120 €
Personnel costs main leg				
Function				**Costs per operating hour**
Train driver				35,38 €
Train dispatcher				32,43 €
Wagon inspector				35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant
Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport	Total	
	Total	**Per LU**
First road leg	3.756 €	87,35 €
First transhipment	4.354 €	101,26 €
450 km main leg	7.134 €	165,92 €
850 km main leg	12.425 €	288,96 €
Second transhipment	4.354 €	101,26 €
Second road leg	3.643 €	84,72 €
LU costs transport chain 600 km main leg	144 €	3,34 €
LU costs transport chain 1.000 km main leg	192 €	4,48 €
Intermodal organizational costs 600 km main leg (25%)	5.846,29 €	135,96 €
Intermodal organizational costs 1.000 km main leg (25%)	7.181,18 €	167,00 €
Grand total 600 km	23.385 €	679,80 €
Grand total 1.000 km	28.725 €	835,02 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	581,83 €
Maximum value costs range 600 km transport in EU	762,81 €
Minimum value costs range 1.000 km transport in EU	737,05 €
Maximum value costs range 1.000 km transport in EU	918,03 €

External costs

		Total	Per LU
First road leg	75 km	3.980 €	92,57 €
First transhipment		11 €	0,25 €
Main leg	450 km	8.976 €	208,75 €
	850 km	16.955 €	394,31 €
Second transhipment		11 €	0,25 €
Second road leg	75 km	3.980 €	92,57 €
Full transport chain per LU	600 km	16.937 €	394,39 €
	1.000 km	24.916 €	579,94 €

9 Fact sheet for “Mobile harbour crane – IWW/Road”

Picture of the technology:

Source: Liebherr

Description of the transhipment technology and transhipment process (road → main leg):

A mobile harbour crane is a crane that can be used flexibly in the harbour area due to its rubberised wheels. It combines the performance of normal fixed or rail-mounted cranes with the advantage of being able to be used flexibly along transhipment tracks or quays. Due to the crane's mass, however, a corresponding area structure is necessary. In addition to handling bulk goods, this crane can also handle intermodal loading units with the help of a spreader.
Generally equipped with a hoist rope, wire ropes or chains, and sheaves, that can be used both to lift and lower cargo like intermodal loading units.
The mobile crane can be operated in two ways when transhipping from rail or waterway to road. One variant is to extend the crane at the place of its support legs and to carry out the transhipment from this place. Once the working area of the crane has been worked through, the train or ship is moved and the crane can work on the next section. With this variant, additional vehicles such as reach stackers are usually used. The second variant is after the working area has been completed, the crane moves to the next working area and carries out the handling there. Since the crane can only move slowly and the extension and retraction of the support legs is time-consuming, this variant is slow when handling between the modes of transport.

Process:

- Mobile Harbour Crane moves to the transhipment place
- The crane extends the support legs and starts the transhipment operation.
- Crane moves the Spreader to the loading unit. Spreader is locked or closed.
- Crane lift the loading unit via spreader and hoist rope
- Crane moves the loading unit to the destination
- Hoist rope lowers spreader with loading unit
- Spreader is opened or unlocked
- Spreader is lifted and crane moves to next order

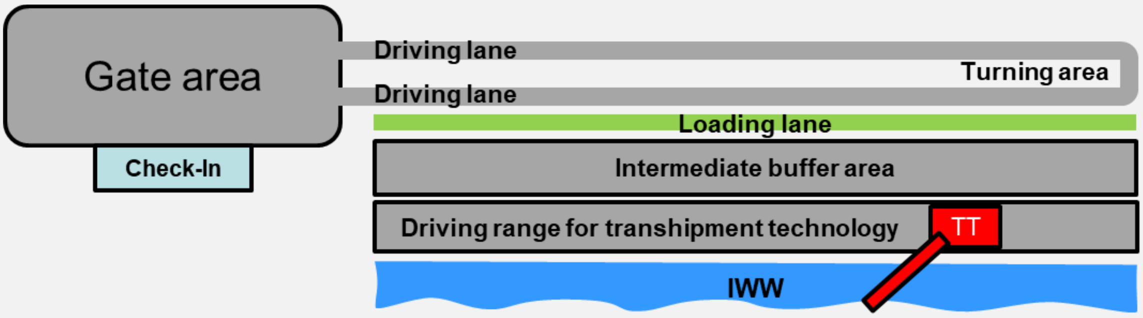
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network with other vertical handling systems. The focus of the technology is more on transhipment of conventional goods, but can also be used for transhipment of intermodal loading units.	

Indicative qualitative assessment:	
Strengths	**Weaknesses and limitations**
• Flexible use in the port • Can also be used for other goods, not only for intermodal loading units	• High acquisition costs • Special structure needed to withstand the weight of the crane.

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets (Not used in practice)
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	84 t

9.1.1 Fact Sheet "Mobile harbour crane – IWW/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Barges (110 m, 2.800 t, 200 TEU)

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:

For 20’ containers on barge with no further special equipment (assuming 85% load factor)	126 (107)
For 40’ containers on barge with no further special equipment (assuming 85% load factor)	100 (85)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2 min
	Handling equipment driver	2 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	4 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	30 min
Further procedures for departure:	non	0 min
Departure:	Crew	25 min
Departure duration:	**Total**	40 min
Process steps unloading main leg	**Involved personnel**	**Time**

Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	25 min
Further arrival procedures:	non	0 min
Terminal check-in:	Groundsman ship	30 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	2 min
	Truck driver	4 min
Handover duration per LU:	**Total LU**	6 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 13 min • Only Transhipment: 6 min
	Unloading	• All process steps: 10 min • Only Transhipment: 6 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one ship (excl. headway):	**Loading**	• 20’-Container: 650 min • 40’-Container: 518 min
	Unloading	• 20’-Container: 650 min • 40’-Container: 518 min
Total time for loading /unloading one ship (incl. headway):	**Loading**	• 20’-Container: 690 min • 40’-Container: 558 min
	Unloading	• 20’-Container: 690 min

	• 40'-Container: 558 min
Ships that can be handled in an 8-hour shift:	• 20'-Container: 0,33 • 40'-Container: 0,41

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full ship: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	321 min 321 min 963 min 642 min 0 min 0 min 34 min 30 min 25 min 2336 min	255 min 255 min 765 min 510 min 0 min 0 min 35 min 30 min 25 min 1875 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 3.400 min**	Crew:	3.400 min	3.400 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 1.800 min**	Crew:	1.800 min	1.800 min
Second transhipment full ship: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	0 min 0 min 642 min 642 min 0 min 34 min 214 min 0 min 25 min 1557 min	0 min 0 min 510 min 510 min 0 min 35 min 170 min 0 min 25 min 1250 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	82,17 h	77,77 h
	600 km	55,50 h	51,10 h
	1.000 km	525 h	452 h

Total working hours transport chain	**600 km**	445 h	372 h
Total working hours per LU	**1.000 km**	4,90 h	5,32 h
	600 km	4,16 h	4,38 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60	1	80 €/m²	6.000 m²	480.000 €
Driving lane	240,0 m	3,5	2	80 €/m²	1.680 m²	134.400 €
Loading lane	240,0 m	3,5	1	80 €/m²	840 m²	67.200 €
Turning area	25,0 m	25	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	180,0 m	2,6	4	90 €/m²	1.872 m²	168.480 €
Inland port quay per metre	240,0 m	10	1	45.000 €/m	2.400 m²	10.800.000
Crane tracks	240,0 m	0	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	240,0 m	15	1	90 €/m²	3.600 m²	324.000 €
Total area complete terminal					17.017 m²	
Structural engineering (50 €/m²)					850.850 €	
Earthworks and civil engineering (100 €/m²)					1.701.700 €	
Building costs terminal					14.573.505 €	
Planning costs 20%					2.914.701 €	
Total building costs complete terminal					17.488.206 €	
Terminal building costs range in EU						
Minimum value based on European construction cost index					8.114.528 €	
Maximum value based on European construction cost index					25.424.354 €	
Depreciation time terminal (years)					25	
Terminal building costs per year					1.181.744,01 €	

Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Mobile harbour crane	2.400.000 €	1	2.400.000 €	9
Spreader	100.000 €	1	100.000 €	10
Equipment costs terminal	**Investment costs**		2.500.000 €	
	Planning costs (20%)		500.000 €	
	Total		3.000.000 €	
Total equipment costs terminal per year			400.693 €	

Initial investment costs complete terminal and equipment incl. planning costs	20.488.206 €
Total investment costs complete terminal and equipment per year	1.582.437 €

9.1.1.1 Fact Sheet “Mobile harbour crane – IWW/Road – 20’ Container”

Total terminal handling capacity per year (transhipments)	35.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	728.675 €
Mobile harbour crane	2,8	67.200 €
Spreader	2,8	2.800 €
Total maintenance costs per year		798.675 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	18.719 kWh	2.340 €
Mobile harbour crane	Diesel	1,2 l	84.000 l	94.080 €
Total energy costs per year				96.420 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.097 €
Maximum value electricity costs	3.392 €
Minimum value diesel costs	77.491 €
Maximum value diesel costs	114.967 €

Minimum value total energy costs	78.588 €
Maximum value diesel energy costs	118.359 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	33.000 €	66.000 €
Gate agent	1	3,5	35.000 €	122.500 €
Handling equipment driver	0	0	32.000 €	- €
Terminal truck driver	0	0	31.000 €	- €
Instructor "Groundsman"	1	3,5	37.000 €	129.500 €
Dispatcher	0,5	2	26.500 €	53.000 €
Total terminal personnel costs per year				371.000 €
Terminal personnel costs range in EU				
Minimum value personnel costs				80.359 €
Maximum value personnel costs				598.690 €

Total area costs (5,00 €/m² per year)	85.085 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 170.170 €

Total costs per year	2.933.617 €

Cost per transhipment for total terminal investment		45,21 €
Operational costs per transhipment	**Personnel costs**	10,60 €
	Energy costs	2,75 €
	Maintenance costs	22,82 €
	Total	36,17 €
Ground costs per transhipment		2,43 €
Total costs for one transhipment		83,82 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		48,34 €
Maximum value total costs transhipment		113,90 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
20' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €
Total main leg investment costs					3.000.000 €
Total investment costs per operating hour					38,72 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Barge (110 m)	2,7	80.000 €	16,67 €
Total maintenance costs per operating hour			16,67 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Barge (110 m)	Gas oil	0,006	233 l	167,42 €
Total energy costs per operating hour				167,42 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Inland shipping tax	0,00 €	0 €
Total other operational costs per operating hour		0 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	60,40 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €

Reasonable fleet size (truck/semi-trailer ratio)	Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	9.346 €	87,35 €
First transhipment	8.968 €	83,82 €
450 km main leg	16.284 €	152,18 €
850 km main leg	23.836 €	222,76 €
Second transhipment	8.968 €	83,82 €
Second road leg	9.065 €	84,72 €
LU costs transport chain 600 km main leg	510 €	4,77 €
LU costs transport chain 1.000 km main leg	755 €	7,06 €
Intermodal organizational costs 600 km main leg (25%)	13.285,45 €	124,16 €
Intermodal organizational costs 1.000 km main leg (25%)	15.234,74 €	142,38 €
Grand total 600 km	53.142 €	620,82 €
Grand total 1.000 km	60.939 €	711,90 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	549,86 €
Maximum value costs range 600 km transport in EU	680,98 €
Minimum value costs range 1.000 km transport in EU	640,95 €
Maximum value costs range 1.000 km transport in EU	772,07 €

External costs			
		Total	Per LU
First road leg	75 km	2.525 €	23,60 €
First transhipment		36 €	0,34 €
Main leg	450 km	33.135 €	309,67 €
	850 km	62.588 €	584,93 €
Second transhipment		36 €	0,34 €
Second road leg	75 km	2.525 €	23,60 €
Full transport chain per LU	600 km	38.184 €	357,54 €
	1.000 km	67.637 €	632,80 €

9.1.1.2 Fact Sheet “Mobile harbour crane – IWW/Road – 40’ Container”

Total terminal handling capacity per year (transhipments)	35.000

Terminal maintenance costs		
	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	728.675 €
Mobile harbour crane	2,8	67.200 €
Spreader	2,8	2.800 €
Total maintenance costs per year		798.675 €

Terminal energy consumption				
Consumer	Energy type	Consumption per transhipment	Consumption per year	Energy costs per year
Infrastructure	Electricity	-	18.719 kWh	2.340 €
Mobile harbour crane	Diesel	1,2 l	84.000 l	94.080 €
Total energy costs per year				96.420 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.097 €
Maximum value electricity costs	3.392 €

Minimum value diesel costs	77.491 €
Maximum value diesel costs	114.967 €
Minimum value total energy costs	78.588 €
Maximum value diesel energy costs	118.359 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	1	3,5	35.000 €	122.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0	0	31.000 €	- €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				371.000 €
Terminal personnel costs range in EU				
Minimum value personnel costs				80.359 €
Maximum value personnel costs				598.690 €

Total area costs (5,00 €/m² per year)	85.085 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 170.170 €

Total costs per year	2.933.617 €

Cost per transhipment for total terminal investment		45,21 €
Operational costs per transhipment	**Personnel costs**	10,60 €
	Energy costs	2,75 €
	Maintenance costs	22,82 €
	Total	36,17 €
Ground costs per transhipment		2,43 €
Total costs for one transhipment		83,82 €
Total transhipment costs range in EU		

Minimum value total costs transhipment	48,34 €
Maximum value total costs transhipment	113,90 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
40’ Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Barge (110 m)	3.000.000 €	1	3.000.000 €	30	38,72 €
Total main leg investment costs					3.000.000 €
Total investment costs per operating hour					38,72 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Barge (110 m)	2,7	80.000 €	16,67 €
Total maintenance costs per operating hour			16,67 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Barge (110 m)	Gas oil	0,006	211 l	152,19 €
Total energy costs per operating hour				152,19 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Inland shipping tax	0,00 €	0 €
Total other operational costs per operating hour		0 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	60,40 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €

Chassis	26.000 €	11		0,85 €
Total road leg investment costs				126.000 €
Total investment costs per operating hour				4,68 €
Reasonable fleet size (truck/semi-trailer ratio)				Not relevant
Road leg equipment maintenance costs				
Equipment	**Percentage of investment (%)**	**Total per year**		**Costs per operating hour**
Truck	10%	10.000,00 €		2,86 €
Chassis	10%	2.600,00 €		0,74 €
Total maintenance costs per operating hour				3,60 €
Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				
Cost type	**Costs per km**		**Costs per leg**	
Tolls	0,187 €		11,22 €	
Personnel costs road leg				
Function			**Costs per operating hour**	
Truck driver			22,11 €	
Truck dispatcher			24,32 €	

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	7.425 €	87,35 €
First transhipment	7.124 €	83,82 €
450 km main leg	14.054 €	165,34 €
850 km main leg	21.200 €	249,41 €
Second transhipment	7.124 €	83,82 €
Second road leg	7.201 €	84,72 €
LU costs transport chain 600 km main leg	522 €	6,15 €
LU costs transport chain 1.000 km main leg	795 €	9,35 €
Intermodal organizational costs 600 km main leg (25%)	10.862,74 €	127,80 €

Intermodal organizational costs 1.000 km main leg (25%)	12.717,41 €	149,62 €
Grand total 600 km	43.451 €	638,98 €
Grand total 1.000 km	50.870 €	748,08 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		568,03 €
Maximum value costs range 600 km transport in EU		699,15 €
Minimum value costs range 1.000 km transport in EU		677,13 €
Maximum value costs range 1.000 km transport in EU		808,24 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	2.098 €	24,68 €
First transhipment		29 €	0,34 €
Main leg	**450 km**	30.122 €	354,37 €
	850 km	56.896 €	669,37 €
Second transhipment		29 €	0,34 €
Second road leg	**75 km**	2.098 €	24,68 €
Full transport chain per LU	**600 km**	34.318 €	404,42 €
	1.000 km	61.093 €	719,41 €

10 Fact sheet for "Mobile harbour crane – SSS/Road"

Picture of the technology:

Source: Liebherr

Description of the transhipment technology and transhipment process (road → main leg):

A mobile harbour crane is a crane that can be used flexibly in the harbour area due to its rubberised wheels. It combines the performance of normal fixed or rail-mounted cranes with the advantage of being able to be used flexibly along transhipment tracks or quays. Due to the crane's mass, however, a corresponding area structure is necessary. In addition to handling bulk goods, this crane can also handle intermodal loading units with the help of a spreader.
Generally equipped with a hoist rope, wire ropes or chains, and sheaves, that can be used both to lift and lower cargo like intermodal loading units.
The mobile crane can be operated in two ways when transhipping from rail or waterway to road. One variant is to extend the crane at the place of its support legs and to carry out the transhipment from this place. Once the working area of the crane has been worked through, the train or ship is moved and the crane can work on the next section. With this variant, additional vehicles such as reach stackers are usually used. The second variant is after the working area has been completed, the crane moves to the next working area and carries out the handling there. Since the crane can only move slowly and the extension and retraction of the support legs is time-consuming, this variant is slow when handling between the modes of transport.

Process:

- Mobile Harbour Crane moves to the transhipment place
- The crane extends the support legs and starts the transhipment operation.
- Crane moves the Spreader to the loading unit. Spreader is locked or closed.
- Crane lift the loading unit via spreader and hoist rope
- Crane moves the loading unit to the destination
- Hoist rope lowers spreader with loading unit
- Spreader is opened or unlocked
- Spreader is lifted and crane moves to next order

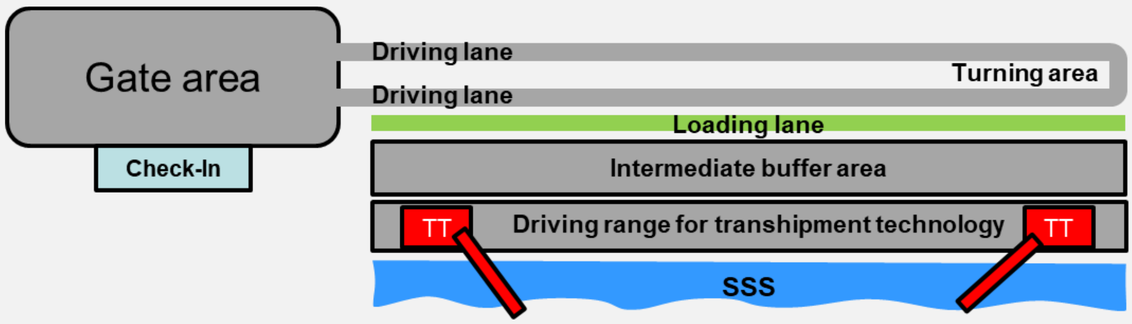
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☒ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network with other vertical handling systems. The focus of the technology is more on transhipment of conventional goods, but can also be used for transhipment of intermodal loading units.	

Indicative qualitative assessment:	
Strengths	**Weaknesses and limitations**
• Flexible use in the port • Can also be used for other goods, not only for intermodal loading units	• High acquisition costs • Special structure needed to withstand the weight of the crane.

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• All
• Inland container	• All craneable
• Swap body	• All craneable
• Semi-trailer	• Yes; top lift or with grappler pockets (Not used in practice)
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	84 t

10.1.1 Fact Sheet "Mobile harbour crane – SSS/Road – Containers"

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis
Necessary main leg equipment:	Short sea container ships (1.000 TEU)

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:

For 20' containers on barge with no further special equipment (assuming 85% load factor)	585 (497)
For 40' containers on barge with no further special equipment (assuming 85% load factor)	500 (425)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,0 min
	Handling equipment driver	2,0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	4 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	10 min
Further procedures for departure:	Crew	20 min
Departure:	Crew	10 min
Departure duration:	**Total**	30 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		

Arrival:	Crew	10 min
Further arrival procedures:	Crew	20 min
Terminal check-in:	Groundsman ship	20 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	2,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	2,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	2 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	2 min
	Truck driver	4 min
Handover duration per LU:	**Total LU**	6 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 13 min • Only Transhipment: 6 min
	Unloading	• All process steps: 10 min • Only Transhipment: 6 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 9 min
	Unloading	• 6 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20’-Container: 1.499 min • 40’-Container: 1.283 min
	Unloading	• 20’-Container: 1.499 min • 40’-Container: 1.283 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 20’-Container: 1.529 min • 40’-Container: 1.313 min
	Unloading	• 20’-Container: 1.529 min • 40’-Container: 1.313 min

Trains that can be handled in an 8-hour shift:	• 20'-Container: 0,14 • 40'-Container: 0,16

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	1.491 min 1.491 min 4.473 min 2.982 min 0 min 0 min 30 min 50 min 240 min 10.757 min	1.275 min 1.275 min 3.825 min 2.550 min 0 min 0 min 30 min 50 min 240 min 9.245 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.619 min**	Crew:	1.619 min	1.619 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 857 min**	Crew:	857 min	857 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	0 min 0 min 2.982 min 2.982 min 0 min 30 min 994 min 100 min 240 min 7.328 min	0 0 min 0 min 2.550 min 2.550 min 0 min 30 min 850 min 100 min 240 min 6.320 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min	75 min 6 min
Total duration transport chain	**1.000 km**	80,62 h	73,42 h
	600 km	67,92 h	60,72 h
Total working hours transport chain	**1.000 km**	1.863 h	1.626 h
	600 km	1.762 h	1.525 h
Total working hours per LU	**1.000 km**	3,75 h	3,83 h

	600 km	3,54 h	3,59 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60	1	80 €/m²	6.000 m²	480.000 €
Driving lane	240,0 m	3,5	2	80 €/m²	1.680 m²	134.400 €
Loading lane	240,0 m	3,5	1	80 €/m²	840 m²	67.200 €
Turning area	25,0 m	25	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	240,0 m	2,6	4	90 €/m²	2.496 m²	224.640 €
Inland port quay per metre	320,0 m	10	1	75.000 €/m	3.200 m²	24.000.000 €
Crane tracks	240,0 m	0	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	240,0 m	15	1	90 €/m²	3.600 m²	324.000 €
Total area complete terminal					18.441 m²	
Structural engineering (50 €/m²)					922.050 €	
Earthworks and civil engineering (100 €/m²)					1.844.100 €	
Building costs terminal					28.043.265 €	
Planning costs 20%					4.206.490 €	
Total building costs complete terminal					32.249.755 €	
Terminal building costs range in EU						
Minimum value based on European construction cost index					14.963.886 €	
Maximum value based on European construction cost index					46.884.693 €	
Depreciation time terminal (years)					25	
Terminal building costs per year					2.179.237 €	
Terminal equipment						

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)

Mobil harbour crane	2.400.000 €	2	4.800.000 €	9
Spreader	100.000 €	2	200.000 €	10

Equipment costs terminal	**Investment costs**	5.000.000 €
	Planning costs (20%)	1.000.000 €
	Total	6.000.000 €
Total equipment costs terminal per year		801.387 €

Initial investment costs complete terminal and equipment incl. planning costs	38.249.755 €
Total investment costs complete terminal and equipment per year	2.980.624 €

10.1.1.1 Fact Sheet “Mobile harbour crane – SSS/Road – 20’ Container”

Total terminal handling capacity per year (transhipments)	70.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	1.402.163 €
Mobil harbour crane	2,8	134.400 €
Spreader	2,8	5.600 €
Total maintenance costs per year		1.542.163 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	20.285 kWh	2.536 €
Mobil harbour crane	Diesel	1,2 l	168.000 l	120.960 €
Total energy costs per year				123.496 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.189 €
Maximum value electricity costs	3.676 €
Minimum value diesel costs	99.630 €
Maximum value diesel costs	147.814 €
Minimum value total energy costs	100.819 €
Maximum value diesel energy costs	151.490 €

Terminal personnel				
Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	1	3,5	31.000 €	108.500 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				472.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				102.344 €
Maximum value personnel costs				762.482 €

Total area costs (5,00 €/m² per year)	92.205 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 184.410 €

Total costs per year	5.210.988 €

Cost per transhipment for total terminal investment		42,58 €
Operational costs per transhipment	Personnel costs	6,75 €
	Energy costs	1,76 €
	Maintenance costs	22,03 €
	Total	30,55 €
Ground costs per transhipment		1,32 €
Total costs for one transhipment		74,44 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		44,69 €
Maximum value total costs transhipment		99,63 €

Loading unit investments and costs:				
Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour

20' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Short Sea Container Ship	20.000.000 €	1	20.000.000 €	25	281,56 €
Total main leg investment costs					20.000.000 €
Total investment costs per operating hour					281,56 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Short Sea Container Ship	2,2	430.647 €	89,72 €
Total maintenance costs per operating hour			89,72 €

Main leg energy consumption				
Consumer	**Energy type**	**Energy consumption per t/h**	**Energy consumption per 450 km transport (ton)**	**Energy consumption per 850 km transport (ton)**
Short Sea Container Ship	Gas oil	1,75	25	47

Other operational costs main leg	
Cost type	**Costs**
Port	1.494 €
Total other operational costs per operating hour	1.494 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	43.412 €	87,35 €
First transhipment	36.998 €	74,44 €
450 km main leg	40.838 €	82,17 €
850 km main leg	58.478 €	117,66 €
Second transhipment	36.998 €	74,44 €
Second road leg	42.105 €	84,72 €
LU costs transport chain 600 km main leg	2.900 €	5,83 €
LU costs transport chain 1.000 km main leg	3.442 €	6,93 €
Intermodal organizational costs 600 km main leg (25%)	50.812,62 €	102,24 €
Intermodal organizational costs 1.000 km main leg (25%)	55.358,18 €	111,38 €
Grand total 600 km	203.250 €	511,19 €
Grand total 1.000 km	221.433 €	556,92 €
Costs range in EU		

Minimum value costs range 600 km transport in EU	451,69 €
Maximum value costs range 600 km transport in EU	561,56 €
Minimum value costs range 1.000 km transport in EU	497,42 €
Maximum value costs range 1.000 km transport in EU	607,29 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	43.977 €	88,49 €
First transhipment		165 €	0,33 €
Main leg	**450 km**	66.255 €	133,31 €
	850 km	125.149 €	251,81 €
Second transhipment		165 €	0,33 €
Second road leg	**75 km**	43.977 €	88,49 €
Full transport chain per LU	**600 km**	154.209 €	310,94 €
	1.000 km	213.103 €	429,44 €

10.1.1.2 Fact Sheet "Mobile harbour crane – SSS/Road – 40' Container"

Total terminal handling capacity per year (transhipments)	70.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	1.402.163 €
Mobil harbour crane	2,8	134.400 €
Spreader	2,8	5.600 €
Total maintenance costs per year		1.542.163 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	20.285 kWh	2.536 €
Mobil harbour crane	Diesel	1,2 l	168.000 l	120.960 €
Total energy costs per year				123.496 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.189 €
Maximum value electricity costs	3.676 €

Minimum value diesel costs	99.630 €
Maximum value diesel costs	147.814 €
Minimum value total energy costs	100.819 €
Maximum value diesel energy costs	151.490 €

Terminal personnel				
Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	1	3,5	31.000 €	108.500 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				472.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				102.344 €
Maximum value personnel costs				762.482 €

Total area costs (5,00 €/m² per year)	92.205 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 184.410 €

Total costs per year	5.210.988 €

Cost per transhipment for total terminal investment		42,58 €
Operational costs per transhipment	Personnel costs	6,75 €
	Energy costs	1,76 €
	Maintenance costs	22,03 €
	Total	30,55 €
Ground costs per transhipment		1,32 €
Total costs for one transhipment		74,44 €
Total transhipment costs range in EU		

Minimum value total costs transhipment	44,69 €
Maximum value total costs transhipment	99,63 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
40' Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Short Sea Container Ship	20.000.000 €	1	20.000.000 €	25	281,56 €
Total main leg investment costs					20.000.000 €
Total investment costs per operating hour					281,56 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Short Sea Container Ship	2,2	430.647 €	89,72 €
Total maintenance costs per operating hour			89,72 €

Main leg energy consumption				
Consumer	**Energy type**	**Energy consumption per t/h**	**Energy consumption per 450 km transport (ton)**	**Energy consumption per 850 km transport (ton)**
Short Sea Container Ship	Gas oil	1,75	25	47

Other operational costs main leg	
Cost type	**Costs**
Port	1.494 €
Total other operational costs per operating hour	1.494 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments

Equipment	Unit costs	Depreciation time (years)	Costs per operating hour
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	37.123 €	87,35 €
First transhipment	31.638 €	74,44 €
450 km main leg	38.165 €	89,80 €
850 km main leg	55.805 €	131,31 €
Second transhipment	31.638 €	74,44 €
Second road leg	36.006 €	84,72 €
LU costs transport chain 600 km main leg	3.104 €	7,30 €

LU costs transport chain 1.000 km main leg	3.753 €	8,83 €
Intermodal organizational costs 600 km main leg (25%)	44.418,15 €	104,51 €
Intermodal organizational costs 1.000 km main leg (25%)	48.990,43 €	115,27 €
Grand total 600 km	177.673 €	522,57 €
Grand total 1.000 km	195.962 €	576,36 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	463,06 €
Maximum value costs range 600 km transport in EU	572,93 €
Minimum value costs range 1.000 km transport in EU	516,85 €
Maximum value costs range 1.000 km transport in EU	626,72 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	39.340 €	92,57 €
First transhipment		141 €	0,33 €
Main leg	**450 km**	63.362 €	149,09 €
	850 km	119.684 €	281,61 €
Second transhipment		141 €	0,33 €
Second road leg	**75 km**	39.340 €	92,57 €
Full transport chain per LU	**600 km**	142.043 €	334,88 €
	1.000 km	198.365 €	467,40 €

11 FACT SHEET FOR "DECK CRANE ON SHORT SEA CONTAINER SHIP – CRANE SHIP – SSS/ROAD"

Picture of the technology:

Source: https://www.liebherr.com/en/ind/products/maritime-cranes/ship-cranes/cylinder-luffing-ship-cranes/cylinder-luffing-onboard-cranes.html#!/accordion-start-module=accordion-item-start-module-1+accordion-item-start-module-3; April 2021

Description of the transhipment technology and transhipment process (road → main leg):

Crane ships, as defined for this study, are short sea container ships with cranes build onto the ships deck for the transhipment of containers to/from the ship. The number, positioning and design of the deck cranes varies depending on the vessel and the operational characteristics.
The ship's crane is invariably permanently mounted on its vessel, usually on the side or in the area behind. It consists of a foundation, a mounted turnstile and the crane itself, which can be controlled via the ship's internal technology. The most common implementation of the ship's crane allows the crane arm to rotate 360 degrees, which makes it easier to pick up and set down loads in all circumstances.

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☐ Rail ☐ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The technology is fully developed; however, our research did not reveal any regular inner European use of the technology for the transhipment of intermodal loading units. Rather, we learned that even outside Europe, ports which previously had no own means for the loading and unloading of container vessels are increasingly switching to their own flexible equipment like a mobile harbor crane. There are two reasons for this. On the one hand, the technology has limited attractiveness to shipping companies as the deck cranes weight and required space reduce the shippable cargo. On the other hand, ports without their own equipment are unattractive for other types of container ships but still need to keep additional handling equipment on shore, as the crane ship only deposits the loading units at the quay and does not load them further. The technology therefore offers limited savings potentials. The result of our research is therefore that crane ships do not play a relevant role in intermodal transport in Europe and are also losing importance worldwide. For these reasons the technology will be excluded from the further evaluation of technologies in this study.	

12 FACT SHEET FOR "FURMIA RTS 500 – RAIL/ROAD"

Picture of the technology:

RTS 500 re-loader prototype, Freeport Budapest, Hungary

Source:https://trimis.ec.europa.eu/sites/default/files/project/documents/20060727_150345_76487_INHOTRA_Final_Report.pdf ; April 2021

Description of the transhipment technology and transhipment process (road → main leg):

The Furmia RTS 500 technology consists of a horizontal transfer machine which can be used for the transhipment of standardized containers and swap bodies below the catenary. The machine is running parallel to the loading track on its own standard gauge track. The machine has two but similar lifting devices on each end which can be moved independent to adjust to loading units of different lengths. For the transhipment process two support legs have to be extended and put on the ground to stabilize the machine. Source: https://trimis.ec.europa.eu/sites/default/files/project/documents/20060727_150345_76487_INHOTRA_Final_Report.pdf ; April 2021		
Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 7: The technology was originally (1999/2000) developed by Neuweiler AG, Switzerland. Development was continued eventually by Bosch Rexroth Hungary in the European InHoTra project between 2000 and 2004. The technology reached the demonstrator stage of the InHoTra project and a prototype was built in the Freeport in Budapest. Although initial plans to build a full terminal for the technology in Budapest were made, this project was dropped and no further market implementation of the technology took place. Our research did not reveal any further indications of current use or further development of the technology. For this reason the technology will be excluded from the further evaluation of technologies in this study. Source: https://trimis.ec.europa.eu/sites/default/files/project/documents/20100506_153150_87620_ERRAC_Project_Evaluation_InHoTra.pdf ; April 2021	

13 Fact sheet for "RoRo Ramp to/from Ship"

13.1 Fact sheet for "RoRo Ramp to/from Ship – SSS/Road"

Picture of the technology:

Source: Port of Kiel; https://www.portofkiel.com/news-reader-en/port-of-kiel-can-nearly-maintain-its-cargo-handling-volumes.html; May 2021

Description of the transhipment technology and transhipment process (road → main leg):

Roll-on/roll-off (RoRo) is a transhipment technology, where wheeled cargo like trucks, trailers or other loading units on special trailers or cassettes is driven onto an especially designed roro-ship, either on its own or with the help of terminal equipment. This is done either with ramps built into the ship, through shore-based ramps or a combination of both. The doors through which the vehicles enter the ship can be located on the stern, bow or to the sides of the ship. Once on board, the loading units are dropped off at their designated transport space and are secured in place via. lashing. RoRo ships come in a wide variety of sizes, layouts and characteristics. There are mixed forms of RoRo-ships, combining the transport of wheeled cargo with container (RoCon) or passenger (RoPax) transport. For this study we will look at pure RoRo-ships with the doors/ramp located at the stern, a capacity of 2500 lane meters on 3 decks and built-in ramps. Furthermore, we will focus on the unaccompanied transport of non-craneable trailers and 45' containers on rolling trailers and on double stacking cassettes which are all driven onto the ship with a tug master.
Trailers can be picked up directly from the intermediate storage area by a tug master to be brought on the ship. There are specialized trestles which can be used for securing the trailers on the ship without additional lashing. For containers on roll trailers an additional device, called gooseneck, is necessary, which attached to the front of the roll trailer, for the tug master to pick them up. An additional device called translifter is used to pick up containers on cassettes with the tug master. The translifter is driven under the length of the cassette and then lifts it up from below. Depending on the ships deck height, the cassettes can be used for the transhipment and transport of double stacked containers, however ships enabling this are uncommon.

Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☐ Rail ☐ Inland waterway	☒ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The technology is fully developed and widely used throughout Europe. We will only evaluate unaccompanied RoRo transport in this study for different reasons: • The traffic distribution between shorter and longer routes correlates to the proportions of accompanied and unaccompanied RoRo transports and the transport distances of 600km/1000km evaluated in this study are comparatively long. • Most RoRo ships have a low passenger capacity (below 12) compared to the total loading capacity.	

Indicative qualitative assessment:

Strengths	Weaknesses and limitations
• High flexibility • Short and easy transhipment • Few requirements towards terminal infrastructure	• Many requirements for the vessel • Low cargo capacity for total ship size→ low utilization of cargo space

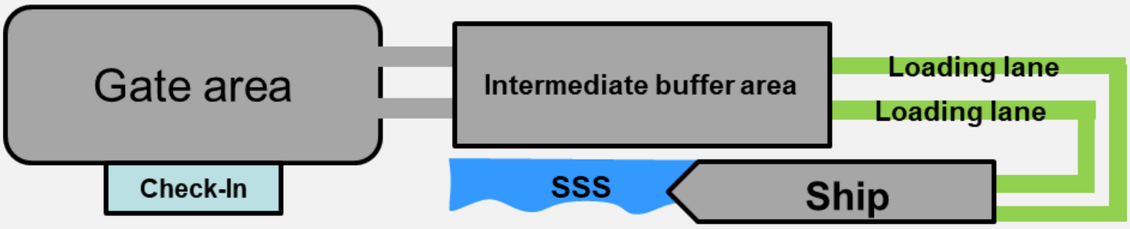
Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• All; on special equipment
• Inland container	• All; on special equipment
• Swap body	• All; on special equipment
• Semi-Trailer	• All
• Complete road vehicle	• All

Transhipable max. weight (loaded goods plus loading unit weight):	90 t

13.1.1 Fact Sheet "RoRo Ramp to/from Ship – SSS/Road"

Description of our model terminal:



Necessary road leg equipment:	Truck for semi-trailer Truck and chassis for Container
Necessary main leg equipment:	RoRo ship, further special equipment depending on the type of loading unit as described

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For Semitrailers (assuming 15 lm per semi-trailer and 85% load factor)	166 (141)
For 40' containers on roll-trailers (assuming 13 lm per roll-trailer and 85% load factor)	192 (163)
For 40' containers on cassettes (assuming 13 lm per cassette and 85% load factor)	384 (326)

13.1.1.1 Fact Sheet "RoRo Ramp to/from Ship – SSS/Road – Semi-trailers"

Detailed description of the transhipment process:

Process steps <u>loading</u> main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3 min
Administrative check-in:	Truck driver	5 min
	Gate agent	3 min
Drive to drop-off/parking:	Truck driver	2 min
Check-in duration per LU:	**Total LU**	7 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5 min
	Handling equipment driver	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Handling equipment driver	0 min
	Groundsman	0 min

Handover duration per LU:	**Total LU**	5 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	0 min
	Terminal truck driver	12 min
	Truck driver	0 min
	Groundsman	14 min
Transhipment duration per LU:	**Total LU**	12 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	10 min
Further procedures for departure:	Crew	20 min
Departure:	Crew	10 min
Departure duration:	**Total**	30 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	10 min
Further arrival procedures:	Crew	20 min
Terminal check-in:	Groundsman ship	20 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	0 min
	Terminal truck driver	12 min
	Truck driver	0 min
	Groundsman	14 min
Transhipment duration per LU:	**Total LU**	12 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	0 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	0 min
	Truck driver	5 min
Handover duration per LU:	**Total LU**	5 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min

Check-out duration per LU:		**Total LU**	2 min
Total time for the transhipment of one LU:	**Loading**	• All process steps: 24 min • Only Transhipment: 12 min	
	Unloading	• All process steps: 19 min • Only Transhipment: 12 min	
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min	
	Unloading	• 7 min	
Total time for loading /unloading one train (excl. headway):	**Loading**	• 172 min	
	Unloading	• 172 min	
Total time for loading /unloading one train (incl. headway):	**Loading**	• 202 min	
	Unloading	• 212 min	
Trains that can be handled in an 8-hour shift:		• 1,24	

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Semi-trailer**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	423 min 423 min 1.692 min 0 min 1.692 min 1.974 min 30 min 50 min 240 min 6.524 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.619 min**	Crew:	1.619 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 857 min**	Crew:	857 min
Second transhipment full train: The LU is transhipped	Checker Gate agent	0 min 0 min

using the transhipment technology as described in detail above.	Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	987 min 0 min 1.692 min 30 min 1.974 min 100 min 240 min 5.023 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	36,38 h
	600 km	23,68 h
Total working hours transport chain	**1.000 km**	790 h
	600 km	689 h
Total working hours per LU	**1.000 km**	5,60 h
	600 km	4,88 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	500,0 m	3,5 m	2	80 €/m²	3.500 m²	280.000 €
Loading lane	0,0 m	0,0 m	0	80 €/m²	m²	- €
Turning area	0,0 m	0,0 m	0	80 €/m²	m²	- €
Intermediate buffer area (stackable)	370,0 m	32,0 m	2	90 €/m²	23.680 m²	2.131.200 €
Inland port quay per metre	420,0 m	10,0 m	1	75.000 €/m	4.200 m²	31.500.000 €
Crane tracks	0,0 m	0,0 m	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	0	90 €/m²	m²	- €
Total area complete terminal					37.380 m²	

Structural engineering (50 €/m²)	1.869.000 €
Earthworks and civil engineering (100 €/m²)	3.738.000 €
Building costs terminal	39.998.200 €
Planning costs 20%	5.999.730 €
Total building costs complete terminal	45.997.930 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	21.343.040 €
Maximum value based on European construction cost index	66.871.791 €
Depreciation time terminal (years)	25
Terminal building costs per year	3.108.254 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Terminal truck	150.000 €	10	1.500.000 €	5

Equipment costs terminal	**Investment costs**	1.500.000 €
	Planning costs (20%)	300.000 €
	Total	1.800.000 €
Total equipment costs terminal per year		395.957 €

Initial investment costs complete terminal and equipment incl. planning costs	47.797.930 €
Total investment costs complete terminal and equipment per year	3.504.210 €

Total terminal handling capacity per year (transhipments)	175.000

Terminal maintenance costs

	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	1.999.910 €
Terminal truck	2,8	42.000 €
Total maintenance costs per year		2.041.910 €

Terminal energy consumption

Consumer	Energy type	Consumption per transhipment	Consumption per year	Energy costs per year
Infrastructure	Electricity	-	41.118 kWh	5.140 €

Terminal truck	Diesel	3 l	1.050.000 l	756.000 €
Total energy costs per year				761.140 €
Terminal energy costs range in EU				
Minimum value electricity costs				2.410 €
Maximum value electricity costs				7.451 €
Minimum value diesel costs				622.693 €
Maximum value diesel costs				923.840 €
Minimum value total energy costs				625.103 €
Maximum value diesel energy costs				931.291 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	2	7	26.500 €	185.500 €
Gate agent	2	7	33.000 €	231.000 €
Handling equipment driver	0	0	35.000 €	- €
Terminal truck driver	10	33	32.000 €	1.056.000 €
Instructor "Groundsman"	12	39,5	31.000 €	1.224.500 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				2.826.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				612.220 €
Maximum value personnel costs				4.561.175 €

Total area costs (5,00 €/m² per year)	186.900 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 373.800 €

Total costs per year	9.320.660 €

Cost per transhipment for total terminal investment		20,02 €
Operational costs per transhipment	**Personnel costs**	16,15 €
	Energy costs	4,35 €

	Maintenance costs	11,67 €
	Total	32,17 €
Ground costs per transhipment		1,07 €
Total costs for one transhipment		53,26 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		28,03 €
Maximum value total costs transhipment		74,30 €

Loading unit investments and costs:				
Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
Semi-trailer non craneable	26.000 €	11	780 €	0,78 €

Main leg investments					
Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Short Sea RoRo Ship (Semi-Trailer)	50.000.000 €	1	50.000.000 €	25	703,89 €
Trestle	3.000 €	166	498.000 €	10	17,55 €
Total main leg investment costs					50.498.000 €
Total investment costs per operating hour					721,44 €

Main leg equipment maintenance costs			
Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Short Sea RoRo Ship (Semi-Trailer)	1,3	638.685 €	133,06 €
Trestle	2,8	1.719,82 €	0,49 €
Total maintenance costs per operating hour			133,55 €

Main leg energy consumption				
Consumer	Energy type	Energy consumption per t/h	Energy consumption per 450 km transport (ton)	Energy consumption per 850 km transport (ton)
Short Sea RoRo Ship (Semi-Trailer)	Gas oil	2,38	34	64

Other operational costs main leg

Cost type	Costs
Port	1.494 €
Total other operational costs per operating hour	1.494 €
Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	12.687 €	89,98 €

First transhipment	7.510 €	53,26 €
450 km main leg	39.484 €	280,03 €
850 km main leg	67.234 €	476,84 €
Second transhipment	7.510 €	53,26 €
Second road leg	12.069 €	85,59 €
LU costs transport chain 600 km main leg	2.616 €	18,56 €
LU costs transport chain 1.000 km main leg	4.019 €	28,51 €
Intermodal organizational costs 600 km main leg (25%)	20.469 €	145,17 €
Intermodal organizational costs 1.000 km main leg (25%)	27.757 €	196,86 €
Grand total 600 km	81.875 €	725,84 €
Grand total 1.000 km	111.029 €	984,30 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	675,38 €
Maximum value costs range 600 km transport in EU	767,92 €
Minimum value costs range 1.000 km transport in EU	933,84 €
Maximum value costs range 1.000 km transport in EU	1.026,38 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	12.261 €	86,96 €
First transhipment		115 €	0,82 €
Main leg	**450 km**	59.064 €	418,90 €
	850 km	111.566 €	791,25 €
Second transhipment		115 €	0,82 €
Second road leg	**75 km**	12.261 €	86,96 €
Full transport chain per LU	**600 km**	83.586 €	594,44 €
	1.000 km	136.087 €	966,79 €

13.1.1.2 Fact Sheet "RoRo Ramp to/from Ship – SSS/Road – Roll-trailers"

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3 min
Administrative check-in:	Truck driver	5 min

	Gate agent	3 min
Drive to drop-off/parking:	Truck driver	2 min
Check-in duration per LU:	**Total LU**	7 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	3 min
	Handling equipment driver	3 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Handling equipment driver	0 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	3 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	0 min
	Terminal truck driver	15 min
	Truck driver	0 min
	Groundsman	18 min
Transhipment duration per LU:	**Total LU**	15 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman ship	10 min
Further procedures for departure:	Crew	20 min
Departure:	Crew	10 min
Departure duration:	**Total**	30 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	10 min
Further arrival procedures:	Crew	20 min
Terminal check-in:	Groundsman ship	20 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	0 min
	Terminal truck driver	15 min
	Truck driver	0 min
	Groundsman	18 min
Transhipment duration per LU:	**Total LU**	15 min

LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	0 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	3 min
	Truck driver	3 min
Handover duration per LU:	**Total LU**	3 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 25 min • Only Transhipment: 15 min
	Unloading	• All process steps: 20 min • Only Transhipment: 15 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 10 min
	Unloading	• 5 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 247 min
	Unloading	• 247 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 277 min
	Unloading	• 287 min
Trains that can be handled in an 8-hour shift:		• 0,86

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:**
		Rolltrailers
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver	489 min 489 min 1.630 min 489 min 2.445 min

	Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	2.934 min 30 min 50 min 240 min 8.796 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.619 min**	Crew:	1.619 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 857 min**	Crew:	857 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	0 min 0 min 815 min 489 min 2.445 min 30 min 2.934 min 100 min 240 min 7.053 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	38,89 h
	600 km	26,19 h
Total working hours transport chain	**1.000 km**	921 h
	600 km	820 h
Total working hours per LU	**1.000 km**	5,65 h
	600 km	5,03 h

Costs and investments associated with the transhipment technology

Terminal infrastructure

Elements	Dimensions (m)		Number of units (#)	Unit costs	Total area	Total costs
	Length	Width				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	500,0 m	3,5 m	2	80 €/m²	3.500 m²	280.000 €
Loading lane	0,0 m	0,0 m	0	80 €/m²	m²	- €
Turning area	0,0 m	0,0 m	0	80 €/m²	m²	- €

Intermediate buffer area (stackable)	370,0 m	32,0 m	2	90 €/m²	23.680 m²	2.131.200 €
Inland port quay per metre	420,0 m	10,0 m	1	75.000 €/m	4.200 m²	31.500.000 €
Crane tracks	0,0 m	0,0 m	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	0	90 €/m²	m²	- €
Total area complete terminal					37.380 m²	
Structural engineering (50 €/m²)						1.869.000 €
Earthworks and civil engineering (100 €/m²)						3.738.000 €
Building costs terminal						39.998.200 €
Planning costs 20%						5.999.730 €
Total building costs complete terminal						45.997.930 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						21.343.040 €
Maximum value based on European construction cost index						66.871.791 €
Depreciation time terminal (years)					25	
Terminal building costs per year						3.108.254 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Terminal truck	150.000 €	10	1.500.000 €	5
Goose neck	18.000 €	10	180.000 €	20
Reach stacker	480.000 €	2	960.000 €	5

Equipment costs terminal	**Investment costs**	2.640.000 €
	Planning costs (20%)	528.000 €
	Total	3.168.000 €
Total equipment costs terminal per year		665.876 €

Initial investment costs complete terminal and equipment incl. planning costs	49.165.930 €
Total investment costs complete terminal and equipment per year	3.774.130 €

Total terminal handling capacity per year (transhipments)	140.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	1.999.910 €
Terminal truck	2,8	42.000 €
Goose neck	1	1.800 €
Reach stacker	2,8	26.880 €
Total maintenance costs per year		2.070.590 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	41.118 kWh	5.140 €
Terminal truck	Diesel	3 l	1.050.000 l	756.000 €
Reach stacker	Diesel	1,65	252.000	181.440 €
Total energy costs per year				942.580 €

Terminal energy costs range in EU	
Minimum value electricity costs	2.410 €
Maximum value electricity costs	7.451 €
Minimum value diesel costs	772.140 €
Maximum value diesel costs	1.145.561 €
Minimum value total energy costs	774.550 €
Maximum value diesel energy costs	1.153.013 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	10	33	32.000 €	1.056.000 €
Instructor “Groundsman”	12	39,5	31.000 €	1.224.500 €

Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				2.863.250 €
Terminal personnel costs range in EU				
Minimum value personnel costs				620.180 €
Maximum value personnel costs				4.620.479 €

Total area costs (5,00 €/m² per year)	186.900 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 373.800 €

Total costs per year	9.837.449 €

Cost per transhipment for total terminal investment		26,96 €
Operational costs per transhipment	**Personnel costs**	20,45 €
	Energy costs	6,73 €
	Maintenance costs	14,79 €
	Total	41,97 €
Ground costs per transhipment		1,34 €
Total costs for one transhipment		70,27 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		37,26 €
Maximum value total costs transhipment		97,89 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40'-Container	4.200 €	12	126 €	0,12 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Short Sea RoRo Ship (Roll-Trailer)	50.000.000 €	1	50.000.000 €	25	703,89 €
Roll-Trailer	12.500 €	192	2.400.000 €	10	68,57 €
Total main leg investment costs					52.400.000 €
Total investment costs per operating hour					772,46 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Short Sea RoRo Ship (Roll-Trailer)	1,3	638.685 €	133,06 €
Roll-Trailer	2,8	6.720,00 €	1,92 €
Total maintenance costs per operating hour			134,98 €

Main leg energy consumption				
Consumer	**Energy type**	**Energy consumption per t/h**	**Energy consumption per 450 km transport (ton)**	**Energy consumption per 850 km transport (ton)**
Short Sea RoRo Ship (Semi-Trailer)	Gas oil	2,38	34	64

Other operational costs main leg	
Cost type	**Costs**
Port	1.494 €
Total other operational costs per operating hour	1.494 €

Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption

Consumer	Energy type	Consumption per 100 km	Consumption per hour	Costs per operating hour
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				

Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	14.380 €	88,22 €
First transhipment	11.454 €	70,27 €
450 km main leg	42.386 €	260,04 €
850 km main leg	70.803 €	434,37 €
Second transhipment	11.454 €	70,27 €
Second road leg	13.666 €	83,84 €
LU costs transport chain 600 km main leg	513 €	3,15 €
LU costs transport chain 1.000 km main leg	762 €	4,68 €
Intermodal organizational costs 600 km main leg (25%)	23.463 €	143,95 €
Intermodal organizational costs 1.000 km main leg (25%)	30.630 €	187,91 €
Grand total 600 km	93.854 €	719,74 €
Grand total 1.000 km	122.519 €	939,57 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	653,72 €
Maximum value costs range 600 km transport in EU	774,98 €
Minimum value costs range 1.000 km transport in EU	873,55 €
Maximum value costs range 1.000 km transport in EU	994,81 €

External costs			
		Total	**Per LU**

First road leg	**75 km**	17.166 €	105,32 €
First transhipment		206 €	1,26 €
Main leg	**450 km**	62.037 €	380,60 €
	850 km	117.182 €	718,91 €
Second transhipment		206 €	1,26 €
Second road leg	**75 km**	17.166 €	105,32 €
Full transport chain per LU	**600 km**	96.370 €	593,75 €
	1.000 km	151.514 €	932,06 €

13.1.1.3 Fact Sheet "RoRo Ramp to/from Ship – SSS/Road – Cassettes (2LU)"

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	6 min
Administrative check-in:	Truck driver	10 min
	Gate agent	6 min
Drive to drop-off/parking:	Truck driver	4 min
Check-in duration per LU:	**Total LU**	14 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	6 min
	Handling equipment driver	6 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Handling equipment driver	0 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	6 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	0 min
	Terminal truck driver	15 min
	Truck driver	0 min
	Groundsman	18 min
Transhipment duration per LU:	**Total LU**	15 min
Departure: The departure on the main leg is prepared and executed.		

Terminal check-out:	Groundsman ship	10 min
Further procedures for departure:	Crew	20 min
Departure:	Crew	10 min
Departure duration:	**Total**	30 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Crew	10 min
Further arrival procedures:	Crew	20 min
Terminal check-in:	Groundsman ship	20 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	0 min
	Terminal truck driver	15 min
	Truck driver	0 min
	Groundsman	18 min
Transhipment duration per LU:	**Total LU**	15 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Handling equipment driver	0 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	6 min
	Truck driver	6 min
Handover duration per LU:	**Total LU**	6 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	4 min
Check-out duration per LU:	**Total LU**	4 min
Total time for the transhipment of one LU:	**Loading**	• All process steps: 35 min • Only Transhipment: 15 min
	Unloading	• All process steps: 25 min • Only Transhipment: 15 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 20 min
	Unloading	• 10 min

Total time for loading /unloading one train (excl. headway):	**Loading**	• 291 min
	Unloading	• 291 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 321 min
	Unloading	• 331 min
Trains that can be handled in an 8-hour shift:		• 0,73

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Rolltrailers**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per ship Groundsman ship Crew Total	1.152 min 1.152 min 3.840 min 1.152 min 2.880 min 3.456 min 30 min 50 min 240 min 13.952 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.619 min**	Crew:	1.619 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 857 min**	Crew:	857 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per ship Groundsman Groundsman ship Crew Total	0 min 0 min 1.920 min 1.152 min 2.880 min 30 min 3.456 min 100 min 240 min 9.778 min
Second road leg: The LU is transported on the second	Truck driver: Dispatcher:	75 min 6 min

road leg over a distance of 75 km. **Duration: 75 min**		
Total duration transport chain	**1.000 km**	40,34 h
	600 km	27,64 h
Total working hours transport chain	**1.000 km**	1.131 h
	600 km	1.030 h
Total working hours per LU	**1.000 km**	5,89 h
	600 km	5,36 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	500,0 m	3,5 m	2	80 €/m²	3.500 m²	280.000 €
Loading lane	0,0 m	0,0 m	0	80 €/m²	m²	- €
Turning area	0,0 m	0,0 m	0	80 €/m²	m²	- €
Intermediate buffer area (stackable)	370,0 m	32,0 m	2	90 €/m²	23.680 m²	2.131.200 €
Inland port quay per metre	420,0 m	10,0 m	1	75.000 €/m	4.200 m²	31.500.000 €
Crane tracks	0,0 m	0,0 m	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	0	90 €/m²	m²	- €
Total area complete terminal					37.380 m²	
Structural engineering (50 €/m²)						1.869.000 €
Earthworks and civil engineering (100 €/m²)						3.738.000 €
Building costs terminal						39.998.200 €
Planning costs 20%						5.999.730 €
Total building costs complete terminal						45.997.930 €
Terminal building costs range in EU						

Minimum value based on European construction cost index	21.343.040 €
Maximum value based on European construction cost index	66.871.791 €
Depreciation time terminal (years)	25
Terminal building costs per year	3.108.254 €

Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Terminal truck	150.000 €	10	1.500.000 €	5
Translifter	330.000 €	10	3.300.000 €	8
Reach stacker	480.000 €	2	960.000 €	5

Equipment costs terminal	**Investment costs**	5.760.000 €
	Planning costs (20%)	1.152.000 €
	Total	6.912.000 €
Total equipment costs terminal per year		1.232.891 €

Initial investment costs complete terminal and equipment incl. planning costs	52.909.930 €
Total investment costs complete terminal and equipment per year	4.341.145 €

Total terminal handling capacity per year (transhipments)	140.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	1.999.910 €
Terminal truck	2,8	42.000 €
Translifter	2,8	92.400 €
Reach stacker	2,8	26.880 €
Total maintenance costs per year		2.161.190 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	41.118 kWh	5.140 €
Terminal truck	Diesel	3 l	1.050.000 l	756.000 €
Reach stacker	Diesel	1,65	504.000 l	362.880 €

Total energy costs per year	1.124.020 €
Terminal energy costs range in EU	
Minimum value electricity costs	2.410 €
Maximum value electricity costs	7.451 €
Minimum value diesel costs	921.586 €
Maximum value diesel costs	1.367.283 €
Minimum value total energy costs	923.996 €
Maximum value diesel energy costs	1.374.734 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	10	33	32.000 €	1.056.000 €
Instructor "Groundsman"	12	39,5	31.000 €	1.224.500 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				2.863.250 €
Terminal personnel costs range in EU				
Minimum value personnel costs				620.180 €
Maximum value personnel costs				4.620.479 €

Total area costs (5,00 €/m² per year)	186.900 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 373.800 €

Total costs per year	10.676.505 €

Cost per transhipment for total terminal investment		31,01 €
Operational costs per transhipment	**Personnel costs**	20,45 €
	Energy costs	8,03 €
	Maintenance costs	15,44 €

Total	43,92 €
Ground costs per transhipment	1,34 €
Total costs for one transhipment	76,26 €
Total transhipment costs range in EU	
Minimum value total costs transhipment	40,85 €
Maximum value total costs transhipment	106,01 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
40'-Container	4.200 €	12	126 €	0,12 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Short Sea RoRo Ship (Roll-Trailer)	50.000.000 €	1	50.000.000 €	25	703,89 €
Cassette	7.500 €	192	1.440.000 €	10	41,14 €
Total main leg investment costs					51.440.000 €
Total investment costs per operating hour					745,04 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Short Sea RoRo Ship (Roll-Trailer)	1,3	638.685 €	133,06 €
Cassette	1,5	2.160,00 €	0,62 €
Total maintenance costs per operating hour			133,68 €

Main leg energy consumption				
Consumer	**Energy type**	**Energy consumption per t/h**	**Energy consumption per 450 km transport (ton)**	**Energy consumption per 850 km transport (ton)**
Short Sea RoRo Ship (Semi-Trailer)	Gas oil	2,38	34	64

Other operational costs main leg	
Cost type	**Costs**
Port	1.494 €

Total other operational costs per operating hour	1.494 €
Personnel costs main leg	
Function	**Costs per operating hour**
Crew	142,88 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	31.617 €	96,98 €

First transhipment	24.861 €	76,26 €
450 km main leg	43.161 €	132,39 €
850 km main leg	71.213 €	218,44 €
Second transhipment	24.861 €	76,26 €
Second road leg	28.761 €	88,22 €
LU costs transport chain 600 km main leg	1.084 €	3,32 €
LU costs transport chain 1.000 km main leg	1.582 €	4,85 €
Intermodal organizational costs 600 km main leg (25%)	38.586 €	118,36 €
Intermodal organizational costs 1.000 km main leg (25%)	45.723 €	140,26 €
Grand total 600 km	154.344 €	591,81 €
Grand total 1.000 km	182.894 €	701,28 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	521,00 €
Maximum value costs range 600 km transport in EU	651,31 €
Minimum value costs range 1.000 km transport in EU	630,47 €
Maximum value costs range 1.000 km transport in EU	760,78 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	32.254 €	98,94 €
First transhipment		491 €	1,51 €
Main leg	**450 km**	74.257 €	227,78 €
	850 km	140.264 €	430,26 €
Second transhipment		491 €	1,51 €
Second road leg	**75 km**	32.254 €	98,94 €
Full transport chain per LU	**600 km**	138.766 €	428,68 €
	1.000 km	204.773 €	631,15 €

14 FACT SHEET FOR "METROCARGO – RAIL/ROAD"

Picture of the technology:

Source: metrocargo.it

Description of the transhipment technology and transhipment process (road → main leg):

Metrocargo is a horizonal transhipment system able to operate under the overhead catenary to shift loading units from train to train or from train to terminal. It has been developed by I-LOG Srl with the engineering support of Metrocargo Automazzione Srl in different EU Projects[80]. The intended operation is highly automated. It can work with standard rail wagon and standard containers without modification. The system can also be used to shift loading units between wagon of different rail gauges. One Metrocargo module consist of four lifting towers (each for one corner of a container), one shuttle (made of two semi-shuttles to adapt to different container length) and stacking platforms. The shuttle is operating on dedicated rails next to or between two rail tracks. The shuttle together with the four lifting towers is able to move containers between the neighbouring rail tracks or stacking platform. The transhipment from rail to platform vs was demonstrated while the handling of trucks was not.
It is therefore assumed that the containers are loaded from truck to platform manually by a Reach Stacker or equipment of the truck (Mobiler etc). The platform lifts the container so that carriage

[80] http://www.mitproject.eu/

beams of the shuttle can move laterally under the container. After the platform has lowered the containers, the shuttle transfers the container on itself and moves them longitudinal to the wagon appointed for loading. Then the four lifting towers are moved to the same place. After that the carriage beams with the containers are laterally moved above the (empty) wagon. When placed above the wagon the lifting towers lift the containers in the four lower corner castings and place them on the pins of the wagon. The beam returns to the shuttle and the container is lowered to the pins. The lifting tower is detached and moves similar as the shuttle to the next loading/unloading place. Adjustment of the pins to different length and weight of containers is possible by a “pin changer” machine. For a full train unloading and reloading it is necessary to operate from both sides of the rail track in order to make sure that sufficient number of loading units are available.		
Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 6: Technology demonstrated in relevant environment in the framework of an EU RTD project until 2013 but not brought to market use since then. The company Metrocargo Italia Srl is an intermodal operator using standard intermodal equipment for its real-life operation between Italy and France rather than the “Metrocargo” system. Our research did not reveal any further indications of current use or further development of the technology. For this reason, the technology will be excluded from the further evaluation of technologies in this study.	

15 FACT SHEET FOR "N.E.H.T.S. (NEUWEILER) – RAIL/ROAD"

Picture of the technology:

Source:https://trimis.ec.europa.eu/sites/default/files/project/documents/20060727_150345_76487_INHOTRA_Final_Report.pdf/ ; April 2021

Description of the transhipment technology and transhipment process (road → main leg):

The N.E.H.T.S. is a horizontal transhipment technology which can handle standardized containers up to 35t by using two top lift beams which are hanging on chains. Additional swap bodies up to 20t can be handled by using grapple arms. The technology consists of two lifting devices which can be moved parallel to the transhipment track. The lifting devices can move independently in order to facilitate the transhipment of different loading unit sizes. The technology can be operated by the truck driver semi-automatically.

Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied

Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 7: The technology was originally (1999/2000) developed by Neuweiler AG, Switzerland. It was part of the European InHoTra project between 2000 and 2004 and reached the demonstrator stage and a prototype was build in Zurich. Although the technology could prove its functionality, it was eventually dropped and no further market implementation of the technology took place. Our research did not reveal any further indications of current use or further development of the technology. For this reason the technology will be excluded from the further evaluation of technologies in this study. Source: https://trimis.ec.europa.eu/sites/default/files/project/documents/20100506_153150_87620_ERRAC_Project_Evaluation_InHoTra.pdf ; April 2021	

16 1FACT SHEET FOR "IUT - INNOVATIVER UMSCHLAGTERMINAL (INNOVATIVE TRANSHIPMENT TERMINAL) – RAIL/ROAD"

Picture of the technology:

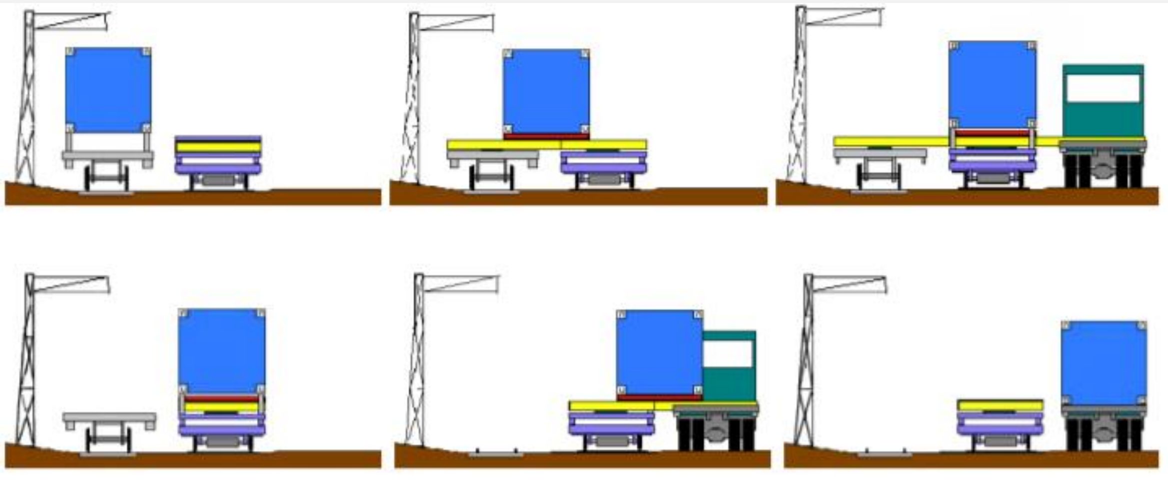
Source: www.railcargo.com ; April 2021

Description of the transhipment technology and transhipment process (road → main leg):		
Basic Idea of this research project was to split the common terminal activities – loading/unloading train, storage and loading/unloading truck in up to 3 different system components. The aim was to get the processes more flexible, to increase throughput and to reduce investment cost. Another issue was to create a storage facility for loading units, which offers random access to the units (instead of block storage as in common terminals). The most benefits would be realized in gateway-terminals. Approx. 2003 a prototype of a handling machine for the storage part was build and technically tested in the premises of ÖBB at Wien-Nordwestbahnhof. The project was discontinued due to technical, commercial and organisational reasons approx. 2006. The prototype was teared down approx. 2010. There were no documents and also no responsible people available for the further investigation.		
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied

Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 7: The technology was originally developed by Rail Cargo Austria. It was part of the European InHoTra project between 2000 and 2004 and reached the demonstrator stage and a prototype was build in Vienna. Although the technology could prove its functionality, it was eventually dropped and no further market implementation of the technology took place. Our research did not reveal any further indications of current use or further development of the technology. For this reason, the technology will be excluded from the further evaluation of technologies in this study. Source: https://trimis.ec.europa.eu/sites/default/files/project/documents/20100506_153150_87620_ERRAC_Project_Evaluation_InHoTra.pdf ; April 2021	

17 FACT SHEET FOR "CARCONTRAIN – RAIL/ROAD"

Picture of the technology:



Source: https://trimis.ec.europa.eu/sites/default/files/project/documents/20060727_150345_76487_INHOTRA_Final_Report.pdf ; April 2021

Description of the transhipment technology and transhipment process (road → main leg):

The CarConTrain technology was designed for the horizontal transfer of standardized containers and swap bodies between specific road and rail vehicles which had to be equipped with special lifting pins. The transhipment is conducted with the help of a transfer vehicle equipped with arms for the freight transfer which is placed between the rail and the road vehicle on a separate transhipment track and which transfers loading units to and from both sides. The technology requires an even surface and the transhipment can be conducted under the catenary.

Sources: https://trimis.ec.europa.eu/sites/default/files/project/documents/20060727_150345_76487_INHOTRA_Final_Report.pdf

Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied

Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 7: The technology was part of the European InHoTra project between 2000 and 2004. The technology failed to reach the demontrator stage of the InHoTra project due to commercial reasons within the developing company and general reasons like a lack of interest from commercial actors in intermodal transport. The development of the technology was eventually continued under the name AMCCT outside of the InHoTra project and a prototype of this new technology was tested in Sweden but it did not reach the market in regular operation. Our research did not reveal any further indications of current use or further development of the technology. For this reason the technology will be excluded from the further evaluation of technologies in this study.	

18 FACT SHEET FOR "SIDELIFTER – RAIL/ROAD"

Picture of the technology:

Source: https://hammarlift.com/products/hammar-110/, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

The Sidelifter- technology is a container/swap body loading device for trucks and rail wagons, which is mounted on a truck or chassis and enables the transfer and transport of standardized swap bodies or ISO containers at any location. The loading unit can be set down on the ground, on another truck, chassis or rail car or on the vehicle it is mounted on independent of other working steps or handling equipment. For the usage of the technology, two lifting devices are necessary on the front and the back of the trailer. Each construction consists of a main lifting arm and a supporting leg movable with hydraulic cylinders. The devices can be moved along the chassis in order to adjust the technology to loading units of different lengths. The sidelifter is usually powered through a power take off from the truck unit, alternatively a variant with a trailer mounted engine (diesel, electric or gasoline) can be used.

For transhipments from the sidelifter onto a rail wagon in general, first the sidelifter chassis stops next to the empty rail wagon. Then the supporting legs are extended over, under or on to the wagon to the side of the loading position. Then From the lifting arm lifting lugs are fixed to the bottom corner castings of the container. In practice, the lifting lugs might still be attached from the loading process. Then the container is lifted up using the hydraulic lifting arm and moved over to the wagon. Transhipment under the line is possible. A stacking option is available with extra supporting legs on the other side, which we will not include in this study. In practice, the Sidelifter can be used in addition to other transhipment technologies, for example using a crane to unload the train and then using the Sidelifter truck for the distribution of loading units to sites where no other dedicated transhipment equipment is feasible.
As a reference for this study, we are using values close to those of the Hammar 110 line of sidelifters, as this product line is specifically designed to facilitate transhipments directly onto rail wagons with its double-mode support legs. The product line offers a variety of configurations, for our study the model 110 S is used as a reference, which is mounted on a fixed gooseneck chassis and uses sliding cranes. The cranes can slide between 20'-40' and have a Safe Working Load (SWL) of 36 metric tonnes. It is equipped with an optional top spreader for handling containers in

the top corner castings with a higher transhipment speed (total costs are 185.000 €; already included are the cost of the spreader of 29.500 €).

Other notable configurations/options for Sidelifter are:

- lifting boom for lifting special loads;
- extendable cranes for lifting loads further away from chassis or for stacking a container two rows deep, two containers high;
- extra support legs, that can be placed below rail wagons if there is no other space for the support legs;
- higher lifting capacity.

Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The technology is fully developed and has been proven in different operational environments. It is used in different European countries, however its usage in intermodal operations and especially in a terminal setting is a niche where it is typically used as supporting equipment and not as the main transhipment technology. Its prevalence in the intermodal market is low.	

Indicative qualitative assessment:

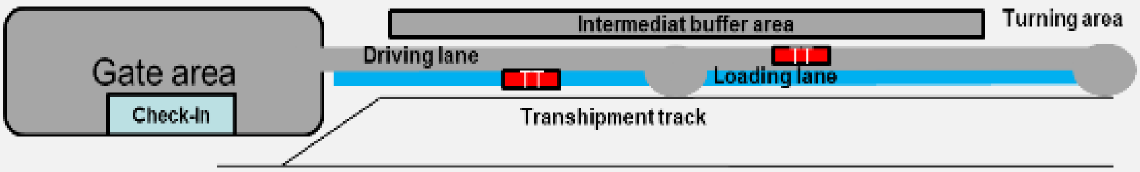
Strengths	Weaknesses and limitations
• High flexibility and possibility of multi-purpose usage as transhipment equipment as well as road transport equipment; • no special infrastructure other than a loading lane next to the tracks for transhipments necessary – no ground reinforcements; • no adaptation of wagon or auxiliary equipment; • linking transhipment and road leg transport/distribution within one vehicle; • truck driver is the only necessary transhipment personnel; • LUs can be placed on/picked-up from the ground without special platforms/ramps; • high safety: only a single operator used, operator is operating outside the vehicle at a safe distance away from the Sidelifter; • easy to move between multiple locations.	• Additional equipment weight lowers max. load weight when driving on public roads by 1 to 6 tons depending on Sidelifter configuration; • not suitable for large scale transhipment operations due to lower manouverability of trucks and length of handling process; • for Sidelifters free space is required for the support legs next to the container or below the rail wagon. Therefore, certain settings of specific containers on specific rail wagons might not be possible to load or unload.

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations

• ISO container	• All; above 40' with telescopic chassis due to road regulations
• Inland container	• All; above 40' with telescopic chassis due to road regulations
• Swap body	• All; class A with telescopic chassis due to road regulations
• Semi-trailer	• Not possible
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	36 t

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis; the Sidelifter chassis could in another setting also be used for road transport.
Necessary main leg equipment:	Loco, Sggrss 80' rail wagons or similar

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For *40' containers* on *Sggrss 80''* wagons with *no further special equipment* (assuming 85% load factor)	50 (43)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	3,0 min
	Handling equipment driver	7,0 min
Movement of loading unit:	Handling equipment driver	3,0 min

	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	10,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	4,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	4,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	99,0 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	108,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	4,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	4,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	3,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	7,0 min
	Truck driver	7,0 min

Handover duration per LU:	**Total LU**	10,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking: **Check-out duration per LU:**	Truck driver **Total LU**	2 min 2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 21 min • Only Transhipment: 14 min
	Unloading	• All process steps: 16 min • Only Transhipment: 14 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 10 min
	Unloading	• 9 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 301 min
	Unloading	• 301 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 410 min
	Unloading	• 341 min
Trains that can be handled in an 8-hour shift:		• 0,56

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Full Vehicle**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above. **Duration Full vehicle: 91 min**	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Groundsman: Terminal dispatcher per train: Groundsman train: Visitor/Wagon inspector: Train driver: Total:	129 min 129 min 430 min 602 min 0 min 0 min 30 min 30 min 99 min 10 min 1459 min
Main leg 1000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1295 min 648 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km.	Train driver: Train dispatcher:	695 min 348 min

Duration: 675 min		
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above. **Duration Full Vehicle: 22 min**	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Terminal dispatcher per train: Groundsman: Groundsman train: Visitor/Wagon inspector: Train driver: Total:	0 min 0 min 387 min 602 min 0 min 30 min 0 min 30 min 0 min 10 min 1059 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	36,26 h
	600 km	26,26 h
Total working hours transport chain	**1.000 km**	191 h
	600 km	176 h
Total working hours per LU	**1.000 km**	4,44 h
	600 km	4,09 h

Costs and investments associated with the transhipment technology							
Terminal infrastructure							
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	2	80 €/m²	1.250 m²	93.750 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	600,0 m	2,6 m	1	80 €/m²	1.560 m²	124.800 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €

Terminal switch	30,0 m	5,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0,0 m	0,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	15,0 m	-	90 €/m²	m²	- €

Total area complete terminal	14.774 m²
Structural engineering (50 €/m²)	738.675 €
Earthworks and civil engineering (100 €/m²)	1.477.350 €
Building costs terminal	3.953.475 €
Planning costs 20%	790.695 €
Total building costs complete terminal	4.744.170 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	2.201.295 €
Maximum value based on European construction cost index	6.897.074 €
Depreciation time terminal (years)	25
Terminal building costs per year	320.581 €

Terminal equipment

Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Sidelifter unit	185.000 €	2	370.000 €	20
Truck	100.000 €	2	200.000 €	9

Equipment costs terminal	**Investment costs**	570.000 €
	Planning costs (20%)	114.000 €
	Total	684.000 €
Total equipment costs terminal per year		66.089 €

Initial investment costs complete terminal and equipment incl. planning costs	5.428.170 €
Total investment costs complete terminal and equipment per year	386.670 €

Total terminal handling capacity per year (transhipments)	24.054

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	197.674 €
Sidelifter unit	2	7.400 €
Truck	10	20.000 €
Total maintenance costs per year		225.074 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	16.251 kWh	2.031 €
Equipment	Diesel	2,4	57.730 l	64.658 €
Total energy costs per year				66.689 €

Terminal energy costs range in EU	
Minimum value electricity costs	953 €
Maximum value electricity costs	2.945 €
Minimum value diesel costs	53.257 €
Maximum value diesel costs	79.013 €
Minimum value total energy costs	54.209 €
Maximum value diesel energy costs	81.958 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	26.500 €	185.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	0,5	2	31.000 €	62.000 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				366.500 €

Terminal personnel costs range in EU	
Minimum value personnel costs	79.384 €

Maximum value personnel costs	591.428 €

Total area costs (5,00 €/m² per year)	73.868 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 147.735 €

Total costs per year	1.044.934 €

Cost per transhipment for total terminal investment		16,07 €
Operational costs per transhipment	**Personnel costs**	15,24 €
	Energy costs	2,77 €
	Maintenance costs	9,36 €
	Total	27,37 €
Ground costs per transhipment		3,07 €
Total costs for one transhipment		46,51 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		22,37 €
Maximum value total costs transhipment		66,86 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
ISO-Container 40’	4.200 €	12	126,00 €	0,12 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Sggrss 80’ wagon	85.000 €	25	2.125.000 €	40	24,57 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.125.000 €
Total investment costs per operating hour					82,39 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Sggrss 80’ wagon	7	150.000 €	31,25 €
Loco	6	300.000 €	62,50 €

Total maintenance costs per operating hour				93,75 €
Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.451 kWh	181,34 €
Total energy costs per operating hour				181,34 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**

Tolls	0,187 €	11,97 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	3.794 €	88,22 €
First transhipment	2.000 €	46,51 €
450 km main leg	7.056 €	164,10 €
850 km main leg	12.347 €	287,13 €
Second transhipment	2.000 €	46,51 €
Second road leg	3.756 €	87,35 €
LU costs transport chain 600 km main leg	136 €	3,16 €
LU costs transport chain 1.000 km main leg	185 €	4,30 €
Intermodal organizational costs 600 km main leg (25%)	4.685,36 €	108,96 €
Intermodal organizational costs 1.000 km main leg (25%)	6.020,26 €	140,01 €
Grand total 600 km	18.741 €	544,81 €
Grand total 1.000 km	24.081 €	700,03 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		496,53 €
Maximum value costs range 600 km transport in EU		585,51 €
Minimum value costs range 1.000 km transport in EU		651,75 €
Maximum value costs range 1.000 km transport in EU		740,73 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	3.980 €	92,57 €
First transhipment		29 €	0,67 €
Main leg	**450 km**	8.976 €	208,75 €
	850 km	16.955 €	394,31 €
Second transhipment		29 €	0,67 €
Second road leg	**75 km**	3.980 €	92,57 €
Full transport chain per LU	**600 km**	16.937 €	395,21 €

	1.000 km	24.916 €	580,77 €

19 FACT SHEET FOR "BOXMOVER – SIDE LODER – Rail/Road"

Picture of the technology:

Source: http://www.boxmover.gmbh/wp-content/uploads/2018/03/BOXmover_Pressemappe_2018-02_final.pdf; June 2021

Description of the transhipment technology and transhipment process (road → main leg):

The BOXmover - side loader – transhipment technology enables the transfer of standardized containers or swap bodies at any location. Although swap bodies can technically be transhipped, there is no demand for this in practice. The transhipment technology can be mounted on a truck, chassis or railcar. In this study we will look at the trailer mounted variant of the technology as the most common and relevant one.

The technology consists of two loading devices with a weight of 1,2 t each. Each device consists of a main lifting arm and supporting leg designed as hydraulic cylinders as well as an anti-slip device designed as a safety rope which together form a closed load triangle.

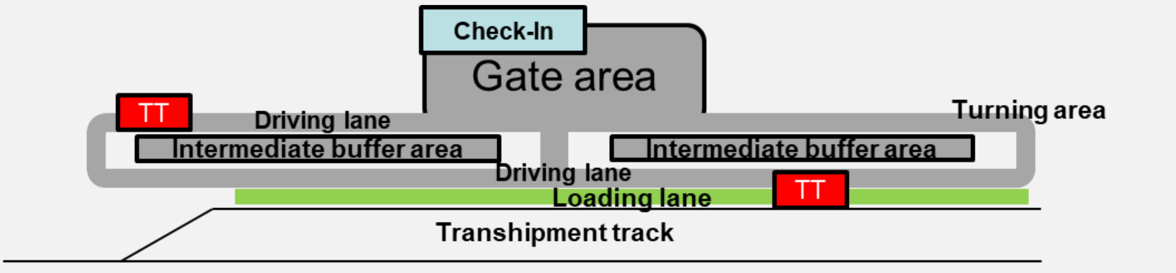
The BOXmover is available in different variants, which differ among other things in price, weight and handling speed. Further variations concern the length of the chassis, movability of the lifting units along the trailer to adjust to different loading unit lengths and the power supply. The energy is commonly either supplied by the truck or by a power pack (tank and generator) on the chassis. There is a variant with an electric plug in which can be supplied through a power cord at the terminal. A battery on the chassis is not feasible as this would be too heavy and thereby limit the load weight too much. With the energy supplied by a powerpack (Euro 3/Euro 4) in the chassis, around 50 transhipments can be conducted with 30l of diesel. Depending on the available power output, the transhipment time is 4 minutes for the powerful and up to 7-8 minutes for the less powerful configurations.

<table>
<tr><td colspan="4">Depending on the chosen variant and additional equipment, the cost for a BOXmover chassis ranges between 98k € and 165k €. A 40' chassis with moveable lifting units, a steering axle and a powerpack with sufficient output for a fast transhipment time of 4 minutes weighs 8,5 t and costs 125k to 130k €. We will assume this configuration for this study.
For a chassis with further optional equipment the weight can go up to 9,15 t.
The loading unit can be transhipped to the ground, another truck, chassis or rail car and onto the vehicle the device is mounted on. In theory, the BOXmover could also be used to, at least partially, load or unload a barge, however this is not done in practice.
For a transhipment from the BOXmover onto a rail wagon, first the loaded BOXmover chassis stops next to the empty rail wagon. Then the supporting legs are extended on to the wagon and the safety rope is tightened closing the load triangle. Then the loading unit is lifted up using the hydraulic lifting arm and lifting straps attached to the bottom corner castings and moved over to the wagon by extension of the lifting arm and respective shortening of the supporting leg, before setting down the loading unit. Afterwards the lifting straps are detached and the lifting arms and support legs are retracted to the BOXmover chassis.
Transhipment under the line is possible. In practice there are no pure BOXmover terminals. Rather, the BOXmover is often used either on its own as a road or transhipment vehicle that can load or unload containers flexibly without additional equipment, or as a supplement to other terminal equipment for pre- and post-rail distribution (usually in close proximity to the terminal when public roads need to be used). Another important area of application is for the transhipment and transport of dangerous goods containers, which can be quickly, directly and safely transferred to a secured storage area, for example in chemical parks.</td></tr>
<tr><td rowspan="2">Classification</td><td colspan="2">☒ Horizontal</td><td>☐ Vertical</td></tr>
<tr><td colspan="2">☐ Accompanied</td><td>☒ Unaccompanied</td></tr>
<tr><td>Connected modes of transport</td><td colspan="2">☒ Rail
☐ Inland waterway</td><td>☐ Short Sea
☒ Road</td></tr>
<tr><td>Technical readiness level and prevalence of the technology:</td><td colspan="3">TRL 9: The technology is fully developed and has been proven in different operational environments. It is used in different European countries, however its usage in intermodal operations and especially in a terminal setting is a niche where it is typically used as supporting equipment. Its prevalence in the intermodal market is low.</td></tr>
<tr><td colspan="4">Indicative qualitative assessment:</td></tr>
<tr><td colspan="2">Strengths</td><td colspan="2">Weaknesses and limitations</td></tr>
<tr><td colspan="2">High flexibility
No special infrastructure for transhipments necessary – no ground reinforcements
No adaptation of wagon or auxiliary equipment
Linking transhipment and road leg transport/distribution within one vehicle
Truck driver is the only necessary transhipment personnel
LUs can be placed on/picked-up from the ground without special platforms/ramps
No torques, only linear forces
High safety: only a single operator used, operator is operating outside the</td><td colspan="2">Additional equipment weight lowers max. load weight in road transport
Not suitable for large scale transhipment operations due to size of trucks and length of handling process
Free space is required for the support legs next to the container
Thus a typical setting of 3 20' containers placed side-to-side on a 60' wagon cannot be handled
Relatively expensive truck/trailer combination when used as a standard road vehicle compared to standard truck/trailer combinations.</td></tr>
</table>

vehicle at a safe distance away from the BOXmover • Easy to move between multiple locations	

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• All; above 40’ with telescopic chassis due to road regulations
• Inland container	• All; above 40’ with telescopic chassis due to road regulations
• Swap body	• All; class A with telescopic chassis due to road regulations
• Semi-trailer	• Not possible
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	35 t

Description of our model terminal:



Necessary road leg equipment:	Truck and chassis; the BOXmover chassis could in another setting also be used for road transport.
Necessary main leg equipment:	Loco and Sggrss 80’’ rail wagons or similar

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 40’ containers on Sggrss 80’’ wagons with no further special equipment (assuming 85% load factor)	50 (43)

Detailed description of the transhipment process:		
Process steps <u>loading</u> main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min

Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	4,0 min
	Handling equipment driver	10,0 min
Movement of loading unit:	Handling equipment driver	5,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	15,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	5,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	5,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	98,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	108,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	5,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	5,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		

Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	5,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	10,0 min
	Truck driver	10,0 min
Handover duration per LU:	**Total LU**	15,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min
Total time for the transhipment of one LU:	**Loading**	• All process steps: 27 min • Only Transhipment: 20 min
	Unloading	• All process steps: 22 min • Only Transhipment: 20 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 11 min
	Unloading	• 12 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 430 min
	Unloading	• 430 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 539 min
	Unloading	• 470 min
Trains that can be handled in an 8-hour shift:		• 0,42

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Full Vehicle**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above. **Duration Full vehicle: 91 min**	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Groundsman: Terminal dispatcher per train: Groundsman train:	129 min 129 min 473 min 860 min 0 min 0 min 30 min 30 min

	Visitor/Wagon inspector: Train driver: Total:	99 min 10 min 1.760 min
Main leg 1000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1295 min 648 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	695 min 348 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above. **Duration Full Vehicle: 22 min**	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Terminal dispatcher per train: Groundsman: Groundsman train: Visitor/Wagon inspector: Train driver: Total:	0 min 0 min 516 min 860 min 0 min 30 min 0 min 30 min 0 min 10 min 1.446 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	40,56 h
	600 km	30,56 h
Total working hours transport chain	**1.000 km**	202 h
	600 km	187 h
Total working hours per LU	**1.000 km**	4,70 h
	600 km	4,35 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	2	80 €/m²	1.250 m²	93.750 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	0	90 €/m²	m²	- €

Intermediate buffer area (non-stackable)	600,0 m	2,6 m	1	80 €/m²	1.560 m²	124.800 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	30,0 m	5,0 m	0	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0,0 m	0,0 m	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	15,0 m	0	90 €/m²	m²	- €
Total area complete terminal					14.774 m²	
Structural engineering (50 €/m²)					738.675 €	
Earthworks and civil engineering (100 €/m²)					1.477.350 €	
Building costs terminal					3.953.475 €	
Planning costs 20%					790.695 €	
Total building costs complete terminal					4.744.170 €	
Terminal building costs range in EU						
Minimum value based on European construction cost index					2.201.295 €	
Maximum value based on European construction cost index					6.897.074 €	
Depreciation time terminal (years)					25	
Terminal building costs per year					320.581 €	

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Trailer mounted BOXmover unit	130.000 €	2	260.000 €	20
Truck	100.000 €	2	200.000 €	9

Equipment costs terminal	**Investment costs**	460.000 €
	Planning costs (20%)	92.000 €
	Total	552.000 €

Total equipment costs terminal per year	56.001 €

Initial investment costs complete terminal and equipment incl. planning costs	5.296.170 €
Total investment costs complete terminal and equipment per year	376.583 €

Total terminal handling capacity per year (transhipments)	17.902

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	197.674 €
Trailer mounted BOXmover unit	0,8	2.080 €
Truck	10	20.000 €
Total maintenance costs per year		219.754 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	16.251 kWh	2.031 €
Equipment	Diesel	2,4	42.966 l	48.122 €
Total energy costs per year				50.153 €

Terminal energy costs range in EU	
Minimum value electricity costs	953 €
Maximum value electricity costs	2.945 €
Minimum value diesel costs	39.636 €
Maximum value diesel costs	58.805 €
Minimum value total energy costs	40.589 €
Maximum value diesel energy costs	61.750 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €

Handling equipment driver	2	7	26.500 €	185.500 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	0,5	2	31.000 €	62.000 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				366.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				79.384 €
Maximum value personnel costs				591.428 €

Total area costs (5,00 €/m² per year)	73.868 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 147.735 €

Total costs per year	1.086.857 €

Cost per transhipment for total terminal investment		21,04 €
Operational costs per transhipment	**Personnel costs**	20,47 €
	Energy costs	2,80 €
	Maintenance costs	12,28 €
	Total	35,55 €
Ground costs per transhipment		4,13 €
Total costs for one transhipment		60,71 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		28,74 €
Maximum value total costs transhipment		87,59 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
ISO-Container 40’	4.200 €	12	126,00 €	0,12 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour

Sggrss 80' wagon	85.000 €	25	2.125.000 €	40	24,57 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					7.125.000 €
Total investment costs per operating hour					82,39 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Sggrss 80' wagon	7	150.000 €	31,25 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			93,75 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.451 kWh	181,34 €
Total energy costs per operating hour				181,34 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €

Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,97 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	3.831 €	89,10 €
First transhipment	2.611 €	60,71 €
450 km main leg	7.291 €	169,55 €
850 km main leg	12.581 €	292,59 €
Second transhipment	2.611 €	60,71 €
Second road leg	3.869 €	89,98 €
LU costs transport chain 600 km main leg	158 €	3,68 €
LU costs transport chain 1.000 km main leg	207 €	4,81 €
Intermodal organizational costs 600 km main leg (25%)	5.092,52 €	118,43 €
Intermodal organizational costs 1.000 km main leg (25%)	6.427,42 €	149,47 €
Grand total 600 km	20.370 €	592,15 €
Grand total 1.000 km	25.710 €	747,37 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	528,21 €
Maximum value costs range 600 km transport in EU	645,92 €
Minimum value costs range 1.000 km transport in EU	683,43 €
Maximum value costs range 1.000 km transport in EU	801,14 €

External costs			
		Total	Per LU
First road leg	75 km	3.980 €	92,57 €
First transhipment		29 €	0,67 €
Main leg	450 km	8.976 €	208,75 €
	850 km	16.955 €	394,31 €
Second transhipment		29 €	0,67 €
Second road leg	75 km	3.980 €	92,57 €
Full transport chain per LU	600 km	16.937 €	395,22 €
	1.000 km	24.916 €	580,78 €

20 FACT SHEET FOR "MOBILER – Rail/Road"

Picture of the technology:


Source: www.railcargo.com

Description of the transhipment technology and transhipment process (road → main leg):

The system consists of a truck-mounted hydraulic loading device, which enables the transfer of a loading unit directly from a rail wagon to the truck and vice versa without any other loading devices.
The system uses specific loading units; they were equipped with two so called "Mobiler-tunnels" on the bottom side of the unit. The tunnels are used to move the loading device of the truck under the loading unit for lifting and lateral moving.
On the wagon only a small piece of sheet metal is needed to support the movement of the device. A bigger share of wagons used within Rail Cargo Austria are equipped with that already.
From the terminal infrastructure view point no special requirements needed, the ground has to be flat and solid for the movement of loaded trucks next to the rail track. The system can therefore use all types of loading places and also industrial sidings in the whole rail network.
The handling process is performed by the truck driver itself; no additional staff is needed.
In an unloading-process of a wagon the truck is placed beside the wagon, so that the loading devices are in line with the two tunnels. Via remote-control device the truckdriver is moving the device in a step-by-step-movement (combination of short lifts and movements) under the loading unit. By removing the loading device back also with a step-by-step-movement the specific loading unit is transferred on the truck and will be placed there on standard corner-casting for load securing during road haulage.
Vice versa a loaded truck is also placed beside a wagon and the specific loading unit is transferred on the wagon by the same step-by-step-movement. During rail transport the loading units is locked to the standard pins on the rail wagon.
Alternatively, the specific loading units can be handled also with any other standard intermodal loading device (crane, reach stacker) by vertical lifting.

The system is mainly used in dedicated logistic chains and therefore the specific loading units were mostly built specifically for the goods to be transported. Main commodities are bulk products, construction materials, environmental cargo, waste wood or paper, recycling glass and all kind of palettized cargo. Also liquid cargo and dangerous goods are possible. Standard 20' ISO or Tank Containers can generally be handled with the aid of a Mobiler adapter unit. Mobiler trucks are owned by different (regional) trucking companies. Purchase of the equipment is co-financed by the Austrian Ministry of Transport (BMK). The transport operators are contracted by RCA or other railway undertakings performing the main (rail) haulage.

Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, mainly used within and to/from Austria and EU relations	

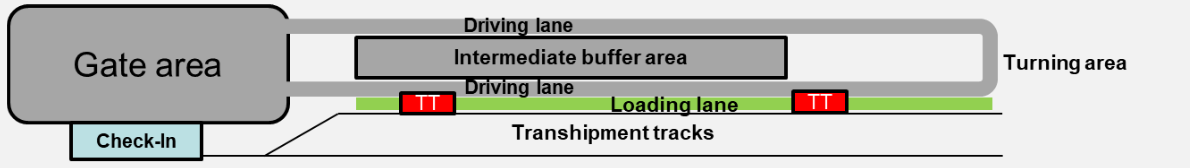
Indicative qualitative assessment:

Strengths	Weaknesses and limitations
• No need of specific terminal infrastructure • Short road leg to/from the costumer • Rail connection of production sides or industrial parks without rail siding. • Decentralized addition to terminal network • Max. technical weights possible if no public roads are used.	• Specific loading units needed (although an adapter-solution is possible: in that case the adapter bears the Mobiler tunnels and the standard loading unit sits on the adapter during road and rail transport) • Special Mobiler truck needed for pre- and on-carriage • Dead weight of about 3.5 tons of the Mobiler loading device on the truck reducing the payload during road haulage

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• 20' (MOBILER-Adapter unit required)
• Inland container	• 20' (MOBILER-Adapter Unit required) • 30'-MOBILER-Container
• Swap body	• Not possible
• Semi-trailer	• Not possible
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	32 t

Description of our model terminal:



Necessary road leg equipment:	Truck with MOBILER-loading device or Truck and chassis with MOBILER-loading device
Necessary main leg equipment:	Loco, Sggmrrss-y 2 x 60' rail wagons or similar

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:

For 30' containers on Sggmrrss-y 2 x 60'' wagons with no further special equipment (assuming 85% load factor)	56 (48)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,5 min
	Handling equipment driver	5,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	7,5 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	5,0 min
	Terminal truck driver	0,0 min

	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	5,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	72,0 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	82,0 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	5,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	5,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	5,0 min
	Truck driver	2,5 min
Handover duration per LU:	**Total LU**	7,5 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 20 min • Only Transhipment: 10 min
	Unloading	• All process steps: 15 min • Only Transhipment: 10 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 10 min
	Unloading	• 5 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 240 min
	Unloading	• 240 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 322 min
	Unloading	• 280 min
Trains that can be handled in an 8-hour shift:		• 0,7

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **30' Container**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	144 min 144 min 456 min 480 min 0 min 0 min 30 min 30 min 72 min 10 min 1.366 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment	Checker Gate agent Truck driver	0 min 0 min 216 min

technology as described in detail above.	Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	480 min 0 min 30 min 0 min 30 min 0 min 10 min 766 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	33,78 h
	600 km	23,78 h
Total working hours transport chain	**1.000 km**	198 h
	600 km	183 h
Total working hours per LU	**1.000 km**	4,12 h
	600 km	3,81 h

Costs and investments associated with the transhipment technology

Terminal infrastructure

Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	500,0 m	2,6 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	300,0 m	15,0 m	1	80 €/m²	4.500 m²	360.000 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	30,0 m	5,0 m	-	62.500 €/unit	m²	- €

Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	740,0 m	3,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	10,0 m	-	90 €/m²	m²	- €
Total area complete terminal					17.089 m²	
Structural engineering (50 €/m²)						854.425 €
Earthworks and civil engineering (100 €/m²)						1.708.850 €
Building costs terminal						4.489.050 €
Planning costs 20%						897.810 €
Total building costs complete terminal						5.386.860 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						2.499.503 €
Maximum value based on European construction cost index						7.831.417 €
Depreciation time terminal (years)					25	
Terminal building costs per year						364.010 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Truck	100.000 €	2	200.000 €	12
Chassis	26.000 €	2	52.000 €	12
MOBILER equipment	160.000 €	2	320.000 €	13

Equipment costs terminal	**Investment costs**	572.000 €
	Planning costs (20%)	114.400 €
	Total	686.400 €
Total equipment costs terminal per year		71.426 €

Initial investment costs complete terminal and equipment incl. planning costs	6.073.260 €
Total investment costs complete terminal and equipment per year	435.437 €

Total terminal handling capacity per year (transhipments)	33.488

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	224.453 €
Truck	5	10.000 €
Chassis	5	2.600 €
MOBILER equipment	6	19.200 €
Total maintenance costs per year		256.253 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	18.797 kWh	2.350 €
Truck	Diesel	1,2 l	40.186 l	45.008 €
Total energy costs per year				47.358 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.102 €
Maximum value electricity costs	3.406 €
Minimum value diesel costs	37.072 €
Maximum value diesel costs	55.001 €
Minimum value total energy costs	38.174 €
Maximum value diesel energy costs	58.407 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				555.500 €

Terminal personnel costs range in EU	
Minimum value personnel costs	120.321 €
Maximum value personnel costs	896.421 €

Total area costs (5,00 €/m² per year)	85.443 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 170.885 €

Total costs per year	1.382.339 €

Cost per transhipment for total terminal investment		13,00 €
Operational costs per transhipment	Personnel costs	16,59 €
	Energy costs	1,48 €
	Maintenance costs	7,65 €
	Total	25,72 €
Ground costs per transhipment		2,55 €
Total costs for one transhipment		41,28 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		18,47 €
Maximum value total costs transhipment		60,26 €

Loading unit investments and costs:				
Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
30’ Mobiler-Container	20.000 €	12	300 €	0,51 €

Main leg investments					
Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Sggmrrss-y 2 x 60'	130.000 €	14	1.820.000 €	40	21,04 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					6.820.000 €
Total investment costs per operating hour					78,86 €

Main leg equipment maintenance costs			
Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour

Sggmrrss-y 2 x 60'	6	111.972 €	23,33 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			85,83 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.422 kWh	177,80 €
Total energy costs per operating hour				177,80 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €

Total energy costs per operating hour		22,18 €
Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €
Personnel costs road leg		

Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	4.214 €	87,79 €
First transhipment	1.981 €	41,28 €
450 km main leg	6.603 €	137,56 €
850 km main leg	11.744 €	244,66 €
Second transhipment	1.981 €	41,28 €
Second road leg	4.003 €	83,40 €
LU costs transport chain 600 km main leg	582 €	12,13 €
LU costs transport chain 1.000 km main leg	820 €	17,08 €
Intermodal organizational costs 600 km main leg (25%)	4.841,31 €	100,86 €
Intermodal organizational costs 1.000 km main leg (25%)	6.185,86 €	128,87 €
Grand total 600 km	19.365 €	504,30 €
Grand total 1.000 km	24.743 €	644,36 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	458,70 €
Maximum value costs range 600 km transport in EU	542,26 €
Minimum value costs range 1.000 km transport in EU	598,75 €
Maximum value costs range 1.000 km transport in EU	682,32 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	4.712 €	98,18 €
First transhipment		16 €	0,34 €
Main leg	**450 km**	8.801 €	183,36 €

	850 km	16.624 €	346,34 €
Second transhipment		16 €	0,34 €
Second road leg	**75 km**	4.712 €	98,18 €
Full transport chain per LU	**600 km**	18.226 €	380,38 €
	1.000 km	26.049 €	543,37 €

21 FACT SHEET FOR "CONTAINERMOVER – Rail/Road"

Picture of the technology:

Source: InnovaTrain, July 2020

Description of the transhipment technology and transhipment process (road → main leg):

The ContainerMover (CM) is a transhipment device mounted on the chassis of the 3-axle-lorry, 2-axle terminal truck or 3-axle semi-trailer chassis. Two support beams slightly raise the loading unit (swap body or container) and carry it to (or from) the rail wagon. The standard rail wagon must be equipped with a detachable intermediate frame, the so called "wagon adapter unit", which remains on the wagon in between operations The transhipment operation is controlled by the lorry driver who needs to be trained for it. The ContainerMover (lorry) enables the driver to perform without interruption both transhipment and pre- or on-carriage, for example to (or from) a nearby factory. Thus, the ContainerMover lorry may carry out transports like an ordinary truck. However, distances should preferably be kept short to make optimal use of its transhipment function. To this purpose, so called Container Docking Stations can be placed on site for intermediate deposit. The ContainerMover parks the loading unit in a Container Docking Station for an ordinary truck to pick it up – or vice versa. The ContainerMover terminal consists of at least a single track and a paved loading lane next to it and may or may not be equipped with an overhead catenary line. The technology can be used in "stand alone" terminals, for example on industrial sites where a rail track is already available, or as an additional support in conventional RMG or reach stacker terminals. ContainerMover transhipment may also be used in combination with a conventional RMG terminal or reach stacker at the other side of the transport route.

Process:

The ContainerMover (lorry) arrives in the terminal and is positioned laterally next to the rail wagon by the truck driver. The four lower twist locks are "unlocked". The supporting legs are lowered. The two support beams slightly raise the loading unit and carry it to the rail wagon. During transhipment these beams are supported by two fixed rails between the lorry and the wagon frame and the wagon adapter unit on the wagon. After the correct position on the wagon has been reached, the support beam is lowered and the loading unit rests on the pins of the wagon adapter unit. The beams return to the Container Mover. The supporting fixed rail and the supporting legs are elevated and the lorry can perform the next transhipment process.

Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied

Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Actual system proven in operational environment; operational in Switzerland and Germany.	

Indicative qualitative assessment:

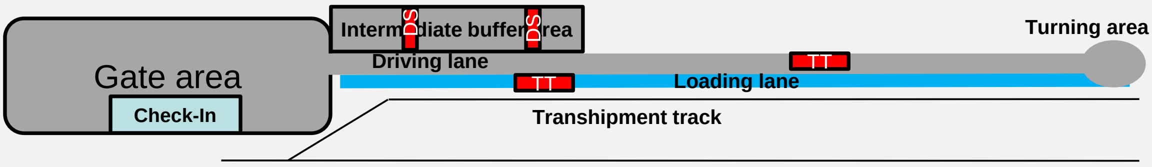
Strengths	Weaknesses and limitations
• Use of standard loading units • No need of specific terminal infrastructure, thus very basic terminal layout possible • ContainerMover vehicle can be used on short road leg to/from the customer • Rail connection of production sites or industrial parks without direct rail siding. • Decentralized supplement to terminal network • Compatible with vertical lifting terminals • Device tested with respect to the limitation of noise emissions.	• No stacking in terminals possible • As a vehicle with a defined length, one single ContainerMover lorry cannot handle loading units that need different footprints (for example 20’ and 40’). • Dead weight of about 2.5 tons of the ContainerMover loading device on the truck reducing the payload during road haulage • Dead weight of Wagon adapter unit reduce payload during rail transport • Wagon Adapter Unit reducing also the loading height by about 15 index points •

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• All, weight not over 18 t (up to34 t prototype)
• Inland container	• All, weight not over 18 t (up to34 t prototype)
• Swap body	• All, weight not over 18 t (up to34 t prototype)
• Semi-trailer	• Not possible
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	18 t

22 Fact Sheet „ContainerMover – Rail/Road – Containers”

Description of our model terminal:



Necessary road leg equipment:	Depending on type of loading units used, most probably a 3 axle truck or a 2 axle truck and 3-4 axle semi-trailer chassis (5 to 6 axles in total) with ContainerMover handling technology For the purposes of this EU-Study the ContainerMover vehicle remains in the terminal and the road leg is carried out by an ordinary road truck and trailer instead
Necessary main leg equipment:	Loco, Sggrss 80’ rail wagons or similar with wagon adapter unit

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For 20’ containers on *Sggrss 80’* wagons with wagon adapter unit (assuming 85% load factor)	80 (68)
For 40’ containers on *Sggrss 80’* wagons with *wagon adapter unit (assuming 85% load factor)*	52 (44)

Detailed description of the transhipment process:

Process steps <u>loading</u> main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	3 min
Administrative check-in:	Truck driver	5 min
	Gate agent	3 min
Drive to drop-off/parking:	Truck driver	2 min
Check-in duration per LU:	**Total LU**	7 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area at the Container Docking Station. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	2,5 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	2,5 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min

Handover duration per LU:	**Total LU**	5,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	7,5 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	7,5 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30 min
Further procedures for departure:	Visitor/Wagon inspector	20’: 79 min 40’: 102 min
Departure:	Train driver	10 min
Departure duration:	**Total**	20’: 89 min 40’: 112 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10 min
Further arrival procedures:	none	0 min
Terminal check-in:	Groundsman train	30 min
Arrival duration:	**Total**	40 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	7,5 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	7,5 min
LU handover: The loading unit is placed in the intermediate buffer area at the Container Docking Station and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	2,5 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	0,0 min
	Truck driver	2,5 min
Handover duration per LU:	**Total LU**	5,0 min
Check-out: The truck drives to the exit and checks out of the terminal		

Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 20 min • Only Transhipment: 10 min
	Unloading	• All process steps: 15 min • Only Transhipment: 10 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 10 min
	Unloading	• 5 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20'-Container: 340 min • 40'-Container: 220 min
	Unloading	• 20'-Container: 340 min • 40'-Container: 220 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 20'-Container: 429 min • 40'-Container: 332 min
	Unloading	• 20'-Container: 380 min • 40'-Container: 260 min
Trains that can be handled in an 8-hour shift:		• 20'-Container: 0,52 • 40'-Container: 0,71

Description of a full 1.000 km (600 km) transport chain:			
Transport element and duration:	**Involved personnel:**	**Working time:**	
		20' Container	**40' Container**
First road leg: The LU is transported on the first road leg over a distance of 80 km. **Duration: 80 min**	Truck driver Dispatcher	80 min 7 min	80 min 7 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above. **Duration 20': 429 min** **Duration 40': 332 min**	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Groundsman: Terminal dispatcher per train: Groundsman train: Visitor/Wagon inspector: Train driver:	204 min 204 min 646 min 680 min 0 min 0 min 30 min 30 min 79 min 10 min	132 min 132 min 418 min 440 min 0 min 0 min 30 min 30 min 102 min 10 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 840 km. **Duration: 1.280 min**	Train driver: Train dispatcher:	1.280 min 640 min	1.280 min 640 min
Main leg 600 km: The LU is transported on the main leg over a distance of 440 km. **Duration: 680 min**	Train driver: Train dispatcher:	680 min 340 min	680 min 304 min

Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above. **Duration 20': 380 min** **Duration 40': 260 min**	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Terminal dispatcher per train: Groundsman: Groundsman train: Visitor/Wagon inspector: Train driver:	0 min 0 min 306 min 680 min 0 min 30 min 0 min 30 min 0 min 10 min	0 min 0 min 198 min 440 min 0 min 30 min 0 min 30 min 0 min 10 min
Second road leg: The LU is transported on the second road leg over a distance of 80 km. **Duration: 80 min**	Truck driver: Dispatcher:	80 min 7 min	80 min 7 min
Total duration transport chain	**1.000 km**	27,23 h	23,62 h
	600 km	27,23 h	23,62 h
Total working hours transport chain	**1.000 km**	266 h	185 h
	600 km	251 h	170 h
Total working hours per LU	**1.000 km**	3,90 h	4,20 h
	600 km	3,68 h	3,86 h

Costs and investments associated with the transhipment technology

Terminal infrastructure

Elements	Dimensions (m)		Number of units (#)	Unit costs	Total area	Total costs
	Length	Width				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	300,0 m	30,0 m	1	80 €/m²	9.000 m²	720.000 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	30,0 m	5,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	740,0 m	3,0 m	-	1.250 €/m	m²	- €

Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	10,0 m	-	90 €/m²	m²	- €
Total area complete terminal					21.589 m²	
Structural engineering (50 €/m²)					1.079.425 €	
Earthworks and civil engineering (100 €/m²)					2.158.850 €	
Total building costs terminal					5.524.050 €	
Planning costs 20%					1.104.810 €	
Total building costs complete terminal					6.628.860 €	
Terminal building costs range						
Minimum value based on European construction cost index					3.075.791 €	
Maximum value based on European construction cost index					9.637.037 €	
Depreciation time terminal (years)					25	
Terminal building costs per year					447.937 €	

Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
ContainerMover	330.000 €	2	660.000 €	8
Container Docking Station	18.000 €	70	144.000 €	12

Equipment costs terminal	**Investment costs**	1.920.000 €
	Planning costs (20%)	384.000 €
	Total	2.304.000 €
Total equipment costs terminal per year		279.173 €

Initial investment costs complete terminal and equipment incl. planning costs	8.932.860 €
Total investment costs complete terminal and equipment per year	727.110 €

23 Fact Sheet „ContainerMover – Rail/Road – 20' Container"

Total terminal handling capacity per year (transhipments)	35.312

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**

Terminal Infrastructure	5	276.203 €
ContainerMover	6	40.000 €
Container Docking Station	1	14.000 €
Total maintenance costs per year		330.203 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	23.747 kWh	2.968 €
ContainerMover	Diesel	1,2 l	42.374 l	47.459 €
Total energy costs per year				50.427 €

Terminal energy costs range	
Minimum value electricity costs	1.392 €
Maximum value electricity costs	4.303 €
Minimum value diesel costs	39.090 €
Maximum value diesel costs	57.995 €
Minimum value total energy costs	40.482 €
Maximum value diesel energy costs	62.299 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				555.500 €

Terminal personnel costs range	
Minimum value personnel costs	120.321 €
Maximum value personnel costs	896.421 €

Total area costs (5,00 €/m² per year)	107.943 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 215.885 €

Total costs per year	1.771.182 €

Cost per transhipment for total terminal investment		20,59 €
Operational costs per transhipment	**Personnel costs**	15,73 €
	Energy costs	1,43 €
	Maintenance costs	9,35 €
	Total	26,51 €
Ground costs per transhipment		3,06 €
Total costs for one transhipment		50,16 €
Total transhipment cost range		
Minimum value total costs transhipment		23,46 €
Maximum value total costs transhipment		72,55 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
20’ Container	3.000 €	12	90 €	0,09 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
Sggrss 80’ wagon	85.000 €	20	1.700.000 €	40	19,66 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Wagon adapter unit	3.500 €	80	280.000 €	12	8,60 €
Total main leg investment costs					6.980.000 €
Total investment costs per operating hour					86,07 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Sggrss 80’ wagons	7	120.000 €	25,00 €
Loco	6	300.000 €	62,50 €
Wagon adapter unit	0	0 €	0 €

Total maintenance costs per operating hour				87,50 €
Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour**
Loco	Electricity	0,02	1.402 kWh	175,20 €
Total energy costs per operating hour				175,20 €
Other operational costs main leg				

Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €
Attendant	30,96 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000,00 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				

Cost type	Costs per km	Costs per leg
Tolls	0,187 €	11,97 €
Personnel costs road leg		

Function	Costs per operating hour
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport	Total	
	Total	Per LU
First road leg	5.969 €	87,79 €
First transhipment	3.411 €	50,16 €
440 km main leg	6.844 €	100,65 €
840 km main leg	12.048 €	177,17 €
Second transhipment	3.411 €	50,16 €
Second road leg	5.672 €	83,40 €
LU costs transport chain 600 km main leg	159 €	2,34 €
LU costs transport chain 1.000 km main leg	214 €	3,15 €
Intermodal organizational costs 600 km main leg (25%)	6.366,39 €	93,62 €
Intermodal organizational costs 1.000 km main leg (25%)	7.681,10 €	112,96 €
Grand total 600 km	25.466 €	468,12 €
Grand total 1.000 km	30.724 €	564,79 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	414,72 €
Maximum value costs range 600 km transport in EU	512,90 €
Minimum value costs range 1.000 km transport in EU	511,39 €
Maximum value costs range 1.000 km transport in EU	609,57 €

External costs		Total	Per LU
First road leg	80 km	5.289 €	77,78 €
First transhipment		23 €	0,34 €
Main leg	440 km	8.672 €	127,54 €
	840 km	16.381 €	240,90 €
Second transhipment		23 €	0,34 €
Second road leg	80 km	5.289 €	77,78 €
Full transport chain per LU	600 km	19.250 €	283,77 €

	1.000 km	26.959 €	397,13 €

24 Fact Sheet „ContainerMover – Rail/Road – 40' Container"

Total terminal handling capacity per year (transhipments)	31.195

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	276.203 €
ContainerMover	6	40.000 €
Container Docking Station	1	14.000 €
Total maintenance costs per year		330.203 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	23.747 kWh	2.968 €
ContainerMover	Diesel	1,2 l	37.434 l	41.926 €
Total energy costs per year (€)				44.895 €

Terminal energy costs range	
Minimum value electricity costs	1.392 €
Maximum value electricity costs	4.303 €
Minimum value diesel costs	34.533 €
Maximum value diesel costs	51.234 €
Minimum value total energy costs	35.925 €
Maximum value diesel energy costs	55.538 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	0	0	32.000 €	- €

Instructor "Groundsman"	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				555.500 €
Terminal personnel costs range				
Minimum value personnel costs				120.321 €
Maximum value personnel costs				896.421 €

Total area costs (5,00 €/m² per year)	107.943 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 215.885 €

Total costs per year	1.765.650 €

Cost per transhipment for total terminal investment		23,31 €
Operational costs per transhipment	**Personnel costs**	17,81 €
	Energy costs	1,44 €
	Maintenance costs	10,59 €
	Total	29,83 €
Ground costs per transhipment		3,46 €
Total costs for one transhipment		56,60 €
Costs range operational costs transhipment		
Minimum value total costs transhipment		26,41 €
Maximum value total costs transhipment		81,91 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
40' Container	4.200 €	12	126 €	0,12 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Sggrss 80' wagon	85.000 €	26	2.210.000 €	40	25,55 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Wagon adapter unit	3.500 €	52	182.000 €	12	5,59 €

Total main leg investment costs(€)	7.392.000 €
Total investment costs per operating hour (€)	88,96 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Sggrss 80' wagons	8	175.000 €	32,50 €
Loco	6	300.000 €	62,50 €
Wagon adapter unit	0	0 €	0 €
Total maintenance costs per operating hour (€)			95,00 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption per ton-km**	**Consumption per hour**	**Costs per operating hour**
Loco	Electricity	0,02	1.225 kWh	153,12 €
Total energy costs per operating hour (€)				153,12 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour (€)		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €
Attendant	30,96 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Chassis	26.000 €	11	0,85 €
Total road leg investment costs			126.000,00 €
Total investment costs per operating hour			4,68 €
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €

Chassis	10%	2.600,00 €	0,74 €
Total maintenance costs per operating hour			3,60 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,97 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per Lu**
First road leg	3.863 €	87,79 €
First transhipment	2.490 €	56,60 €
440 km main leg	6.690 €	152,04 €
840 km main leg	11.776 €	267,65 €
Second transhipment	2.490 €	56,60 €
Second road leg	3.670 €	83,40 €
LU costs transport chain 600 km main leg	125 €	2,84 €
LU costs transport chain 1.000 km main leg	175 €	3,98 €
Intermodal organizational costs 600 km main leg (25%)	4.832,00 €	109,82 €
Intermodal organizational costs 1.000 km main leg (25%)	6.116,18 €	139,00 €
Grand total 600 km	19.328 €	549,09 €
Grand total 1.000 km	24.465 €	695,02 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	488,71 €
Maximum value costs range 600 km transport in EU	599,71 €
Minimum value costs range 1.000 km transport in EU	634,64 €
Maximum value costs range 1.000 km transport in EU	745,64 €

External costs			
		Total	Per LU
First road leg	80 km	3.422 €	77,78 €
First transhipment		15 €	0,34 €
Main leg	440 km	7.579 €	172,26 €
	840 km	14.317 €	325,38 €
Second transhipment		15 €	0,34 €
Second road leg	80 km	3.422 €	77,78 €
Full transport chain per LU	600 km	14.424 €	328,50 €
	1.000 km	21.161 €	481,62 €

25 Fact sheet for "CargoBeamer – Rail/Road horizontal first generation – Rail/Road"

Picture of the technology:

Source: www.cargobeamer.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

The CargoBeamer is a special transhipment technology in which craneable and non-craneable semi-trailers can be transferred from road to rail. The technology consists of special wagons and the corresponding pallet per wagon. Semi-trailers can be loaded into the pallets and then the pallets are transferred horizontally or vertically into the wagons. At the destination terminal, the pallets are again transferred horizontally or vertically from the wagon and the semi-trailer can be pulled out of the pallet with the help of a truck.
Special CargoBeamer terminals are needed for horizontal transhipment, which require corresponding rails for the transverse transfer of the pallets and parking areas for the pallets to the left and right of the track.
The focus is on the horizontal transhipment in the analysis of this study.

Process:

- loading unit arrives at the terminal and is either loaded directly onto the pallet by truck or parked on a separate area. If parking space is used, the semi-trailer is driven into the pallet by a terminal truck;

• when the train arrives at the terminal, the arriving pallets are automatically pushed off the train and then the pallet to be transported is pushed onto the train; • the train leaves the terminal; trucks / terminal trucks can pull the arrived semi-trailers out of the pallets and leave the terminal or take them to a parking area.		
Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Technology is fully developed and used on selected routes in Europe. However only the newer generation is being further developed and produced and it will replace the first generation over time. For this reason the CargoBeamer first generation technology will be excluded from further analysis.	

26 FACT SHEET FOR “CARGOBEAMER HORIZONTAL NEXT GENERATION – RAIL/ROAD”

Picture of the technology:

Source: CargoBeamer, Mai 2021

Description of the transhipment technology and transhipment process (road → main leg):

The CargoBeamer is a rail/road transhipment technology in which craneable and non-craneable semi-trailers can be transferred from road to rail. The technology consists of CargoBeamer rail wagons “Sdkmss” and the corresponding pallet, automated terminals (“CargoBeamer Gates”) and a dedicated logistics software (“CargoBeamer eLogistics”). Semi-trailers can be loaded into the pallets and then the pallets with semi-trailers are transferred horizontally or vertically into the wagons. All kinds of terminals may be used: container cranes, reach stacker or automated CargoBeamer terminals with high throughput. At the destination terminal, the pallets are again transferred horizontally or vertically from the wagon and the semi-trailer can be pulled out of the pallet with the help of a truck.
Process in container crane or reach stacker terminals:

- Reach stacker/crane unloads CB loading pallets from the wagons.
- Terminal truck driver move semi-trailer from the pallet to the parking area, drop off the semi-trailer and pick up the next semi-trailer for transhipment on the wagon.
- Terminal truck driver move the semi-trailer on the pallet.
- Reach stacker/crane load the CB loading pallet on to the CB wagon.
- Semi-trailers are picked up or dropped off by customer’s truck drivers at the parking area.

Process in CargoBeamer automated terminals:

- Loading unit arrives at the terminal and is parked on a parking area.
- The semi-trailer is driven into one of the free pallets by a terminal truck.
- When the train arrives at the terminal, the arriving pallets are automatically pushed off the train and then the preloaded group of pallets waiting for departure is pushed onto the train.
- The train leaves the terminal.

- Trucks / terminal trucks can pull the arrived semi-trailers out of the pallets and leave the terminal or take them to a parking area.

Trucks / terminal trucks load the incoming pallets with new semi-trailers for the next train.

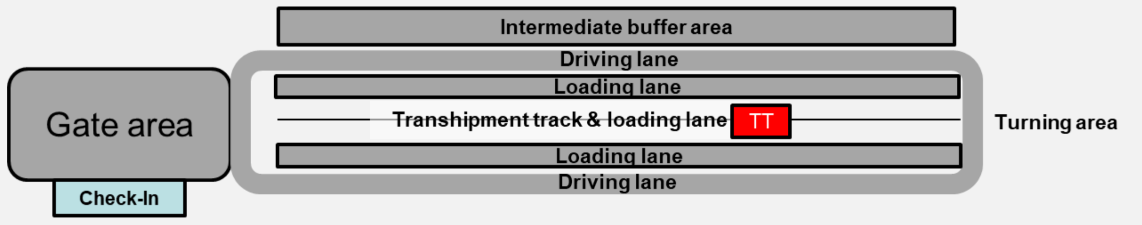
Classification	☒ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Market-ready technology that is ready to use and can be integrated into existing networks.	

Indicative qualitative assessment:

Strengths	Weaknesses and limitations
• All kinds of semi-trailers (silo, flat, curtainsider, Mega, Frigo, Euro-Trailer, walking-floor-trailer may be used. • No additional codification or hardware stiffening or crane edges are required for the semi-trailers, 100% of trailers are compatible with the CB wagon (huge market share) • Wagons are fully compatible with all other wagons • Robust wagons (no electrification, no hydraulics, no sensors, no actuators on the wagon → actual overall wagon availability is >98% • Significantly less transshipment cost (less personnel, less energy, automated, parallelized transshipment • Fast transshipment (20 minutes to load and unload a full train); therefore, higher capacity and asset utilization than crane terminals • Up to 1.000 trailers per day can be un/loaded in a compact terminal (half train rail length 400m) • Works under electrified tracks • compatible with conventional terminals, as pallets can be craned • Low space requirement • Less investment required for CargoBeamer terminals than for conventional crane terminals • Possibility to complete automated loading/unloading process • Low railcar profile enables the transport of semi-trailers with greater heights. CargoBeamer wagon loading level (22-24cm) is lowest in Europe	• Cargo wagons are heavier • Investment cost of wagons (currently) 20% higher than pocket-wagon (resulting in 7-10 € cost per day)

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• Not possible
• Inland container	• Not possible
• Swap body	• Not possible
• Semi-trailer	• Possible (craneable and non-cranable)
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	37 t

Description of our model terminal:	
	
Necessary road leg equipment:	Truck
Necessary main leg equipment:	Loco, CargoBeamer rail wagons “Sdkmss”
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For Semi-trailer non-craneable on CargoBeamer rail wagons “Sdkmss” with corresponding pallet (assuming 85% load factor)	34 (29)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	5,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5,0 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min

	Terminal truck driver	5,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	10,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	0,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	10,0 min
Further procedures for departure:	Visitor/Wagon inspector	93,2 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	113,2 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	10,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	50,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	0,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	5,0 min

Handover of loading unit to truck:		Handling equipment driver Truck driver	0,0 min 5,0 min
Handover duration per LU:		**Total LU**	10,0 min
Check-out: The truck drives to the exit and checks out of the terminal			
Drive from drop-off/parking:		Truck driver	2 min
Check-out duration per LU:		**Total LU**	2 min
Total time for the transhipment of one LU:	**Loading**	• All process steps: 17 min • Only Transhipment: 10 min	
	Unloading	• All process steps: 12 min • Only Transhipment: 10 min	
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min	
	Unloading	• 7 min	
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20 min	
	Unloading	• 20 min	
Total time for loading /unloading one train (incl. headway):	**Loading**	• 133 min	
	Unloading	• 70 min	
Trains that can be handled in an 8-hour shift:		• 2,07	

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Semi-trailer**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	145 min 87 min 348 min 0 min 145 min 0 min 30 min 10 min 93 min 10 min 868 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min

Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	0 min 0 min 203 min 0 min 145 min 30 min 0 min 40 min 0 min 10 min 428 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	27,14 h
	600 km	17,14 h
Total working hours transport chain	**1.000 km**	132 h
	600 km	117 h
Total working hours per LU	**1.000 km**	4,56 h
	600 km	4,05 h

Costs and investments associated with the transhipment technology							
Terminal infrastructure							
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	7,0 m	2	80 €/m²	10.360 m²	828.800 €
Loading lane	740,0 m	3,5 m	2	80 €/m²	10.360 m²	828.800 €
Turning area	57,0 m	25,0 m	1	80 €/m²	1.425 m²	106.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	740,0 m	11,0 m	2	80 €/m²	16.000 m²	1.280.000 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €

Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	0,0 m	0,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0,0 m	0,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	-	90 €/m²	m²	- €

Total area complete terminal	44.929 m²
Structural engineering (50 €/m²)	2.246.425 €
Earthworks and civil engineering (100 €/m²)	4.492.850 €
Building costs terminal	10.888.250 €
Planning costs 20%	2.177.650 €
Total building costs complete terminal	13.065.900 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	6.062.578 €
Maximum value based on European construction cost index	18.995.205 €
Depreciation time terminal (years)	25
Terminal building costs per year	882.912 €

Terminal equipment

Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
CB Module	580.000 €	34	19.720.000 €	40
Terminal truck	150.000 €	4	600.000 €	5
CB pallet	20.000 €	34	680.000	5

Equipment costs terminal	**Investment costs**	21.000.000 €
	Planning costs (20%)	4.200.000 €
	Total	25.200.000 €
Total equipment costs terminal per year		1.651.306 €

Initial investment costs complete terminal and equipment incl. planning costs	38.265.900 €

Total investment costs complete terminal and equipment per year	2.534.219 €

Total terminal handling capacity per year (transhipments)	59.941

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	544.413 €
CB Module	0,4	69.020 €
Terminal truck	2,8	16.800 €
CB pallet	2,8	19.040 €
Total maintenance costs per year		649.273 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	49.421 kWh	6.178 €
CB Module	Electricity	1,2 kWh	71.929 kWh	8.991 €
Terminal truck	Diesel	1,2 l	71929 l	80.561 €
Total energy costs per year				95.729 €

Terminal energy costs range in EU	
Minimum value electricity costs	7.113 €
Maximum value electricity costs	21.991 €
Minimum value diesel costs	66.355 €
Maximum value diesel costs	98.446 €
Minimum value total energy costs	73.468 €
Maximum value diesel energy costs	120.437 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	0	0	35.000 €	- €

Terminal truck driver	4	13,5	32.000 €	432.000 €
Instructor "Groundsman"	1	3,5	31.000 €	108.500 €
Dispatcher	0	0	37.000 €	- €
Total terminal personnel costs per year				748.750 €
Terminal personnel costs range in EU				
Minimum value personnel costs				162.179 €
Maximum value personnel costs				1.208.272 €

Total area costs (5,00 €/m² per year)	224.643 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 449.285 €

Total costs per year	4.252.613 €

Cost per transhipment for total terminal investment		42,28 €
Operational costs per transhipment	**Personnel costs**	12,49 €
	Energy costs	1,60 €
	Maintenance costs	10,83 €
	Total	24,92 €
Ground costs per transhipment		3,75 €
Total costs for one transhipment		70,95 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		34,38 €
Maximum value total costs transhipment		101,96 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
Semi-trailer non craneable	26.000 €	11	780,00 €	0,78 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
"Sdkmss" with „CargoBeamer JetModule"	130.000 €	34	4.420.000 €	40	51,11 €

Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					9.420.000 €
Total investment costs per operating hour					108,92 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
"Sdkmss" with „CargoBeamer JetModule"	5	238.000 €	49,58 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			112,08 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.478 kWh	184,74 €
Total energy costs per operating hour				184,74 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)		**600 km**	1:2,9
		1.000 km	1:4,2
Road leg equipment maintenance costs			

Equipment	Percentage of investment (%)	Total per year	Costs per operating hour
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	2.542 €	87,66 €
First transhipment	2.057 €	70,95 €
450 km main leg	7.265 €	250,52 €
850 km main leg	13.039 €	449,60 €
Second transhipment	2.057 €	70,95 €
Second road leg	2.419 €	83,42 €
LU costs transport chain 600 km main leg	389 €	13,43 €
LU costs transport chain 1.000 km main leg	605 €	20,86 €
Intermodal organizational costs 600 km main leg (25%)	4.182,68 €	144,23 €
Intermodal organizational costs 1.000 km main leg (25%)	5.679,89 €	195,86 €
Grand total 600 km	16.731 €	721,15 €
Grand total 1.000 km	22.720 €	979,29 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	648,02 €
Maximum value costs range 600 km transport in EU	783,18 €

Minimum value costs range 1.000 km transport in EU	906,16 €
Maximum value costs range 1.000 km transport in EU	1.041,32 €

External costs			
		Total	Per LU
First road leg	75 km	2.522 €	86,96 €
First transhipment		11 €	0,38 €
Main leg	450 km	9.145 €	315,33 €
	850 km	17.273 €	595,63 €
Second transhipment		11 €	0,38 €
Second road leg	75 km	2.522 €	86,96 €
Full transport chain per LU	600 km	14.188 €	489,99 €
	1.000 km	22.317 €	770,29 €

27 FACT SHEET FOR "MODALOHR 1ST GENERATION (AFA) – RAIL/ROAD"

Picture of the technology:

Source: www.lohr.fr, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

A Lohr terminal is made up of stations with devices for loading and unloading the special wagon pockets (pockets turning - opening). The devises are hydraulic ground systems making it possible to open the pockets of the wagons. The special wagons are equipped with pivoting pockets for direct horizontal loading of semi-trailers and complete trucks (split into tractor and semi-trailer).

After the train has entered the terminal and stopped at the intended position, the wagon pockets are rotated by 30 degrees by the turning devices embedded in the track and positioned on the intended ramps. For loading the empty ramps and pockets, the tractor unit and semi-trailer separately are placed on the pocket. After that, the wagon pockets are swiveled back into the track axis and lowered onto the transport wagon with which they are anchored. Then the journey takes place to a suitably equipped destination terminal, where the procedure is repeated in reverse.

Classification	☒ Horizontal	☐ Vertical
	☒ Accompanied	☒ Unaccompanied

Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The system has been in operation on one particular route (Aiton – Orbassano) since 2003, but the transport of tractor units / complete trucks was only for about the first 2-3 years. From then, only semi-trailers were transported. Modalohr AFA wagons are still in operation, as the life cycle of all Lohr Wagons generations is 30 years, even if those wagons are replaced at the Lohr production line by UIC Wagons. The AFA (and NA) wagons are the wagons of first generation, adapted to the low loading gauge GI3. The technical progress allows Lohr to develop more universal wagons UIC type. This new generation of Modalohr UIC Wagons has the same level of performances as AFA and NA wagons, but also adapted to all EU loading gauges and thus can run on all EU railway network. The beforementioned terminals are already modernised in a way that they can handle also the new Modalohr UIC wagons. There are already services running with Modalohr UIC wagons from and to these terminals. The Aiton – Orbassano service could also be run with the Modalohr UIC wagons from technical point of view. For this reason the technology will be excluded from the further evaluation of technologies in this study.	

28 FACT SHEET FOR "MODALOHR 2ND GENERATION (LOHR INDUSTRIE) – RAIL/ROAD"

Picture of the technology:

Source: www.lohr.fr, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

A Lohr terminal is made up of stations with devices for loading and unloading the special wagon pockets (pockets turning - opening). The devises are hydraulic ground systems making it possible to open the pockets of the wagons. The special wagons are equipped with pivoting pockets for direct horizontal loading of semi-trailers and complete trucks (split into tractor and semi-trailer).
After the train has entered the terminal and stopped at the intended position, the wagon pockets are rotated by 30 degrees by the turning devices embedded in the track and positioned on the intended ramps. For loading the empty ramps and pockets, the tractor unit and semi-trailer separately are placed on the pocket. After that, the wagon pockets are swiveled back into the track axis and lowered onto the transport wagon with which they are anchored. Then the journey takes place to a suitably equipped destination terminal, where the procedure is repeated in reverse.

Classification	☒ Horizontal	☐ Vertical
	☒ Accompanied	☒ Unaccompanied

Connected modes of transport	☒ Rail ☐ Short Sea ☐ Inland waterway ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The system has been in operation on one particular route (Le Boulou – Bettembourg) since 2007. Modalohr NA wagons are still in operation, as the life cycle of all Lohr Wagons generations is 30 years, even if those wagons are replaced at the Lohr production line by UIC Wagons. The NA (and AFA) wagons are the wagons of first generation, adapted to the low loading gauge GI3. The technical progress allows Lohr to develop more universal wagons UIC type. This new generation of Modalohr UIC Wagons has the same level of performances as AFA and NA wagons, but also adapted to all EU loading gauges and thus can run on all EU railway network. The beforementioned terminals are already modernised in a way that they can handle also the new Modalohr UIC wagons. There are already services running with Modalohr UIC wagons from and to these terminals. The Le Boulou - Bettembourg service could also be run with the Modalohr UIC wagons from technical point of view. For this reason the technology will be excluded from the further evaluation of technologies in this study.

29 Fact sheet for "Modalohr UIC (Lohr Industrie) – Rail/Road"

Picture of the technology:

Source: VIIA.com, March 2021

Description of the transhipment technology and transhipment process (road → main leg):		
A Lohr terminal is made up of stations with devices for loading and unloading the special wagon pockets (pockets turning - opening). The devises are hydraulic ground systems making it possible to open the pockets of the wagons. The special wagons are equipped with pivoting pockets for direct horizontal loading of semi-trailers and complete trucks (split into tractor and semi-trailer). After the train has entered the terminal and stopped at the intended position, the wagon pockets are rotated by 30 degrees by the turning devices embedded in the track and positioned on the intended ramps. For loading the empty ramps and pockets, the tractor unit and semi-trailer separately are placed on the pocket. After that, the wagon pockets are swiveled back into the track axis and lowered onto the transport wagon with which they are anchored. Then the journey takes place to a suitably equipped destination terminal, where the procedure is repeated in reverse.		
Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied

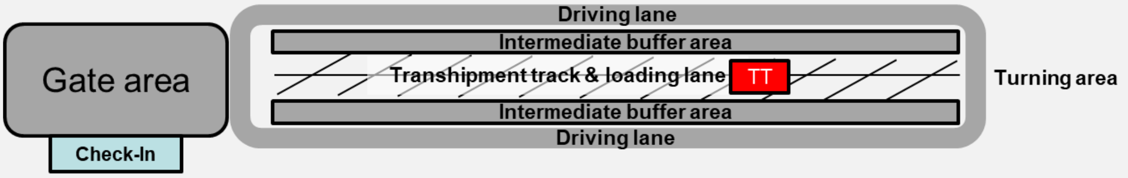
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: the system has been in operation on one particular route (Aiton – Orbassano) since 2003, but the transport of tractor units / complete trucks was only for about the first 2-3 years. From then, only semi-trailers were transported. Thus, the wagon of the type Modalohr AFA is still used, but will not be manufactured anymore. Only Modalohr UIC wagon type is still further developed. That is why this technology will be excluded from further analysis.	

Indicative qualitative assessment:

Strengths	Weaknesses and limitations
• Optimized technology for the rapid transfer of all standard EU semi-trailers from road to rail. Can be used for both: craneable and non-craneable units and all types of semi-trailers (including tank, dump trailers, containers trailers, vans flatted trailers) • Compatible with vertical loading • Maximal number of LU loaded for linear meter of train • Maximal utile loaded mass per train • Terminal size could be optimized depending to the capacity needed • No hydraulic equipment on-board the wagon, the ground devices on the terminal are available to the maintenance • In case of the problem on one loading station, Service on terminal is not interrupted because of the station's interchangeability • Adapted to all EU loading gauges, even to the smallest one like in France, Italy and Spain	• Cargo wagons are heavier • Investment cost of wagons (currently) 20% higher than pocket-wagon (resulting in 7-10 € cost per day)

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• Not possible
• Inland container	• Not possible
• Swap body	• Not possible
• Semi-trailer	• Possible (craneable and non-cranable)
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	38 t

Description of our model terminal:		
		
Necessary road leg equipment:	Truck	
Necessary main leg equipment:	Loco, UIC 2 Intermediate wagon	
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:		
For Semi-trailer non-craneable on UIC 2 Intermediate wagon with no further special equipment (assuming 85% load factor)		40 (34)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	5,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5,0 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Preparing transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	5,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	0,0 min
	Terminal truck driver	5,0 min

	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	5,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	33,0 min
Further procedures for departure:	Visitor/Wagon inspector	78,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	121,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	33,0 min
Arrival duration:	**Total**	43,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	0,0 min
	Terminal truck driver	5,0 min
	Truck driver	0,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	5,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
Handover of loading unit to truck:	Handling equipment driver	0,0 min
	Truck driver	5,0 min
Handover duration per LU:	**Total LU**	5,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 17 min • Only Transhipment: 5 min
	Unloading	• All process steps: 12 min • Only Transhipment: 5 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min
	Unloading	• 7 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 43 min
	Unloading	• 43 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 164 min
	Unloading	• 86 min
Trains that can be handled in an 8-hour shift:		• 1,68

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:**
		Semi-trailer
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	170 min 102 min 408 min 0 min 170 min 0 min 30 min 33 min 79 min 10 min 1.002 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver	0 min 0 min 238 min 0 min 170 min 30 min

	Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	0 min 33 min 0 min 10 min 481 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	27,91 h
	600 km	17,91 h
Total working hours transport chain	**1.000 km**	149 h
	600 km	134 h
Total working hours per LU	**1.000 km**	4,38 h
	600 km	3,94 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	7,0 m	2	80 €/m²	10.360 m²	828.800 €
Loading lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Turning area	57,0 m	25,0 m	1	80 €/m²	1.425 m²	106.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	740,0 m	11,0 m	2	80 €/m²	16.280 m²	1.302.400 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	0,0 m	0,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €

Crane tracks	0,0 m	0,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	-	90 €/m²	m²	- €

Total area complete terminal	40.029 m²
Structural engineering (50 €/m²)	2.001.425 €
Earthworks and civil engineering (100 €/m²)	4.002.850 €
Building costs terminal	9.761.250 €
Planning costs 20%	1.952.250 €
Total building costs complete terminal	11.713.500 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	5.435.064 €
Maximum value based on European construction cost index	17.029.086 €
Depreciation time terminal (years)	25
Terminal building costs per year	791.525 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Hydraulic ground systems	155.000 €	34	5.270.000 €	40
Terminal truck	150.000 €	4	600.000 €	5

Equipment costs terminal	**Investment costs**	5.870.000 €
	Planning costs (20%)	1.174.000 €
	Total	7.044.000 €
Total equipment costs terminal per year		550.178 €

Initial investment costs complete terminal and equipment incl. planning costs	18.757.500 €
Total investment costs complete terminal and equipment per year	1.341.704 €

Total terminal handling capacity per year (transhipments)	57.166

Terminal maintenance costs

	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	488.063 €
Hydraulic ground systems	3,2	168.640 €
Terminal truck	2,8	16.800 €
Total maintenance costs per year		673.503 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Terminal Infrastructure	Electricity	-	44.031 kWh	5.504 €
Hydraulic ground systems	Electricity	7 kWh	400.160 kWh	50.020 €
Terminal truck	Diesel	1,2 l	68.599 l	76.831 €
Total energy costs per year				132.355 €

Terminal energy costs range in EU	
Minimum value electricity costs	26.035 €
Maximum value electricity costs	80.496 €
Minimum value diesel costs	63.283 €
Maximum value diesel costs	93.888 €
Minimum value total energy costs	89.318 €
Maximum value diesel energy costs	174.384 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	2	7	26.500 €	185.500 €
Gate agent	2	7	33.000 €	231.000 €
Handling equipment driver	0	0	35.000 €	- €
Terminal truck driver	4	13,5	32.000 €	432.000 €
Instructor “Groundsman”	0,5	2	31.000 €	62.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				1.040.000 €

Terminal personnel costs range in EU	
Minimum value personnel costs	225.264 €
Maximum value personnel costs	1.678.267 €

Total area costs (5,00 €/m² per year)	200.143 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 400.285 €

Total costs per year	3.387.703 €

Cost per transhipment for total terminal investment		23,47 €
Operational costs per transhipment	**Personnel costs**	18,19 €
	Energy costs	2,32 €
	Maintenance costs	11,78 €
	Total	32,29 €
Ground costs per transhipment		3,50 €
Total costs for one transhipment		59,26 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		28,17 €
Maximum value total costs transhipment		85,31 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
Semi-trailer non craneable	26.000 €	11	780,00 €	0,78 €

Main leg investments					
UIC 2	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
UIC 2	325.000 €	20	6.500.000 €	40	75,16 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					11.500.000 €
Total investment costs per operating hour					132,98 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**

UIC 2	3	200.000 €	41,67 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			104,17 €
Main leg energy consumption			

Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.447 kWh	180,84 €
Total energy costs per operating hour				180,84 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)		**600 km**	1:2,9
		1.000 km	1:4,2

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €

Total energy costs per operating hour		22,18 €
Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	2.981 €	87,66 €
First transhipment	2.015 €	59,26 €
450 km main leg	7.548 €	221,99 €
850 km main leg	13.444 €	395,40 €
Second transhipment	2.015 €	59,26 €
Second road leg	2.836 €	83,42 €
LU costs transport chain 600 km main leg	477 €	14,04 €
LU costs transport chain 1.000 km main leg	730 €	21,47 €
Intermodal organizational costs 600 km main leg (25%)	4.467,87 €	131,41 €
Intermodal organizational costs 1.000 km main leg (25%)	6.004,95 €	176,62 €
Grand total 600 km	17.871 €	657,04 €
Grand total 1.000 km	24.020 €	883,08 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		594,87 €
Maximum value costs range 600 km transport in EU		709,14 €
Minimum value costs range 1.000 km transport in EU		820,91 €
Maximum value costs range 1.000 km transport in EU		935,19 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	2.956 €	86,96 €
First transhipment		18 €	0,52 €
Main leg	**450 km**	8.952 €	263,28 €

	850 km	16.909 €	497,31 €
Second transhipment		18 €	0,52 €
Second road leg	**75 km**	2.956 €	86,96 €
Full transport chain per LU	**600 km**	14.865 €	438,24 €
	1.000 km	22.821 €	672,26 €

30 FACT SHEET FOR "HELROM – RAIL/ROAD"

Picture of the technology:

Source: www.helrom.com, April 2021

Description of the transhipment technology and transhipment process (road → main leg):

Helrom GmbH, Frankfurt am Main is moving freight volumes from road to rail using the HELROM rail wagon and terminal technology. The HELROM technology allows to transport all kinds of standard semi-trailers on rail. The HELROM wagon is an articulated six axle wagon which opens (and closes) to be horizontally loaded (and unloaded) from any paved area next to the loading track. For loading the wagon is parked on a paved area, the loading platform disconnects from the bogy, swivels to one side and lowers itself down to the ground. The truck (or a terminal tractor) pushes the semi-trailer backwards onto the loading platform under the surveillance of an operator. The margin between the wheels and the side walls of the trailers and the wagon are quite small so that a certain training of the driver and sufficient illumination is needed. The trailer is lowered on its legs and the truck (or terminal truck) leave the area for the next duty. The platform is lifted and

swivelled back to the rail side where is hooks with the bogy. Finally, the king pin support plate is lifted and fixes the king pin during rail transport. Electric energy for the hydraulics installed on the wagon is provided from a mobile device in the terminal.		
Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Actual system proven in operational environment; in service on the route Düsseldorf (DE) – Wien (AT) since autumn 2020. However, Helrom did not disclose technical data relevant to complete the fact sheet. Therefore we are unable to conduct an in-depth analysis of the technology and it will be excluded from further evaluation in this study.	

31 Fact sheet for "NIKRASA – Rail/Road" (crane terminal)

Picture of the technology:

Source: TX LOGISTIK

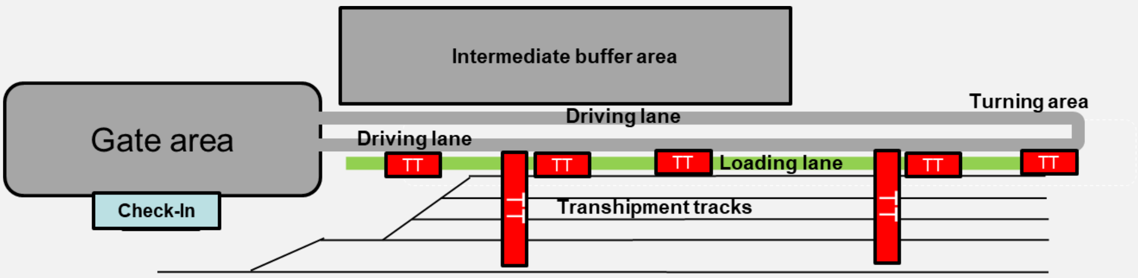
Description of the transhipment technology and transhipment process (road → main leg):		
The NiKRASA system consists of the terminal platform and the transport platform, which must additionally be present in a normal transshipment terminal. The terminal platform is located on the ground and serves to hold the transport platform. The terminal truck drives onto the terminal platform for transhipment and positions the trailer centrally on the transport platform. There are gripping edges for the transhipment equipment. The terminal transhipment equipment can pick up the transport platform using a spreader with grapple arms. For transhipment and transport on the pocket wagon, the trailer and the transport platform form a unit that is transported together and thus behaves like a craneable trailer. On the pocket wagon, the transport platform is positioned so that the king pin of the trailer fits exactly into the support frame.		
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network. Currently in use and easily integrated into the existing intermodal network.	
Indicative qualitative assessment:		
Strengths	**Weaknesses and limitations**	

• Standardised system and compatible with common craneable loading units • Fast transhipment rate • Automation and digitalisation easy to implement • Remote control is more employee-friendly (more interesting for employee recruitment) • - Large working area is covered, which is used very efficiently (a lot of storage area and transshipment area in relation to the traffic area of the crane (crane track)). • Compact storage area under crane, which can be used to 100%. • Efficient technology for consumption and transhipment speed • Low life cycle costs • Long service life	• Weight of a frame of 2.275 tonnes reduces payload of the train • higher transport costs compared to craneable trailers

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• Not possible
• Inland container	• Not possible
• Swap body	• Not possible
• Semi-trailer	• Yes
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	38,725 t

Description of our model terminal:



The terminal consists of a normal crane terminal and two loading lanes with 40 NiKRASA terminal modules.

Necessary road leg equipment:	Truck
Necessary main leg equipment:	Loco, T3000e rail wagons or similar with two transport platforms

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:

For Semi-trailer non-craneable on T3000e wagons with two transport platforms (assuming 85% load factor)	40 (34)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	5,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5,0 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	3,0 min
Preparing transhipment:	Terminal truck driver	2,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	10,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	3,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	3,0 min
Transhipment duration per LU:	**Total LU**	3,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	78,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	88,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min

Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	3,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	3,0 min
Transhipment duration per LU:	**Total LU**	3,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	2,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	5,0 min
Handover of loading unit to truck:	Handling equipment driver	0,0 min
	Truck driver	5,0 min
Handover duration per LU:	**Total LU**	12,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 20 min • Only Transhipment: 3 min
	Unloading	• All process steps: 17 min • Only Transhipment: 3 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min
	Unloading	• 7 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 51 min
	Unloading	• 51 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 140 min
	Unloading	• 91 min
Trains that can be handled in an 8-hour shift:		• 4,12

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Semi-trailer**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	170 min 102 min 408 min 102 min 170 min 102 min 30 min 30 min 79 min 10 min 1.203 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total:	0 min 0 min 238 min 102 min 238 min 30 min 102 min 30 min 0 min 10 min 750 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	27,60 h
	600 km	17,60 h
Total working hours transport chain	**1.000 km**	157 h
	600 km	142 h
Total working hours per LU	**1.000 km**	4,61 h
	600 km	4,17 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	740,0 m	32,0 m	1	80 €/m²	23.680 m²	1.894.400 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	4	1.000 €/m	13.912 m²	2.960.000 €
Terminal switch	30,0 m	5,0 m	3	62.500 €/unit	450 m²	187.500 €
Buffer stop	15,0 m	4,7 m	4	12.000 €/unit	282 m²	48.000 €
Crane tracks	740,0 m	4,7 m	2	1.250 €/m	6.956 m²	1.850.000 €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	-	90 €/m²	m²	- €
Total area complete terminal					62.500 m²	
Structural engineering (50 €/m²)						3.125.000 €
Earthworks and civil engineering (100 €/m²)						6.250.000 €
Building costs terminal						17.783.075 €
Planning costs 20%						3.556.615 €
Total building costs complete terminal						21.339.690 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						9.901.616 €

Maximum value based on European construction cost index	31.023.641 €
Depreciation time terminal (years)	25
Terminal building costs per year	1.442.003 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Gantry crane	3.550.000 €	2	7.100.000 €	25
Spreader with gripper arms	150.000 €	2	300.000 €	10
Terminal truck	150.000 €	5	750.000 €	5
Terminal module	22.500 €	40	900.000	20

Equipment costs terminal	**Investment costs**	9.050.000 €
	Planning costs (20%)	1.810.000 €
	Total	10.860.000 €
Total equipment costs terminal per year		900.644 €

Initial investment costs complete terminal and equipment incl. planning costs	32.199.690 €
Total investment costs complete terminal and equipment per year	2.342.647 €

Total terminal handling capacity per year (transhipments)	140.000

Terminal maintenance costs

	Percentage of investment (%)	Total costs per year
Terminal Infrastructure	5	889.154 €
Gantry crane	2,8	198.800 €
Spreader with gripper arms	2,8	8.400 €
Terminal truck	2,8	21.000 €
Total maintenance costs per year		1.083.369 €

Terminal energy consumption

Consumer	Energy type	Consumption per transhipment	Consumption per year	Energy costs per year
Infrastructure	Electricity	-	68.750 kWh	8.594 €
Gantry Crane	Electricity	2,5 kWh	350.000 kWh	43.750 €
Terminal truck	Diesel	1,2 l	168.000 l	188.160 €

Total energy costs per year	240.504 €
Terminal energy costs range in EU	
Minimum value electricity costs	24.544 €
Maximum value electricity costs	75.886 €
Minimum value diesel costs	154.981 €
Maximum value diesel costs	229.933 €
Minimum value total energy costs	179.525 €
Maximum value diesel energy costs	305.819 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1,5	5	26.500 €	132.500 €
Gate agent	1,5	5	33.000 €	165.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	5	16,5	32.000 €	528.000 €
Instructor "Groundsman"	1,5	5	31.000 €	155.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				1.355.000 €
Terminal personnel costs range in EU				
Minimum value personnel costs				293.493 €
Maximum value personnel costs				2.186.588 €

Total area costs (5,00 €/m² per year)	312.500 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 599.100 €

Total costs per year	5.368.005 €

Cost per transhipment for total terminal investment		16,73 €
Operational costs per transhipment	**Personnel costs**	9,68 €
	Energy costs	1,72 €
	Maintenance costs	7,98 €

Total	19,38 €
Ground costs per transhipment	2,23 €
Total costs for one transhipment	38,34 €
Total transhipment costs range in EU	
Minimum value total costs transhipment	19,12 €
Maximum value total costs transhipment	54,58 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
Semi-trailer non craneable	26.000 €	11	780,00 €	0,78 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
T3000e	140.000 €	20	2.800.000 €	40	32,38 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Transport platform	17.500 €	34	595.000 €	10	15,29 €
Total main leg investment costs					8.395.000 €
Total investment costs per operating hour					105,48 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
T3000e	5	139.800 €	29,13 €
Loco	6	300.000 €	62,50 €
Transport platform	0,6	3.400,00 €	0,71 €
Total maintenance costs per operating hour			92,33 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.414 kWh	176,74 €
Total energy costs per operating hour				176,74 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**

Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)		**600 km**	1:2,9
		1.000 km	1:4,2

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport

	Total	
	Total	Per LU
First road leg	2.981 €	87,66 €
First transhipment	1.304 €	38,34 €
450 km main leg	6.780 €	199,43 €
850 km main leg	12.242 €	360,06 €
Second transhipment	1.304 €	38,34 €
Second road leg	2.836 €	83,42 €
LU costs transport chain 600 km main leg	469 €	13,79 €
LU costs transport chain 1.000 km main leg	721 €	21,22 €
Intermodal organizational costs 600 km main leg (25%)	3.918,32 €	115,24 €
Intermodal organizational costs 1.000 km main leg (25%)	5.346,83 €	157,26 €
Grand total 600 km	15.673 €	576,22 €
Grand total 1.000 km	21.387 €	786,30 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	537,79 €
Maximum value costs range 600 km transport in EU	608,69 €
Minimum value costs range 1.000 km transport in EU	747,86 €
Maximum value costs range 1.000 km transport in EU	818,76 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	2.956 €	86,96 €
First transhipment		14 €	0,40 €
Main leg	**450 km**	8.749 €	257,31 €
	850 km	16.525 €	486,04 €
Second transhipment		14 €	0,40 €
Second road leg	**75 km**	2.956 €	86,96 €
Full transport chain per LU	**600 km**	14.662 €	432,02 €
	1.000 km	22.438 €	660,75 €

32 Fact sheet for "ISU – Innovativer Sattelanhänger Umschlag/Innovative sami-trailer transhipment – Rail/Road" (crane terminal)

Picture of the technology:


Source: RCA

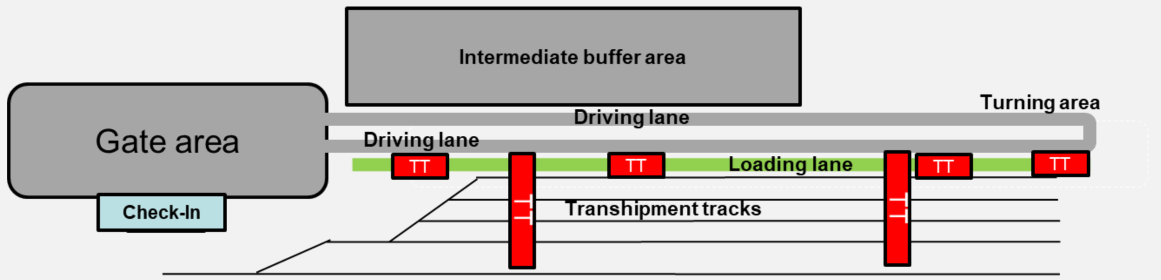
Description of the transhipment technology and transhipment process (road → main leg):		
The system addresses the market of non-craneable semi-trailers. The system was designed starting 2005 in the framework of the EU-FP7-project BRAVO and was implemented during 2011 till 2013 within the EU-FP7 project CREAM and is in operation since then. The idea is, to lift a standard road semi-trailer on the wheels and on the kingpin with special adapter parts, the so called "ISU-king-pin beam" and the "ISU-wheel gripper". These special designed parts were placed on a steel ramp in special recesses. In turn the ramp is placed beside the train. A terminal tractor or standard truck pulls the trailer on the ramp and place it there on its support legs. A steel frame with elastic belts is fixed on the twist locks of the spreader of the standard handling equipment. The frame is placed above the ramp, the belts are connected with the ISU king-pin beam and the ISU wheel grippers and the trailer is lifted into the wagon. In the wagon, the trailer is fixed to the king-pin support of the standard pocket wagon and the belts are disconnected. The ISU king-pin beam and the ISU wheel grippers remain on the wagon during the rail transport. During the unloading process of a wagon the loading device with the ISU-steel frame is placed above the trailer on the wagon, the belts are connected to king pin beam and the wheel grippers, the semi-trailer is lifted and placed on the ISU-ramp. The ISU-king pin beam and the wheel grippers sinking in special recesses in the ramp and a terminal tractor or standard road truck pulls the trailer to the yard and the next trailer for loading can be placed on the ramp. The ISU-king-pin beam and the wheel grippers are part of the wagon to avoid additional logistic processes and to ensure that the equipment is always available. The king pin beam enlarges the loading profile of the trailer by about 15 cm. This can be compensated by the variation of the height of the king pin support on the wagon. The system is designed as a "bridge technology" to help clients to start with intermodal business; the aim is, to lead this companies to invest in craneable equipment if they are satisfied with the intermodal transport service.		
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, mainly used to/from Austria and EU relations.	
Indicative qualitative assessment:		

Strengths	Weaknesses and limitations
• No additional investment in fixed terminal infrastructure, terminal handling equipment, wagons and trailers needed. • Can be implemented in a normal terminal process. • Rail transportation is similar to normal intermodal trains. • Small investment in additional equipment • Simple technology which can be moved from one terminal to the other if market changes	• Handling process takes longer compared to craneable trailer mainly due to longitudinal movement to/from the ISU ramp(s) • Additional staff necessary for handling the system in the terminal • ISU king-pin beam and wheel grippers reduce payload during rail transport • ISU king-pin beam reduces the maximal height of semi-trailers during rail transport

Transhipable loading units:

Type of loading unit	Sizes, exceptions and limitations
• ISO container	• Not possible
• Inland container	• Not possible
• Swap body	• Not possible
• Semi-trailer	• Yes, in particular “non-craneable” Semi-Trailer
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	39 t

Description of our model terminal:



The terminal consists of a normal crane terminal with 2 additional ISU spreaders and 4 ISU ramps.

Necessary road leg equipment:	Truck
Necessary main leg equipment:	Loco, T3000e rail wagons or similar with twice king-pin beam and wheel gripper

Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:

For Semi-trailer non-craneable on T3000e wagons with twice ISU king-pin beam and wheel gripper (assuming 85% load factor)	42 (36)

Detailed description of the transhipment process:		
Process steps loading main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	5,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5,0 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	3,0 min
Preparing transhipment:	Terminal truck driver	2,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	10,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	7,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	14,0 min
Transhipment duration per LU:	**Total LU**	14,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	82,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	92,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min

Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	7,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	14,0 min
Transhipment duration per LU:	**Total LU**	14,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	2,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	5,0 min
Handover of loading unit to truck:	Handling equipment driver	0,0 min
	Truck driver	5,0 min
Handover duration per LU:	**Total LU**	12,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 31 min • Only Transhipment: 7 min
	Unloading	• All process steps: 28 min • Only Transhipment: 7 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min
	Unloading	• 7 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 126 min
	Unloading	• 126 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 219 min
	Unloading	• 166 min
Trains that can be handled in an 8-hour shift:		• 1,67

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:**
		Semi-trailer

First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector Train driver Total:	180 min 108 min 432 min 252 min 180 min 504 min 30 min 30 min 83 min 10 min 1.809 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total	0 min 0 min 252 min 252 min 252 min 30 min 504 min 30 min 0 min 10 min 1.330 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	30,16 h
	600 km	20,16 h
Total working hours transport chain	**1.000 km**	182 h
	600 km	167 h
Total working hours per LU	**1.000 km**	5,06 h
	600 km	4,64 h

Costs and investments associated with the transhipment technology
Terminal infrastructure

Elements	Dimensions (m)		Number of units (#)	Unit costs	Total area	Total costs
	Length	Width				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	740,0 m	32,0 m	1	80 €/m²	23.680 m²	1.894.400 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	4	1.000 €/m	13.912 m²	2.960.000 €
Terminal switch	30,0 m	5,0 m	3	62.500 €/unit	450 m²	187.500 €
Buffer stop	15,0 m	4,7 m	4	12.000 €/unit	282 m²	48.000 €
Crane tracks	740,0 m	4,7 m	2	1.250 €/m	6.956 m²	1.850.000 €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	-	90 €/m²	m²	- €
Total area complete terminal					59.910 m²	
Structural engineering (50 €/m²)						2.995.500 €
Earthworks and civil engineering (100 €/m²)						5.991.000 €
Building costs terminal						17.187.375 €
Planning costs 20%						3.437.475 €
Total building costs complete terminal						20.624.850 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						9.569.930 €
Maximum value based on European construction cost index						29.984.407 €
Depreciation time terminal (years)					25	

Terminal building costs per year				1.393.699 €
Terminal equipment				
Equipment	**Unit costs**	**Number of units (#)**	**Total costs**	**Depreciation time (years)**
Gantry crane	3.550.000 €	2	7.100.000 €	25
Spreader	100.000 €	2	200.000 €	10
Terminal truck	150.000 €	4	600.000 €	5
ISU spreader	10.000 €	2	20.000 €	8
ISU ramp	12.000 €	4	48.000 €	20
Equipment costs terminal	**Investment costs**			7.968.000 €
	Planning costs (20%)			1.593.600 €
	Total			9.561.600 €
Total equipment costs terminal per year				771.651 €

Initial investment costs complete terminal and equipment incl. planning costs	30.186.450 €
Total investment costs complete terminal and equipment per year	2.165.350 €

Total terminal handling capacity per year (transhipments)	60.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	859.369 €
Gantry crane	2,8	198.800 €
Spreader	2,8	5.600 €
Terminal truck	2,8	16.800 €
ISU spreader	2,8	560 €
ISU ramp	2,8	1.344 €
Total maintenance costs per year		1.082.473 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	65.901 kWh	8.238 €
Gantry Crane	Electricity	2,5 kWh	150.000 kWh	18.750 €
Terminal truck	Diesel	1,2 l	72.000 l	80.640 €

Total energy costs per year	107.628 €
Terminal energy costs range in EU	
Minimum value electricity costs	12.654 €
Maximum value electricity costs	39.126 €
Minimum value diesel costs	66.421 €
Maximum value diesel costs	98.543 €
Minimum value total energy costs	79.075 €
Maximum value diesel energy costs	137.669 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	0,5	2	26.500 €	53.000 €
Gate agent	0,5	2	33.000 €	66.000 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	4	13,5	32.000 €	432.000 €
Instructor “Groundsman”	1,5	5	31.000 €	155.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				1.080.500 €
Terminal personnel costs range in EU				
Minimum value personnel costs				234.036 €
Maximum value personnel costs				1.743.623 €

Total area costs (5,00 €/m² per year)	299.550 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 599.100 €

Total costs per year	4.735.500 €

Cost per transhipment for total terminal investment		36,09 €
Operational costs per transhipment	**Personnel costs**	18,01 €
	Energy costs	1,79 €
	Maintenance costs	18,04 €

	Total	37,84 €
Ground costs per transhipment		4,99 €
Total costs for one transhipment		78,92 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		40,01 €
Maximum value total costs transhipment		111,85 €

Loading unit investments and costs:				
Loading unit	**Unit costs**	**Depreciation time (years)**	**Maintenance per year**	**Costs per operating hour**
Semi-trailer non craneable	26.000 €	11	780,00 €	0,78 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
T3000e	140.000 €	21	2.940.000 €	40	34,00 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
King-pin beam and wheel gripper	10.000 €	36	360.000 €	5	16,50 €
Total main leg investment costs					8.300.000 €
Total investment costs per operating hour					108,31 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
T3000e	5	146.790 €	30,58 €
Loco	6	300.000 €	62,50 €
King-pin beam and wheel gripper	0,6	3.600 €	0,75 €
Total maintenance costs per operating hour			93,83 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.454 kWh	181,70 €
Total energy costs per operating hour				181,70 €
Other operational costs main leg				

Cost type	Costs per km	Costs per operating hour
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €
Personnel costs main leg		

Function	Costs per operating hour
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)		**600 km**	1:3,3
		1.000 km	1:4,5

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €
Personnel costs road leg		

Function	Costs per operating hour
Truck driver	22,11 €
Truck dispatcher	24,32 €

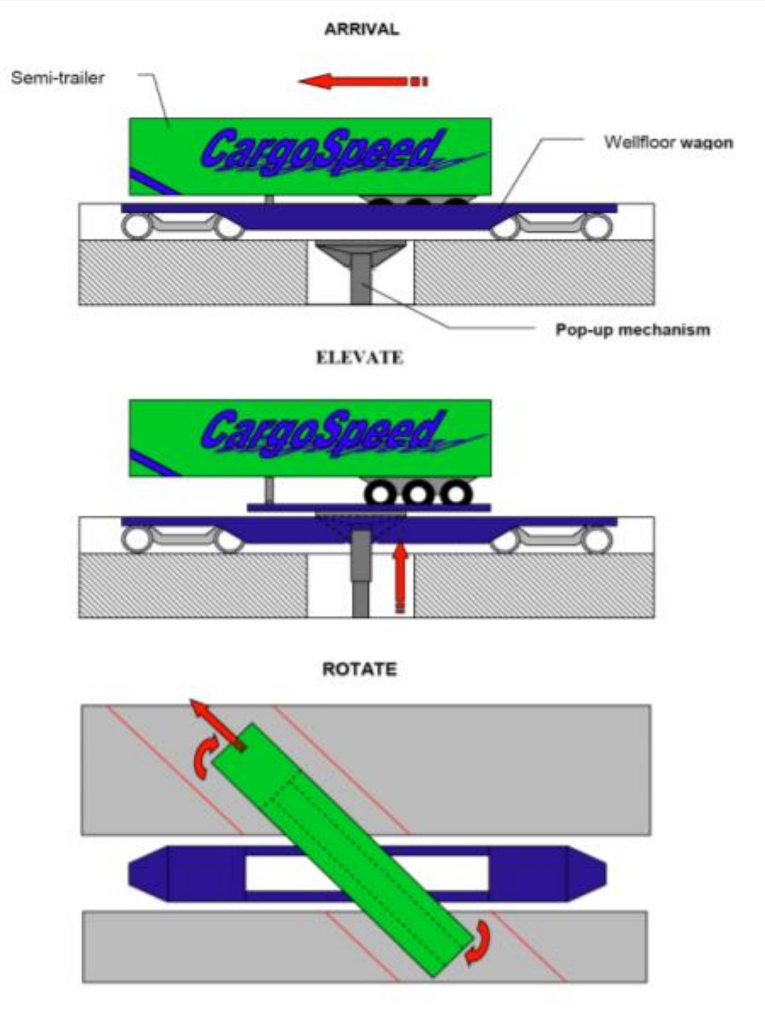
Total costs 600 km/1.000 km transport	Total	
	Total	Per LU
First road leg	3.156 €	87,66 €
First transhipment	2.841 €	78,92 €
450 km main leg	7.071 €	196,42 €
850 km main leg	12.625 €	350,71 €
Second transhipment	2.841 €	78,92 €
Second road leg	3.003 €	83,42 €
LU costs transport chain 600 km main leg	569 €	15,80 €
LU costs transport chain 1.000 km main leg	836 €	23,23 €
Intermodal organizational costs 600 km main leg (25%)	4.870,33 €	135,29 €
Intermodal organizational costs 1.000 km main leg (25%)	6.325,79 €	175,72 €
Grand total 600 km	19.481 €	676,44 €
Grand total 1.000 km	25.303 €	878,58 €

Costs range in EU	
Minimum value costs range 600 km transport in EU	598,60 €
Maximum value costs range 600 km transport in EU	742,28 €
Minimum value costs range 1.000 km transport in EU	800,74 €
Maximum value costs range 1.000 km transport in EU	944,43 €

External costs		Total	Per LU
First road leg	**75 km**	3.819 €	106,08 €
First transhipment		15 €	0,42 €
Main leg	**450 km**	8.994 €	249,84 €
	850 km	16.989 €	471,93 €
Second transhipment		15 €	0,42 €
Second road leg	**75 km**	3.819 €	106,08 €
Full transport chain per LU	**600 km**	16.632 €	462,83 €
	1.000 km	24.627 €	684,92 €

33 FACT SHEET FOR "CARGOSPEED – RAIL/ROAD"

Picture of the technology:



Source: http://www.railway-research.org/IMG/pdf/cargospeed.pdf/ ; April 2021

Description of the transhipment technology and transhipment process (road → main leg):

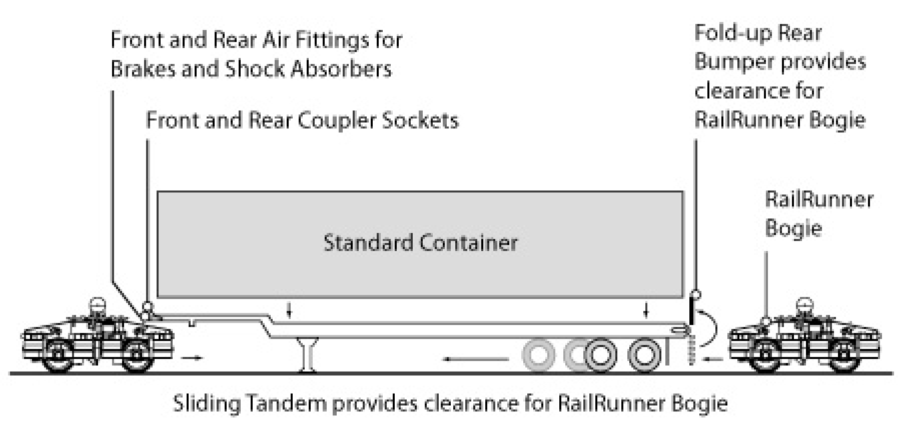
The Corgospeed technology was designed to facilitate the horizontal transhipment of non-cranable semitrailers with a specialized rail wagon. The wagon floor turns out for loading/unloading semi-trailers with the help of a pop up mechanism located between the rails in the terminal which is used to lift and drop the wagon floor for the unloading/loading process. The wagons have to be positioned over these mechanism with a tolerance of +-35cm. Once turned out, the wagons can be loaded/unloaded from both sides and transhipments are possible under the catenary.

Sources:
https://trimis.ec.europa.eu/sites/default/files/project/documents/20060727_143123_02411_CARGOSPEED_Final_Report.pdf ; April 2021

Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 4: The technology was developped as part of the European FP5 Competitive and Sustainable Growth programme from 2001 to 2004 by a consortium under the German BLG Consult GmbH. Prototypes for parts of the system, i.e. the pop up and the wagon floor, have been built at a test site and the marketability has been proven. The technology didn't leave this prototype stage and is has not been developed or marketed further. Our research did not reveal any further indications of current use or further development of the technology. For this reason the technology will be excluded from the further evaluation of technologies in this study. Sources: http://www.railway-research.org/IMG/pdf/cargospeed.pdf ; April 2021	

34 FACT SHEET FOR "RAIL RUNNER – RAIL/ROAD"

Picture of the technology:



Source: https://railrunner.com/terminal-anywhere-solution/ ; April 2021

Description of the transhipment technology and transhipment process (road → main leg):

The Rail Runner technology enables the transhipment of intermodal loading units between rail and road by directly assembling the Rail Runner semitrailer or chassis used in road transport into an intermodal train with the help of Rail Runner bogie units. The chassis can be loaded with standardized containers and has receiver boxes on both ends to be couple with the bogie units. The bogie units have symmetrical elements on both sides to enable the coupling of the bogie with the chassis which is done over the rail.

Classification	☒ Horizontal	☐ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The technology is fully developed and in operational use outside Europe, however it did not receive the Certification and Homologation necessary for European operations. The Railrunner Europe GmbH was established in 2015 to establish the technology in Europe. Between 2017 and 2019 the company operated one conventional intermodal train for 18 months between Braunschweig, DE and Brattislava, SK before filling for bankruptcy in early 2019. The Rail Runner technology was never established on the European market and no current initiatives to do so are known. For this reason the technology will be excluded from the further evaluation of technologies in this study. Sources: https://www.railfreight.com/intermodal/2019/01/21/railrunner-europe-files-for-insolvency ; April 2021	

35 Fact sheet for "RoLa – Rail/Road"

Picture of the technology:

Quelle: ÖBB-Infrastruktur AG; Chris Zenz

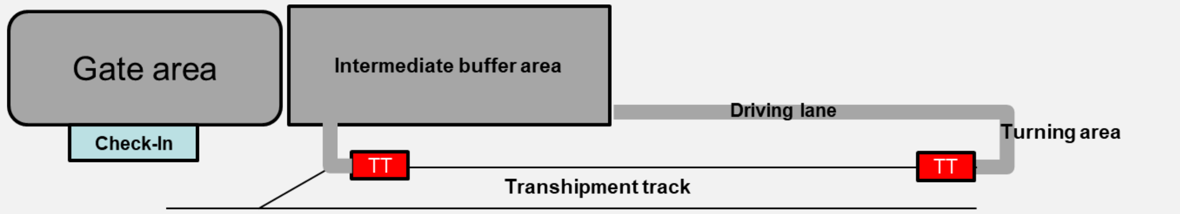
Description of the transhipment technology and transhipment process (road → main leg):		
The Rolling Road (RoLo) is a transport system for accompanied combined transport in which complete lorries or articulated lorries are transported by rail. The short-coupled low-floor wagons used for this purpose have continuous driving lanes over the entire train. During the journey, the drivers are accommodated in additionally attached escort wagons. Special loading ramps are located at the end points of the connections for easy loading and unloading of the trucks.		
Classification	☒ Horizontal	☐ Vertical
	☒ Accompanied	☐ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The technology is fully developed, tested and currently in use. The focus in use is on Alpine transit.	

Indicative qualitative assessment:	
Strengths	**Weaknesses and limitations**
• Freight forwarder saves fuel, toll charges, time lost due to traffic jams	• Much dead load is transported in relation to the cargo load

and operating kilometres for his vehicles. • Drivers can comply with the legally prescribed rest periods for the train • Avoidance of night or weekend driving bans • Permissible total weight of 44 t • short loading time (High annual transhipment volumes possible) • Comparatively low terminal investment	• High costs for maintenance of the wagons due to the small running wheels

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• Not possible
• Inland container	• Not possible
• Swap body	• Not possible
• Semi-trailer	• Not possible
• Complete road vehicle	• Yes
Transhipable max. weight (loaded goods plus loading unit weight):	44 t

Description of our model terminal:



Necessary road leg equipment:	None
Necessary main leg equipment:	Loco, Low floor wagon (Saadkms), club car
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For Full vehicles on Low floor wagon (Saadkms) with one club car (assuming 85% load factor)	35 (30)

Detailed description of the transhipment process:		
Process steps <u>loading</u> main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	5 min
Administrative check-in:	Truck driver	5 min
	Gate agent	3 min

Drive to drop-off/parking:	Truck driver	2 min
Check-in duration per LU:	**Total LU**	7 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	0 min
	Handling equipment driver	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Terminal truck driver	0 min
	Handling equipment driver	0 min
	Groundsman	0 min
Handover duration per LU:	**Total LU**	0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
	Truck driver	20,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	20,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	5,0 min
Further procedures for departure:	Visitor/Wagon inspector	120,0 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	130,0 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	5,0 min
Arrival duration:	**Total**	15,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	0,0 min
	Terminal truck driver	0,0 min
	Truck driver	20,0 min
	Groundsman	0,0 min
Transhipment duration per LU:	**Total LU**	20,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		

Preparing Transhipment:	Terminal truck driver	0 min
	Handling equipment driver	0 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	0 min
	Truck driver	0 min
Handover duration per LU:	**Total LU**	0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 27 min • Only Transhipment: 20 min
	Unloading	• All process steps: 22 min • Only Transhipment: 20 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 157 min
	Unloading	• 37 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 20 min
	Unloading	• 20 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 150 min
	Unloading	• 35 min
Trains that can be handled in an 8-hour shift:		• 2,27

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Full Vehicle**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Groundsman: Terminal dispatcher per train: Groundsman train:	150 min 90 min 810 min 0 min 0 min 0 min 30 min 5 min

	Visitor/Wagon inspector: Train driver: Attendant: Total:	120 min 10 min 10 min 1.215 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Attendant: Train dispatcher:	1275 min 1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Attendant Train dispatcher:	675 min 675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Terminal dispatcher per train: Groundsman: Groundsman train: Visitor/Wagon inspector: Train driver: Attendant: Total:	0 min 0 min 660 min 0 min 0 min 30 min 0 min 5 min 0 min 10 min 10 min 705 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	26,83 h
	600 km	16,83 h
Total working hours transport chain	**1.000 km**	167 h
	600 km	142 h
Total working hours per LU	**1.000 km**	5,57 h
	600 km	4,73 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	50,0 m	60,0 m	1	80 €/m²	3.000 m²	240.000 €
Driving lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Loading lane	740,0 m	3,5 m	-	80 €/m²	m²	- €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €

Intermediate buffer area (non-stackable)	150,0 m	32,0 m	2	80 €/m²	9.600 m²	768.000 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	30,0 m	5,0 m	-	62.500 €/unit	m²	- €
Buffer stop	15,0 m	4,7 m	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0,0 m	0,0 m	-	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	740,0 m	15,0 m	-	90 €/m²	m²	- €
Total area complete terminal					19.599 m²	
Structural engineering (50 €/m²)						979.925 €
Earthworks and civil engineering (100 €/m²)						1.959.850 €
Building costs terminal						5.066.350 €
Planning costs 20%						1.013.270 €
Total building costs complete terminal						6.079.620 €
Terminal building costs range in EU						
Minimum value based on European construction cost index						2.820.944 €
Maximum value based on European construction cost index						8.838.552 €
Depreciation time terminal (years)					25	
Terminal building costs per year						410.823 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
RoLa ramp	10.000 €	2	20.000 €	5
Ramp mover	7.000 €	2	14.000 €	5

Equipment costs terminal	**Investment costs**	34.000 €
	Planning costs (20%)	6.800 €
	Total	40.800 €
Total equipment costs terminal per year		8.975 €

Initial investment costs complete terminal and equipment incl. planning costs	6.120.420 €
Total investment costs complete terminal and equipment per year	419.798 €

Total terminal handling capacity per year (transhipments)	68.108

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	253.318 €
RoLa ramp	20	4.000 €
Ramp mover	29	4.060 €
Total maintenance costs per year		261.378 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	21.558 kWh	2.695 €
Total energy costs per year				2.695 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.264 €
Maximum value electricity costs	3.907 €
Minimum value diesel costs	- €
Maximum value diesel costs	- €
Minimum value total energy costs	1.264 €
Maximum value diesel energy costs	3.907 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	2	7	33.000 €	231.000 €
Handling equipment driver	0	0	35.000 €	- €
Terminal truck driver	0	0	32.000 €	- €
Instructor “Groundsman”	1	3,5	31.000 €	108.500 €

Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				561.750 €
Terminal personnel costs range in EU				
Minimum value personnel costs				121.675 €
Maximum value personnel costs				906.506 €

Total area costs (5,00 €/m² per year)	97.993 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 195.985 €

Total costs per year	410.823 €

Cost per transhipment for total terminal investment		6,16 €
Operational costs per transhipment	**Personnel costs**	8,25 €
	Energy costs	0,04 €
	Maintenance costs	3,84 €
	Total	12,13 €
Ground costs per transhipment		1,44 €
Total costs for one transhipment		19,73 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		8,50 €
Maximum value total costs transhipment		29,04 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
Full vehicle	126.000 €	10	10.780,00 €	5,66 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Low floor wagon (Saadkms)	220.000 €	35	7.700.000 €	40	89,04 €
Club car	1.500.000 €	1	1.500.000 €	40	17,34 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Head end	22.000 €	2	44.000 €	40	0,23 €
Total main leg investment costs					14.244.000 €

Total investment costs per operating hour			154,89 €
Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
Low floor wagon (Saadkms)	27	2.100.000 €	437,50 €
Club car	7	105.000 €	21,88 €
Loco	6	300.000 €	62,50 €
Head end	2,8	616 €	0,13 €
Total maintenance costs per operating hour			522,00 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.445 kWh	180,61 €
Total energy costs per operating hour				180,61 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €
Attendant	30,96 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
n/a			
Total road leg investment costs			n/a
Total investment costs per operating hour			n/a
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant
Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
n/a			
Total maintenance costs per operating hour			

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,97 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

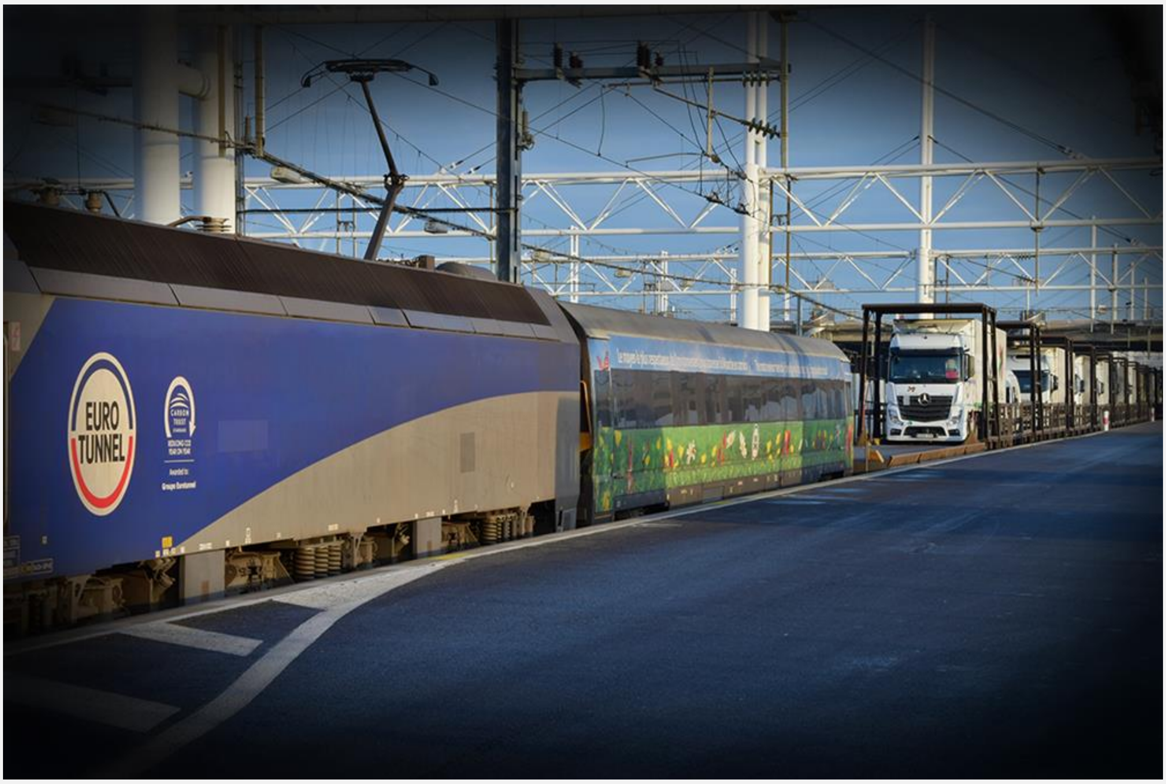
Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	2.671 €	89,04 €
First transhipment	592 €	19,73 €
450 km main leg	15.066 €	502,19 €
850 km main leg	25.666 €	855,54 €
Second transhipment	592 €	19,73 €
Second road leg	2.561 €	85,35 €
LU costs transport chain 600 km main leg	2.769 €	92,30 €
LU costs transport chain 1.000 km main leg	4.246 €	141,52 €
Intermodal organizational costs 600 km main leg (25%)	6.062,57 €	202,09 €
Intermodal organizational costs 1.000 km main leg (25%)	9.081,86 €	302,73 €
Grand total 600 km	24.250 €	1.010,43 €
Grand total 1.000 km	36.327 €	1.513,64 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		987,98 €
Maximum value costs range 600 km transport in EU		1.029,06 €
Minimum value costs range 1.000 km transport in EU		1.491,19 €
Maximum value costs range 1.000 km transport in EU		1.532,27 €

External costs			
		Total	**Per LU**

First road leg	**75 km**	2.609 €	86,96 €
First transhipment		0 €	0,01 €
Main leg	**450 km**	8.940 €	298,01 €
	850 km	16.887 €	562,90 €
Second transhipment		0 €	0,01 €
Second road leg	**75 km**	2.609 €	86,96 €
Full transport chain per LU	**600 km**	14.157 €	471,93 €
	1.000 km	22.104 €	736,83 €

36 FACT SHEET FOR "EUROTUNNEL FREIGHT SHUTTLE – RAIL/ROAD"

Picture of the technology:



Source: https://www.eurotunnelfreight.com/uk/about/library/ ; April 2021

Description of the transhipment technology and transhipment process (road → main leg):

The Eurotunnel freight shuttle is a special type of rolling highway used for the transport of heavy goods vehicles via rail through the channel tunnel.
The shuttle train for heavy goods vehicles consists of different types of rail wagons. For the 3rd generation truck shuttles, the wagon sets consist of 1 club car for the passengers, 32 open vehicle carrying wagons (in 2 sections of 16 wagons each), 2 end loading wagons and 1 center loading wagon between the two sections. Furthermore, due to safety regulations for the channel tunnel rail traffic with passengers, there is one manned loco at each end of the train. All wagons between and

including the two end loading wagons form a continuous surface which vehicles can drive on. The coupling height of the wagons is 820mm over the railhead. The carrying wagons hold one heavy goods vehicle each which are secured using wagon chocks. The carrying wagons have a roofed area in the front over the truck cabin. The loading wagons are used by the vehicles to enter or leave the train to the side. This necessitates a platform at wagon surface height for the loading/unloading of the vehicles in the terminal. A decoupling of wagons or locos it not necessary to load or unload the train. During the transport, the truck drivers are in the club car and not with their vehicles. A terminal bus is used to transport the drivers between their vehicles and the club car.
A fully loaded Eurotunnel train set has a length of up to 800m and a total weight of up to 2.500t. For the freight shuttles 17 wagon sets, thereof 3 of the 3rd generation are in use. On average there is one departure per direction every 8 to 10 minutes meaning 6 to 7 departures per hour, however with the available infrastructure and equipment between 8 to 10 departures are possible in each direction. The trains travel at speeds of up to 140 km/h and are able to cross the channel in 35 minutes.
The Eurotunnel does not require special low-floor cars with smaller wheel diameters. This is because the loading gauge on the channel tunnel line permits trains with a height of 5,6m and a width of 4,1m which is larger than the common European loading gauge with a height of 4,65m and a width of 3,15m. However, as a consequence the Eurotunnel freight shuttle wagons are also too large for both the British and the European standard loading gauges and can only be used on the 50km long Eurotunnel line between the terminals in Coquelles and Folkstone without traveling onto the national rail networks.

Sources:
https://www.getlinkgroup.com/en/our-group/eurotunnel/
https://www.eurotunnelfreight.com/uk/home/
https://www.waggonbau-niesky.com/en/products/car-transport-wagons/hgv-loading-train-%E2%80%93-eurotunnel/

Classification	☒ Horizontal	☐ Vertical
	☒ Accompanied	☐ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: The technology is fully developed and has been proven to work in the Eurotunnel freight operations. The Eurotunnel freight shuttle and the Eurotunnel terminals form a highly specialized transhipment environment specifically designed to achieve a high terminal throughput and fast transhipment time. This is due to the high share of the transhipment time in the total transport time for the only 50km long transport distance. The technology is exclusively used in the Eurotunnel and is not transferable to general intermodal transport on a national rail network due to its loading gauge and to a lesser extent its train length and train weight. Due to the highly specialized nature of the transhipment technology, the non-transferability of the technology to other parts of the Trans-European Transport Network and the resulting exclusive use in the Eurotunnel, the technology will not be included in the further analysis for this study.	

37 FACT SHEET FOR "FLEXIWAGGON – RAIL/ROAD"

Picture of the technology:

Source: https://www.flexiwaggon.se/flexiwaggon-is-moving-forward-and-preparing-to-raise-capital/, June 2021

Description of the transhipment technology and transhipment process (road → main leg):
The Flexiwaggon transhipment technology consists of a specialized rail wagon for the transport of full vehicles, which can be loaded or unloaded, without a dedicated terminal infrastructure, almost everywhere. The wagon can be used for any other type of unaccompanied loading unit which can be placed inside the wagon cradle using standard vertical or horizontal transhipment technologies. However, the main purpose of the wagon is the transport of full vehicles. The only infrastructure requirement for the transhipment is for the rail track to be surrounded by a 7m wide firm base which can hold the weight of the vehicle to be loaded or unloaded. The max. weight for a vehicle to be transhipped with the Flexiwaggon is 52 t with an own wagon weight of 45 t. The max. speed in transport is up to 140 km/h (disc brake 160 km/h). For this study we are looking at the Flexiwaggon standard wagon (SW) for the transport of goods as the other models are designed and equipped to support rescue and peacekeeping operations. The Flexiwaggon SW is a special 26,16 m long pocket wagon with a loading cradle of 17,3 m usable loading length between two bogies, the front and back of which can be swung out to either side and in any simultaneous configuration. Then ramps are extended from the cradle ends to the floor. The whole process is enabled by a system of movable supports and actuators and takes around 7 minutes. The road vehicles drive via the ramps onto the wagon and are automatically secured when the loading cradle is retracted. The Flexiwaggons are equipped with all necessary sensors to directly determine and provide feedback on whether the loading unit and the cradle are in the correct position safely secured on the wagon. This can substitute a manual inspection. Further sensors can detect overheating in the wheel stock as well as fluctuations and reductions in braking power, so depending on the regulatory framework the Flexiwaggon allows for a fully automated technical inspection and brake check. The wagons have their own energy supply for the transhipment process from shaft generators (78 kW) and battery packs on each wagon. During transport loaded vehicles can be connected to the power supply if necessary, for example for reefer loading units or for charging electric vehicles. Due to the independent power supply of each wagon, the Flexiwaggon can be used independently from other power supply, like a catenary.

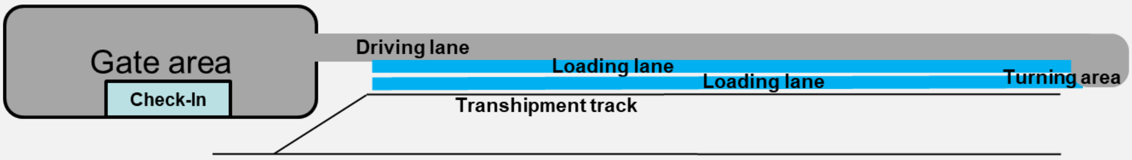
The handling of the Flexiwaggon is simple enough to be done by the vehicle driver. The drivers can unlock the wagon via a console on the wagon and then use a remote control with two buttons to control the transhipment process by extending and retracting the wagon cradle. Alternatively, the train driver can use a special console in the loco to control the wagons. The vehicles can be transhipped under the line. Full Flexiwaggon trains with one club car for the vehicle drivers are possible and will be chosen for the analysis in this study. However, another area of use is for single or small numbers of Flexiwaggons to be incorporated into other trains, even passenger trains. This is viable due to the Flexiwaggon being able to tranship almost everywhere, so like passengers, full vehicles can simply roll on or roll off at stations without any other necessary equipment, shunting or personnel if the regulatory framework permits this type of operation. Either way, the duration of the rail transport can be used by the vehicle drivers to rest and for mandatory break periods from driving. For the club car the same specifications as for the other accompanied rail transport are chosen. These are a length of 26,4 m, a weight of 43 t and sufficient space for up to 32 passengers.		
Classification	☒ Horizontal	☐ Vertical
	☒ Accompanied	☐ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 8: The technology is fully developed and has demonstrated its functionality in an operational environment. It is not yet in regular operational use but is market-ready.	

Indicative qualitative assessment:	
Strengths	**Weaknesses and limitations**
• High flexibility; • No special infrastructure for transhipments necessary; • Truck driver is only necessary transhipment personnel; • Can be used during the truck drivers resting period as a mobile rest; Low loading height; • Electrical supply on the wagon enables the loading of vehicle batteries or powering transported equipment on the wagon everywhere regardless of the available infrastructure.	• Comparatively long and heavy rail wagons for a single loading unit limit the loading unit capacity for a full train (26m wagon length); • Utilization of full potential is highly dependent on regulatory framework.

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• Technically possible but not feasible and not considered in this study
• Inland container	• Technically possible but not feasible and not considered in this study
• Swap body	• Technically possible but not feasible and not considered in this study

• Semi-trailer	• Technically possible but not feasible and not considered in this study
• Complete road vehicle	• Up to a length of 17,3m and a width of 2,9m
Transhipable max. weight (loaded goods plus loading unit weight):	52 t

Description of our model terminal:



For our model we are assuming a terminal, however in practice the Flexiwaggon could be loaded/unloaded outside of dedicated terminals as detailed in the description.

Necessary road leg equipment:	None
Necessary main leg equipment:	Loco, Flexiwaggon, club car
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For *Full vehicles* on *Flexiwaggon* wagons with *one club car* (assuming 85% load factor)	23 (19)

Detailed description of the transhipment process:

Process steps loading main leg	Involved personnel	Time
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	5 min
Administrative check-in:	Truck driver	5 min
	Gate agent	3 min
Drive to drop-off/parking:	Truck driver	2 min
Check-in duration per LU:	**Total LU**	7 min
LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	0 min
	Handling equipment driver	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Preparing transhipment:	Terminal truck driver	0 min
	Handling equipment driver	0 min
	Groundsman	0 min

Handover duration per LU:	**Total LU**	0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	0 min
	Terminal truck driver	0 min
	Truck driver	10 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	10 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	0 min
Further procedures for departure:	Visitor/Wagon inspector	64 min (could go as low as 0 min if technical features of the wagon are permitted and used to replace the manual wagon inspection)
Departure:	Train driver	10 min
Departure duration:	**Total**	74 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10 min
Further arrival procedures:	none	0 min
Terminal check-in:	Groundsman train	0 min
Arrival duration:	**Total**	10 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	0 min
	Terminal truck driver	0 min
	Truck driver	10 min
	Groundsman	0 min
Transhipment duration per LU:	**Total LU**	10 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		
Preparing Transhipment:	Terminal truck driver	0 min
	Handling equipment driver	0 min
	Groundsman	0 min
Movement of loading unit:	Handling equipment driver	0 min
	Terminal truck driver	0 min
Handover of loading unit to truck:	Handling equipment driver	0 min
	Truck driver	0 min

Handover duration per LU:	**Total LU**	0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking: **Check-out duration per LU:**	Truck driver **Total LU**	2 min 2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 17 min • Only Transhipment: 10 min
	Unloading	• All process steps: 12 min • Only Transhipment: 10 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 91 min
	Unloading	• 22 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• Full vehicle: 10 min
	Unloading	• Full vehicle: 10 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• Full vehicle: 84 min
	Unloading	• Full vehicle: 20 min
Trains that can be handled in an 8-hour shift:		• Full vehicle: 4,02

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Full Vehicle**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Groundsman: Terminal dispatcher per train: Groundsman train: Visitor/Wagon inspector: Train driver: Attendant: Total:	100 min 60 min 340 min 0 min 0 min 0 min 30 min 0 min 64 min 10 min 10 min 604 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Attendant: Train dispatcher:	1275 min 1275 min 638 min

Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Attendant Train dispatcher:	675 min 675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker: Gate agent: Truck driver: Handling equipment driver: Terminal truck driver: Terminal dispatcher per train: Groundsman: Groundsman train: Visitor/Wagon inspector: Train driver: Attendant: Total:	0 min 0 min 240 min 0 min 0 min 30 min 0 min 0 min 0 min 10 min 10 min 280 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	25,49 h
	600 km	15,49 h
Total working hours transport chain	**1.000 km**	120 h
	600 km	95 h
Total working hours per LU	**1.000 km**	6,14 h
	600 km	4,89 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	30	80	1	80 €/m²	2.400 m²	192.000 €
Driving lane	740	8	1	80 €/m²	5.920 m²	473.600 €
Loading lane	740	4	2	80 €/m²	5.920 m²	473.600 €
Turning area	25	25	1	80 €/m²	625 m²	46.875 €
Intermediate buffer area (stackable)	0	0	0	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	0	0	0	80 €/m²	m²	- €
Switch from main line	0	0	1	62.500 €/unit	m²	62.500 €
Line connection	50	4,7	1	1.000 €/m	235 m²	50.000 €

Transhipment track	740	4,7	1	1.000 €/m	3.478 m²	740.000 €
Terminal switch	0	0	0	62.500 €/unit	m²	- €
Buffer stop	15	4,7	1	12.000 €/unit	71 m²	12.000 €
Crane tracks	0	0	0	1.250 €/m	m²	- €
Driving range reach stacker/mobile harbour crane/HMHC	0	0	0	90 €/m²	m²	- €

Total area complete terminal	18.649 m²
Structural engineering (50 €/m²)	932.425 €
Earthworks and civil engineering (100 €/m²)	1.864.850 €
Building costs terminal	4.847.850 €
Planning costs 20%	969.570 €
Total building costs complete terminal	5.817.420 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	2.699.283 €
Maximum value based on European construction cost index	8.457.365 €
Depreciation time terminal (years)	25
Terminal building costs per year	393.105 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
n/a				

Equipment costs terminal	**Investment costs**	
	Planning costs (20%)	
	Total	
Total equipment costs terminal per year		

Initial investment costs complete terminal and equipment incl. planning costs	5.817.420 €
Total investment costs complete terminal and equipment per year	393.105 €

Total terminal handling capacity per year (transhipments)	80.460

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	242.393 €
Total maintenance costs per year		242.393 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	20.513 kWh	2.564 €
Total energy costs per year				2.564 €

Terminal energy costs range in EU	
Minimum value electricity costs	1.202 €
Maximum value electricity costs	3.717 €
Minimum value diesel costs	-
Maximum value diesel costs	-
Minimum value total energy costs	1.202 €
Maximum value diesel energy costs	3.717 €

Terminal personnel				
Function	**Number of FTE working per shift (#)**	**Number of FTE employed per year (#)**	**Personnel costs per year for one employee**	**Total personnel costs per year**
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	0	0	35.000 €	- €
Terminal truck driver	0	0	32.000 €	- €
Instructor "Groundsman"	0	0	31.000 €	- €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				337.750 €

Terminal personnel costs range in EU	
Minimum value personnel costs	52.254,75 €
Maximum value personnel costs	389.309,57 €

Total area costs (5,00 €/m² per year)	93.243 €

Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 186.485 €

Total costs per year	1.069.054 €

Cost per transhipment for total terminal investment		4,83 €
Operational costs per transhipment	**Personnel costs**	4,15 €
	Energy costs	0,03 €
	Maintenance costs	2,98 €
	Total	7,16 €
Ground costs per transhipment		1,15 €
Total costs for one transhipment		13,13 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		6,13 €
Maximum value total costs transhipment		19,03 €

Loading unit investments and costs:

Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
Full vehicle	126.000 €	10	10.780,00 €	5,66 €

Main leg investments

Equipment	Unit costs	Number of units (#)	Total Costs	Depreciation time (years)	Total costs per operating hour
Flexiwaggon	320.000 €	23	7.360.000 €	40	85,10 €
Club car	1.500.000 €	1	1.500.000 €	40	17,34 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Total main leg investment costs					13.860.000 €
Total investment costs per operating hour					160,26 €

Main leg equipment maintenance costs

Equipment	Percentage of investment (%)	Costs per year	Costs per operating hour
Flexiwaggon	3	230.000 €	47,92 €
Club car	7	105.000 €	21,88 €
Loco	6	300.000 €	62,50 €
Total maintenance costs per operating hour			132,29 €

Main leg energy consumption

Consumer	Energy type	Consumption in kWh per ton-km	Consumption per hour	Costs per operating hour(€)
Loco	Electricity	0,02	1.480 kWh	185,00 €
Total energy costs per operating hour				185,00 €
Other operational costs main leg				

Cost type	Costs per km	Costs per operating hour
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €
Personnel costs main leg		

Function	Costs per operating hour
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €
Attendant	30,96 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**
n/a			
Total road leg investment costs			n/a
Total investment costs per operating hour			n/a
Reasonable fleet size (truck/semi-trailer ratio)			Not relevant
Road leg equipment maintenance costs			

Equipment	Percentage of investment (%)	Total per year	Costs per operating hour
n/a			
Total maintenance costs per operating hour			
Road leg energy consumption			

Consumer	Energy type	Consumption per 100 km	Consumption per hour	Costs per operating hour
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €
Other operational costs road leg				

Cost type	Costs per km	Costs per leg
Tolls	0,187 €	11,97 €
Personnel costs road leg		

Function	Costs per operating hour

Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	Per LU
First road leg	1.633 €	81,66 €
First transhipment	263 €	13,13 €
450 km main leg	8.860 €	442,99 €
850 km main leg	15.661 €	783,04 €
Second transhipment	263 €	13,13 €
Second road leg	1.559 €	77,97 €
LU costs transport chain 600 km main leg	1.697 €	84,83 €
LU costs transport chain 1.000 km main leg	2.681 €	134,05 €
Intermodal organizational costs 600 km main leg (25%)	3.568,59 €	178,43 €
Intermodal organizational costs 1.000 km main leg (25%)	5.514,95 €	275,75 €
Grand total 600 km	14.274 €	892,15 €
Grand total 1.000 km	22.060 €	1.378,74 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		878,14 €
Maximum value costs range 600 km transport in EU		903,94 €
Minimum value costs range 1.000 km transport in EU		1.364,73 €
Maximum value costs range 1.000 km transport in EU		1.390,53 €

External costs			
		Total	Per LU
First road leg	**75 km**	1.739 €	86,96 €
First transhipment		0 €	0,01 €
Main leg	**450 km**	9.158 €	457,88 €
	850 km	17.298 €	864,88 €
Second transhipment		0 €	0,01 €
Second road leg	**75 km**	1.739 €	86,96 €
Full transport chain per LU	**600 km**	12.636 €	631,80 €
	1.000 km	20.776 €	1.038,80 €

38 FACT SHEET FOR "ROADRAILLINK 2.0 – TRAILER USE – RAIL/ROAD" (CRANE TERMINAL)

Picture of the technology:

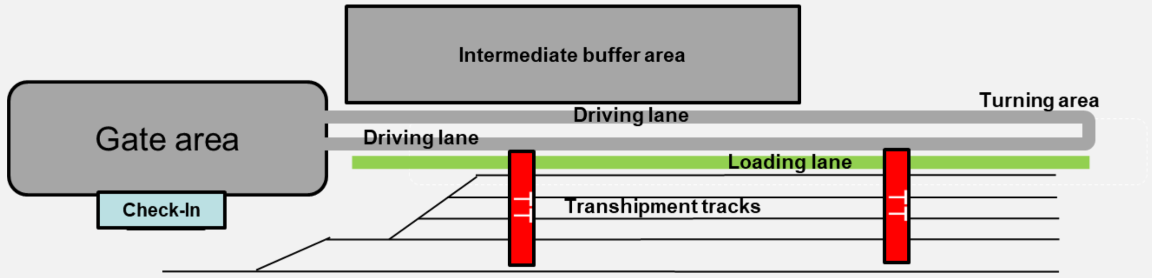
Source: roadraillink.eu, August 2020

Description of the transhipment technology and transhipment process (road → main leg):		
The load carrier can be loaded into the standard pocket wagon in any rail terminal by reach stacker or terminal crane. The enhanced intermodal transport solution r2L 2.1 Trailer Use was designed especially for the handling of non-craneable semi-trailers of every type. It is already implemented in plenty train concepts of different operators all across Europe, which enables to load any rubber wheeled vehicle on to standard pocket rail wagons.		
Classification	☐ Horizontal	☒ Vertical
	☐ Accompanied	☒ Unaccompanied
Connected modes of transport	☒ Rail ☐ Inland waterway	☐ Short Sea ☒ Road
Technical readiness level and prevalence of the technology:	TRL 9: Widespread technology, dense European network. Currently in use and easily integrated into the existing intermodal network.	

Indicative qualitative assessment:	
Strengths	**Weaknesses and limitations**
• Enables also to carry non-craneable trailers	• Additional weight of 4.300 kg per adapter

• Can be carried on train while pocket wagon is loaded with other loading units (containers, WAB)	

Transhipable loading units:	
Type of loading unit	**Sizes, exceptions and limitations**
• ISO container	• Not possible
• Inland container	• Not possible
• Swap body	• Not possible
• Semi-trailer	• Yes
• Complete road vehicle	• Not possible
Transhipable max. weight (loaded goods plus loading unit weight):	36 t

Description of our model terminal:	
	
Necessary road leg equipment:	Truck
Necessary main leg equipment:	Loco, T3000e rail wagons or similar with two transport platforms
Max. no. of LU on full trains (740 m, 2.000 t) / barges (110 m) / ships (1.000 TEU / 2.500 lm) assuming 20t loaded weight per LU:	
For Semi-trailer non-craneable on T3000e wagons with two transport platforms (assuming 85% load factor)	38 (32)

Detailed description of the transhipment process:		
Process steps <u>loading</u> main leg	**Involved personnel**	**Time**
Check-in: The technical and administrative check-in are conducted in parallel before the truck enters the terminal.		
Technical check-in:	Checker	5,0 min
Administrative check-in:	Truck driver	5,0 min
	Gate agent	3,0 min
Drive to drop-off/parking:	Truck driver	2,0 min
Check-in duration per LU:	**Total LU**	7,0 min

LU handover: The LU is handed over to the terminal and placed in the intermediate buffer area. From there it is picked up and if necessary prepared for transhipment.		
Handover of loading unit:	Truck driver	5,0 min
	Handling equipment driver	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	3,0 min
Preparing transhipment:	Terminal truck driver	2,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Handover duration per LU:	**Total LU**	10,0 min
LU transhipment: The loading unit is transhipped onto the main leg.		
Transhipment of LU:	Handling equipment driver	3,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	3,0 min
Transhipment duration per LU:	**Total LU**	3,0 min
Departure: The departure on the main leg is prepared and executed.		
Terminal check-out:	Groundsman train	30,0 min
Further procedures for departure:	Visitor/Wagon inspector	74,8 min
Departure:	Train driver	10,0 min
Departure duration:	**Total**	84,8 min
Process steps unloading main leg	**Involved personnel**	**Time**
Terminal arrival: The arrival from the main leg and the terminal check-in take place.		
Arrival:	Train driver	10,0 min
Further arrival procedures:	none	0,0 min
Terminal check-in:	Groundsman train	30,0 min
Arrival duration:	**Total**	40,0 min
LU transhipment: The loading unit is transhipped from the main leg to the terminal.		
Transhipment:	Handling equipment driver	3,0 min
	Terminal truck driver	0,0 min
	Truck driver	0,0 min
	Groundsman	3,0 min
Transhipment duration per LU:	**Total LU**	3,0 min
LU handover: The loading unit is placed in the intermediate buffer area and is handed over to the truck later.		

Preparing Transhipment:	Terminal truck driver	2,0 min
	Handling equipment driver	0,0 min
	Groundsman	0,0 min
Movement of loading unit:	Handling equipment driver	0,0 min
	Terminal truck driver	5,0 min
Handover of loading unit to truck:	Handling equipment driver	0,0 min
	Truck driver	5,0 min
Handover duration per LU:	**Total LU**	12,0 min
Check-out: The truck drives to the exit and checks out of the terminal		
Drive from drop-off/parking:	Truck driver	2 min
Check-out duration per LU:	**Total LU**	2 min

Total time for the transhipment of one LU:	**Loading**	• All process steps: 20 min • Only Transhipment: 3 min
	Unloading	• All process steps: 17 min • Only Transhipment: 3 min
Time spent in Terminal for the road haulage operator:	**Loading**	• 12 min
	Unloading	• 7 min
Total time for loading /unloading one train (excl. headway):	**Loading**	• 48 min
	Unloading	• 48 min
Total time for loading /unloading one train (incl. headway):	**Loading**	• 133 min
	Unloading	• 88 min
Trains that can be handled in an 8-hour shift:		• 4,38

Description of a full 1.000 km (600 km) transport chain:		
Transport element and duration:	**Involved personnel:**	**Working time:** **Semi-trailer**
First road leg: The LU is transported on the first road leg over a distance of 75 km. **Duration: 75 min**	Truck driver Dispatcher	75 min 6 min
First transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Groundsman Terminal dispatcher per train Groundsman train Visitor/Wagon inspector	160 min 96 min 384 min 96 min 160 min 96 min 30 min 30 min 75 min

	Train driver Total:	10 min 1.137 min
Main leg 1.000 km: The LU is transported on the main leg over a distance of 850 km. **Duration: 1.275 min**	Train driver: Train dispatcher:	1275 min 638 min
Main leg 600 km: The LU is transported on the main leg over a distance of 450 km. **Duration: 675 min**	Train driver: Train dispatcher:	675 min 338 min
Second transhipment full train: The LU is transhipped using the transhipment technology as described in detail above.	Checker Gate agent Truck driver Handling equipment driver Terminal truck driver Terminal dispatcher per train Groundsman Groundsman train Visitor/Wagon inspector Train driver Total	0 min 0 min 224 min 96 min 224 min 30 min 96 min 30 min 0 min 10 min 710 min
Second road leg: The LU is transported on the second road leg over a distance of 75 km. **Duration: 75 min**	Truck driver: Dispatcher:	75 min 6 min
Total duration transport chain	**1.000 km**	27,43 h
	600 km	17,43 h
Total working hours transport chain	**1.000 km**	150 h
	600 km	135 h
Total working hours per LU	**1.000 km**	4,68 h
	600 km	4,21 h

Costs and investments associated with the transhipment technology						
Terminal infrastructure						
Elements	**Dimensions (m)**		**Number of units (#)**	**Unit costs**	**Total area**	**Total costs**
	Length	**Width**				
Gate area	100,0 m	60,0 m	1	80 €/m²	6.000 m²	480.000 €
Driving lane	740,0 m	3,5 m	2	80 €/m²	5.180 m²	414.400 €
Loading lane	740,0 m	3,5 m	1	80 €/m²	2.590 m²	207.200 €
Turning area	25,0 m	25,0 m	1	80 €/m²	625 m²	46.875 €

Intermediate buffer area (stackable)	0,0 m	0,0 m	-	90 €/m²	m²	- €
Intermediate buffer area (non-stackable)	740,0 m	32,0 m	1	80 €/m²	23.680 m²	1.894.400 €
Switch from main line	0,0 m	0,0 m	1	62.500 €/unit	m²	62.500 €
Line connection	50,0 m	4,7 m	1	1.000 €/m	235 m²	50.000 €
Transhipment track	740,0 m	4,7 m	4	1.000 €/m	13.912 m²	2.960.000 €
Terminal switch	30,0 m	5,0 m	3	62.500 €/unit	450 m²	187.500 €
Buffer stop	15,0 m	4,7 m	4	12.000 €/unit	282 m²	48.000 €
Crane tracks	740,0 m	4,7 m	2	1.250 €/m	6.956 m²	1.850.000 €
Driving range reach stacker/mobile harbour crane/HMHC	0,0 m	0,0 m	-	90 €/m²	m²	- €

Total area complete terminal	59.910 m²
Structural engineering (50 €/m²)	2.995.500 €
Earthworks and civil engineering (100 €/m²)	5.991.000 €
Building costs terminal	17.187.375 €
Planning costs 20%	3.437.475 €
Total building costs complete terminal	20.624.850 €
Terminal building costs range in EU	
Minimum value based on European construction cost index	9.569.930 €
Maximum value based on European construction cost index	29.984.407 €
Depreciation time terminal (years)	25
Terminal building costs per year	1.393.699 €

Terminal equipment

Equipment	Unit costs	Number of units (#)	Total costs	Depreciation time (years)
Gantry crane	3.550.000 €	2	7.100.000 €	25
Spreader with gripper arms	150.000 €	2	300.000 €	10
Terminal truck	150.000 €	4	600.000 €	5

Equipment costs terminal	**Investment costs**	8.000.000 €
	Planning costs (20%)	1.600.000 €
	Total	9.600.000 €
Total equipment costs terminal per year		778.513 €

Initial investment costs complete terminal and equipment incl. planning costs	30.224.850 €
Total investment costs complete terminal and equipment per year	2.172.212 €

Total terminal handling capacity per year (transhipments)	140.000

Terminal maintenance costs		
	Percentage of investment (%)	**Total costs per year**
Terminal Infrastructure	5	859.369 €
Gantry crane	2,8	198.800 €
Spreader with gripper arms	2,8	8.400 €
Terminal truck	2,8	21.000 €
Total maintenance costs per year		1.087.569 €

Terminal energy consumption				
Consumer	**Energy type**	**Consumption per transhipment**	**Consumption per year**	**Energy costs per year**
Infrastructure	Electricity	-	65.901 kWh	8.238 €
Gantry Crane	Electricity	2,5 kWh	350.000 kWh	43.750 €
Terminal truck	Diesel	1,2 l	168.000 l	188.160 €
Total energy costs per year				240.148 €

Terminal energy costs range in EU	
Minimum value electricity costs	24.377 €
Maximum value electricity costs	75.370 €
Minimum value diesel costs	154.981 €
Maximum value diesel costs	229.933 €
Minimum value total energy costs	179.358 €
Maximum value diesel energy costs	305.303 €

Terminal personnel

Function	Number of FTE working per shift (#)	Number of FTE employed per year (#)	Personnel costs per year for one employee	Total personnel costs per year
Checker	1	3,5	26.500 €	92.750 €
Gate agent	1	3,5	33.000 €	115.500 €
Handling equipment driver	2	7	35.000 €	245.000 €
Terminal truck driver	4	13,5	32.000 €	432.000 €
Instructor "Groundsman"	1,5	5	31.000 €	155.000 €
Dispatcher	1	3,5	37.000 €	129.500 €
Total terminal personnel costs per year				1.355.000 €
Terminal personnel costs range in EU				
Minimum value personnel costs				253.368 €
Maximum value personnel costs				1.887.647 €

Total area costs (5,00 €/m² per year)	312.500 €
Alternative area costs (0 - 10,00 €/m² per year)	0,00 € - 599.100 €

Total costs per year	5.008.824 €

Cost per transhipment for total terminal investment		15,80 €
Operational costs per transhipment	Personnel costs	8,36 €
	Energy costs	1,72 €
	Maintenance costs	7,77 €
	Total	17,84 €
Ground costs per transhipment		2,14 €
Total costs for one transhipment		35,78 €
Total transhipment costs range in EU		
Minimum value total costs transhipment		18,19 €
Maximum value total costs transhipment		50,68 €

Loading unit investments and costs:				
Loading unit	Unit costs	Depreciation time (years)	Maintenance per year	Costs per operating hour
Semi-trailer non craneable	26.000 €	11	780,00 €	0,78 €

Main leg investments					
Equipment	**Unit costs**	**Number of units (#)**	**Total Costs**	**Depreciation time (years)**	**Total costs per operating hour**
T3000e	140.000 €	19	2.660.000 €	40	30,76 €
Loco	5.000.000 €	1	5.000.000 €	40	57,82 €
Mobile and flexible loading device	20.000 €	32	640.000 €	10	29,33 €
Total main leg investment costs					8.300.000 €
Total investment costs per operating hour					117,90 €

Main leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Costs per year**	**Costs per operating hour**
T3000e	5	139.800 €	27,67 €
Loco	6	300.000 €	62,50 €
Mobile and flexible loading device	3	17.920 €	3,73 €
Total maintenance costs per operating hour			93,90 €

Main leg energy consumption				
Consumer	**Energy type**	**Consumption in kWh per ton-km**	**Consumption per hour**	**Costs per operating hour(€)**
Loco	Electricity	0,02	1.402 kWh	175,25 €
Total energy costs per operating hour				175,25 €

Other operational costs main leg		
Cost type	**Costs per km**	**Costs per operating hour**
Track access	3,00 €	120 €
Total other operational costs per operating hour		120 €

Personnel costs main leg	
Function	**Costs per operating hour**
Train driver	35,38 €
Train dispatcher	32,43 €
Wagon inspector	35,38 €

Road leg investments			
Equipment	**Unit costs**	**Depreciation time (years)**	**Costs per operating hour**

Truck	100.000 €	9	3,83 €
Total road leg investment costs			100.000 €
Total investment costs per operating hour			3,83 €
Reasonable fleet size (truck/semi-trailer ratio)		**600 km**	1:2,9
		1.000 km	1:4,2

Road leg equipment maintenance costs			
Equipment	**Percentage of investment (%)**	**Total per year**	**Costs per operating hour**
Truck	10%	10.000,00 €	2,86 €
Total maintenance costs per operating hour			2,86 €

Road leg energy consumption				
Consumer	**Energy type**	**Consumption per 100 km**	**Consumption per hour**	**Costs per operating hour**
Truck	Diesel	33 l	19,8 l	22,18 €
Total energy costs per operating hour				22,18 €

Other operational costs road leg		
Cost type	**Costs per km**	**Costs per leg**
Tolls	0,187 €	11,22 €

Personnel costs road leg	
Function	**Costs per operating hour**
Truck driver	22,11 €
Truck dispatcher	24,32 €

Total costs 600 km/1.000 km transport		
	Total	
	Total	**Per LU**
First road leg	2.805 €	87,66 €
First transhipment	1.145 €	35,78 €
450 km main leg	7.027 €	219,60 €
850 km main leg	12.614 €	394,18 €
Second transhipment	1.145 €	35,78 €
Second road leg	2.669 €	83,42 €
LU costs transport chain 600 km main leg	437 €	13,66 €
LU costs transport chain 1.000 km main leg	675 €	21,09 €
Intermodal organizational costs 600 km main leg (25%)	3.807,13 €	118,97 €

Intermodal organizational costs 1.000 km main leg (25%)	5.263,18 €	164,47 €
Grand total 600 km	15.229 €	594,86 €
Grand total 1.000 km	21.053 €	822,37 €
Costs range in EU		
Minimum value costs range 600 km transport in EU		559,69 €
Maximum value costs range 600 km transport in EU		624,67 €
Minimum value costs range 1.000 km transport in EU		787,20 €
Maximum value costs range 1.000 km transport in EU		852,18 €

External costs			
		Total	**Per LU**
First road leg	**75 km**	2.783 €	86,96 €
First transhipment		13 €	0,40 €
Main leg	**450 km**	8.675 €	271,09 €
	850 km	16.386 €	512,06 €
Second transhipment		13 €	0,40 €
Second road leg	**75 km**	2.783 €	86,96 €
Full transport chain per LU	**600 km**	14.240 €	445,80 €
	1.000 km	21.951 €	686,77 €

7.2 Annex 2: analysis of the corridor studies update 2 (spring 2021) with regard to identified ten-t core network capacity problems

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Introduction

This annex includes the study finding from the following sources of information:

- Corridor Study update 2 from all nine core network corridors, European Commission, 2021.
- Transport and infrastructure connectivity bottleneck analysis for the stretch Oslo - Hamburg, STRING network, 2021.
- Corridor alignment descriptions from the respective corridor descriptions on https://ec.europa.eu/transport/themes/infrastructure.

Baltic-Adriatic Corridor

The Baltic-Adriatic Corridor crosses six Member States (Poland, Czech Republic, Slovak Republic, Austria, Italy and Slovenia) and connects the Baltic ports of Gdynia/Gdańsk and Szczecin/Świnoujście in Poland with the ports in the Adriatic basin, Trieste, Venezia, Ravenna, Ancona, Koper.

For ports the corridor study reveals the following capacity issues in connection with the rail and road modes of transport:

- Gdynia, Gdańsk and at the Adriatic ports: Initiatives to expand capacity in view of future traffic increase are foreseen or already ongoing for railway transport;
- Baltic ports, Venezia, Ravenna, Ancona and Koper: Initiatives to expand capacity in view of future traffic increase are foreseen or already ongoing for road transport.
- Venezia and Ravenna (IT): Due to their location within or in the proximity of urban nodes, measures to reduce/mitigate the impact of rail traffic either at present or in the future are also required.
- In the latter ports as well as in Gdynia, Szczecin, Świnoujście, Ancona and Koper: solutions to mitigate the impact of road transport on the respective urban areas are also needed.
- For all Baltic-Adriatic Corridor seaports last mile railway and/or road port interconnections issues are present and limit the growth of the ports.
- Ports on the Baltic Sea, except in Gdańsk as well as in Ancona in the Adriatic: Works to increase the standards of the road links are envisaged.

An overview of the issues affecting rail last mile connections, including capacity issues, is shown in the following pictures:

Figure 43: Issues affecting rail last mile connections, including capacity issues

Ports	Need to improve standards on dedicated link(s) (electrification, axle load, speed, train length as appropriate)	Need to upgrade or further develop the existing dedicated link(s) to increase capacity	Need to adequate infrastructure within the port area	Reduce/ mitigate the impact of rail traffic on urban areas crossed by rail links to ports
Gdynia (PL)	X	X	X	
Gdańsk (PL)	X	X		
Szczecin (PL) Świnoujście (PL)	X			
Bratislava (SK)			X	
Wien (AT)				
Trieste (IT)	X	X	X	
Venezia (IT)		X	X	X
Ravenna (IT)	X	X	X	X
Ancona (IT)	X	X		
Koper (SI)	X	X	X	

Source: BA Corridor study consortium

Figure 44: Issues affecting road last mile connections

Ports	Need to improve standards on dedicated link(s)	Need to upgrade or further develop the existing dedicated link(s) to increase capacity	Need to adequate infrastructure within the port area (including parking)	Reduce/ mitigate the impact of road traffic on urban areas crossed by road links to ports
Gdynia (PL)	X	X	X	X
Gdańsk (PL)		X	X	
Szczecin (PL) Świnoujście (PL)	X	X	X	X
Bratislava (SK)			X	
Wien (AT)				
Trieste (IT)				
Venezia (IT)		X	X	X
Ravenna (IT)		X		X
Ancona (IT)	X	X	X	X
Koper (SI)		X	X	X

Source: BA Corridor study consortium

With regard to rail infrastructure, the following necessary, planned or on-going measures to increase the rail infrastructure capacity were identified; thus it can be expected that today such capacity constraints exist:

- Koper – Ljubljana (SI): Increase capacity, fulfil the following minimum technical parameters: axle load of 22.5 tonnes, train length of 740 metres, ERTMS and electrification. The basis for project speed is up to 160 km/h for passenger transport and up to 100 km/h for freight transport;

- Section Maribor – Šentilj (SI): Construction of the second track; compliance with TEN-T standards to be achieved; sufficient axle load and capacity to be ensured, train length of 740 m, deployment of ERTMS;
- Přerov – Ostrava (CZ): Start the construction of high-speed railway lines, solving also current capacity problems;
- Brno – Ostrava-Katowice (CZ): The Přerov – Ostrava section will be a new construction, as the existing line is already overloaded in terms of capacity. The section Brno-Přerov will be built as a line for long-distance passenger, freight and suburban transport;
- Main railway junctions (especially Praha, Brno, then also Ostrava, Ústí nad Labem and others): The capacity of railway junctions may occur significant limiting factor in the development of the High-speed railway system, and solutions are often very expensive.

As concerns rail/road terminals, the following issue could be identified:

- Capacity constraints at the Poznań (PL) railway bypass and Bratislava (SK) railway node and local urban road accessibility and traffic in Poznań, Warszawa and Wrocław (PL).

North Sea-Baltic Corridor

The North Sea-Baltic Corridor consists of 5.947 km of railways, 4.029 km of roads, and 2.186 km of inland waterways and connects the ports of the eastern shore of the Baltic Sea with ports of the North Sea, situated in Northern Germany, Belgium and the Netherlands.

For the rail infrastructure, the following capacity problem was identified on this corridor:

- In Germany and Belgium there is a number of capacity bottlenecks that are not expected to be solved by 2030. These are located at Antwerp, Bremen, the area around Braunschweig and to the west of Berlin.

The corridor study identified the following capacity issue for the road network:

- Latvia: the Via Baltica is a two-lane road with capacity problems between the Riga bypass and Bauska, where some sections require widening the road from two lanes to four (including the construction of bypasses). The capacity of this Polish-Lithuanian section is also to be considered to be a bottleneck for the main city bypasses. A noticeable problem on this road section is the safety question due to heavy road use and road safety.

Mediterranean Corridor

The Mediterranean Corridor is the main east-west axis in the TEN-T Network south of the Alps. It runs between the south-western Mediterranean region of Spain and the Ukrainian border with Hungary, following the coastlines of Spain and France and crossing the Alps towards the east through Italy, Slovenia and Croatia and continuing through Hungary up to its eastern border with Ukraine.

The following capacity problems were identified from the corridor study for the rail mode of transport on this corridor:

- Koper – Ljubljana (SI): increase capacity, fulfil the following minimum technical parameters: axle load of 22.5 tonnes, train length of 740 metres, ERTMS and electrification (same as for Baltic-Adriatic Corridor);
- Zidani Most – Dobova (SI): to comply with TEN-T standards upgrades have top be undertaken on the corridor with regard to sufficient axle load, speed, electrification, and capacity. An upgrade is required relating to the length of trains (740 m) and deployment of ERTMS. The line should allow speeds up to 160 km/h for passenger transport and up to 100 km/h for freight transport, upgrading of the line to achieve higher speeds (same as for Baltic-Adriatic Corridor).

Orient – East Med Corridor

The Orient/East-Med Corridor connects large parts of Central Europe with the ports of the North, Baltic, Black and Mediterranean Seas. The corridor incorporates the Elbe River as a key inland waterway and will improve multimodal connections between Northern Germany, the Czech Republic, the Pannonian region and South-eastern Europe. The corridor will also provide an improved link to Cyprus.

No specific capacity issues were identified in the corridor study.

Scandinavian-Mediterranean Corridor

The Scandinavian-Mediterranean Corridor encompasses seven EU Member States (Finland, Sweden, Denmark, Germany, Austria, Italy and Malta) and one Member State of the European Economic Area, Norway. It is the largest of the corridors in terms of core network length – with a network of more than 11,900 km of core rail and more than 8,400 km of core road – together with 30 core ports, 20 core airports, 31 core intermodal terminals and 21 core urban nodes, when considering the alignment according to the CEF-II proposal.

Because a detailed analysis of capacity issues was recently conducted as part of STRING project for the stretch Oslo - Hamburg (STRING network, 2021), information from the corridor study was supplemented with the results of this bottleneck analysis.

The following capacity problems were identified for rail on this corridor:

- Ny Ellebjerg Station (København, DK)": Project ongoing that eases the bottleneck at Ny Ellebjerg St. enabling more trains to pass from the Roskilde Line to the Øresund Line and vice versa. The Øresund Line can hereby be operated with several direct trains bypassing Copenhagen Central Station where capacity is currently being used to the limit.
- Moss (NO): Limited capacity in Moss
- Älvängen –Gothenburg, Gothenburg – Kungsbacka (SE): Capacity issues in and around Gothenburg hub including Central station
- Halmstadt Railway station (SE): Limited capacity
- Lund – Flackarp – Arlöv (SE): Two-track railway, but limited capacity
- Öresund bridge land connection (SE/DK): Insufficient capacity on the Öresund Fixed Link land connections
- Kalvebod – Peberholm (SE/DK): Part of Öresund Fixed Link, insufficient rail capacity foreseen for the future
- Vordingborg - Nykobing Falster (DK): Only single-track
- Fehmarn Belt (DK/DE): no fixed link, limited capacity on ferry (not running currently)

- Fehmarn Sound Bridge (DE): Limited capacity of the existing Fehmarn Sound Bridge cause by capacity issues in the hinterland connection from and to the Fehmarn Belt Fixed Link.
- Bad Oldesloe – Hamburg (DE): Limited rail track capacity between Bad Oldesloe and Hamburg
- Elmshorn – Hamburg (DE): Limited capacity between Elmshorn and Hamburg
- Hamburg main and Altona station (DE): Hamburg main station and Altona station are over 100 years old and no longer able to cope with the increasing traffic

With regard to road infrastructure capacity, the following issues were identified:

- Malmö – Helsingborg (SE): Partial capacity issues exist, sensitive for incidents
- Vellinge – Trelleborg (SE): Only a 2-lane road leads through Trelleborg to the port, which limits port and logistic centre development
- Kalvebod Bridge (SE/DK): Bridge with 2 x 2 lanes and annual traffic at 110,000 vehicles is at maximum capacity
- Copenhagen Eastern Ring Road (DK): A feasibility study is finalised analysing how a ring road can relieve traffic congestion. Can possibly add more traffic to the STRING corridor and strain capacity elsewhere
- Fredericia – Kolding (DK): 2x2 lane motorway. Peak hour congestions. EIA for widening to 6/8 lanes has been carried out, but funding not yet provided
- Odense SØ –Odense V (DK): 2x2 motorway. Peak hour congestion. EIA and Construction Act has been approved. Funding not yet provided
- Odense V – Middelfart (DK): 2x2 lane motorway currently being widened to 3x3. Complete in 2022. Peak hour congestions
- Little Belt (SK) The current motorway bridge across Little Belt carries just under 90.000 vehicles per day (weekdays, 2019) and peak hour congestion is expected to increase in near future
- Fehmarn Belt Fixed Link (DK/DE): Currently only ferry link
- Fehmarn Sound Bridge (DE): Limited capacity of the existing Fehmarn Sound Bridge as hinterland connection from and to the Fehmarn Belt Fixed Link.
- Hamburg (DE): Limited capacity at the motorway A7 as it is used by both commuter/local and long-distance traffic north of Hamburg
- Hamburg (DE): Permitted traffic intensity of motorway A7 south of Elbe Tunnel is exceeded by 31%
- Hamburg (DE): The motorway A1 between the triangle-junction Hamburg-Southeast and Hamburg-Harburg is already highly frequented and much more traffic is forecasted
- Hamburg (DE): Prolongation of motorway A26 to connect A7 and A1 needed to improve connectivity of port, relieve inner city traffic
- Hamburg (DE): Koehlbrandbrücke, an important connection to the port, is old and can no longer cope with the increasing heavy weight traffic

For the intermodal terminals and marshalling yards, we could identify the following bottlenecks on the corridor:

- Malmö Kombiterminal (SE): Already at full capacity
- Marshalling yards in region Skåne (Malmö and Helsingborg, SE): Already at full capacity
- Lübeck Skandinavienkai (DE): Already at full capacity

The following capacity issues for the ports could be identified, however Gothenburg, Malmö and Trelleborg have generally excellent ports and port terminals. Accessibility to the ports is very good for Gothenburg and Malmö.

- Trelleborg (SE): port accessibility needs to be improved.

Rhine-Alpine Corridor

The Rhine-Alpine Corridor stretches from the northern seaports in the Netherlands and Belgium to the Mediterranean basin in Genoa right through most of the important and economically strong urban regions of Europe. Countries directly involved are the Netherlands, Belgium, Germany, Switzerland, Northern Italy and the eastern part of France, namely the Strasbourg area and Luxembourg (Moselle).

The following capacity problems were identified on this corridor for IWW:

- Neckar river (DE): Upgrades are necessary to accommodate large barges with 135m in length (11.4m wide, 2.8m draught).
- Plochingen (DE): Additional port area is needed to increase capacity
- Moselle river (DE): Due to the increasing traffic of larger barges on the river, lock capacity is lacking and limiting the operational volume. New lock chambers are needed between Koblenz and Trier in Germany to adjust to demand.

For rail, current and expected capacity limitations are reported with respect to:

- Northern feeder lines for new trans-alpine tunnels Gotthard and Ceneri, in particular in the upper Rhine valley ("Karlsruhe – Basel");
- DE/NL-border to Ruhr-area ("Emmerich – Oberhausen")
- Nodes of Antwerpen, Gent, Brussels, Liége Cologne, Basel

Several issues on the road network - especially around urban nodes – are mentioned in the Rhine-Alpine Corridor Study due to increasing traffic volumes meeting an already fully utilized infrastructure capacity for road traffic. The compliance map highlights these bottlenecks in capacity and sections where peak-hour congestion is expected on the motorway network in 2030.

For a variety of rail/road terminals capacity bottlenecks were identified in different federal states/terminal areas in the corridor study. Several projects were postponed due to the impact of the COVID-19 crisis. Nevertheless, increased terminal handling capacity is required for a variety of areas in different federal states, according to estimated mid- and long-term market needs. More detailed information on the concerned areas can be found in the previous update on the corridor studies. An assessment of necessary capacity upgrades in Germany is currently on-going in the framework of the evaluation of the German funding regulation for intermodal terminals, and it is expected that additional terminal capacity to cope with the increasing demand is required until 2030.

Atlantic Corridor

The Atlantic Corridor stretches from the ports of the Iberian Peninsula to the port of Le Havre in Northern France, and the cities of Strasbourg and Mannheim near the French/German border.

The following capacity problems were identified for seaports and the maritime infrastructure on this corridor:

- Port of Leixões (PT): Bottlenecks, which are related with the urgent need to enhance capacity (access channels and berths) for both terminals and storage areas, to cope with increasing international traffic and enhanced size of vessels.

Rail:

- From and to Iberian Peninsula: A missing link hampering the corridor and the network. The alternative routes for traffic to and from the Iberian Peninsula are currently insufficient to move freight via rail: the existing conventional line from Spain up to Bordeaux has insufficient capacity and needs upgrading.

North Sea-Mediterranean Corridor

The fundamental change for the current phase of the study is the adoption of a new definition of the corridor, following the UK's exit from the EU in January 2020, the end of the Brexit transition period (up to 31st December 2020), and from the revision of the Connecting Europe Facility (CEF) legislation. Under the new definitions, the main North-South route from Amsterdam to Marseille is kept intact, as is the Paris-Amsterdam branch, but now there is a maritime connection between Ireland and the ports in the Le-Havre-Amsterdam range. Additionally, there are inland sections added in France and Ireland, incorporating the ports of Rouen, Le Havre, and Shannon-Foynes. Into the core network

No specific capacity issues were identified from the corridor study.

Rhine-Danube Corridor

The Rhine-Danube Corridor provides the main east-west link across continental Europe. Tracing its route along the Danube River, it connects Strasbourg and Southern Germany with the European cities of Vienna, Bratislava and Budapest, before passing through the Romanian capital Bucharest to culminate at the Black Sea port of Constanta. A second branch of the corridor tracks a path from Frankfurt to the Slovakian/Ukrainian border, linking Munich, Prague, Zilina and Kosice.

No specific capacity issues were identified from the corridor study.

7.3 Annex 3: Result from the industry assessment and ten-t cnc 2021 project list.

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RESULTS FROM THE INDUSTRY ASSESSMENT

Table 82: Results from the industry assessment carried out by European Commission

Member States	TET-Tec	RINF	Case studies	Other sources	Industry assessment	Final %
AT	97	80				97
BE	78	82		82		82
BU	7	8	0		No problems	95
CZ	20		89		No problems	95
DK	96					96
DE	92					92
EE					No problems	95
EL						
FI	67			99		99
FR			20			
HR	79				No problems	95
HU					No problems	95
IT	36	27	42			42
LU		31		100		100
LV					No problems	95
LT					No problems	95
NL	46	78			No problems	100
PL	36				No problems	95
PT						
RO					No problems	95
SE	59			100	No problems	100
SK	99				No problems	99
SI	48		100		No problems	100
SP			4			4

TEN-T CNC 2021 PROJECT LIST – CHAPTER 4.7

Table 83: TEN-T CNC 2021 Project List – Task 3.7 Cost analysis

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Brenner base tunnel (BBT)	Galleria di Base del Brennero - Brenner Basistunnel BBT SE	Scandinavian-Mediterranean	AT/ IT	Innsbruck (AT) - Fortezza (IT)	Cross-border railway tunnel between Innsbruck (Austria) and Fortezza (Italy).	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	12/2004	12/2028	7067,00
Brno - Blažovice: railway modernization to 200 km/h	Railway Infrastructure Administration, state organization (Správa železnic)	Baltic-Adriatic	CZ	Brno - Holubice (HS)	Upgrade of railway track to high speed track.	Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones, Train length ≥ 740 m	04/2026	09/2030	365,73
HSR Dresden - Praha (part border - Usti nad Labem)	Railway Infrastructure Administration, state organization (Správa železnic)	Orient-East Med	CZ	Usti nad Labem - State Border DE/CZ	Construction of a high speed rail between Dresden and Prague (section from CZ/DE border to Usti nad Labem), optimization of the line and connection of CR to the HSR network.	Electrification, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	01/2026	12/2037	2500,00
HSR Dresden - Praha (part Lovosice / Litomerice - Praha)	Railway Infrastructure Administration, state organization (Správa železnic)	Orient-East Med	CZ	Lovosice / Litomerice - Praha	Construction of a high speed rail between Dresden and Prague (section from Lovosice / Litomerice to Prague), optimization of the line	Electrification, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	01/2025	12/2030	2000,00

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
					and connection of CR to the HSR network.				
New Rail Line Dresden - Praha (Section Heidenau - State Border DE/CZ)	BMVI (DB Netz)	Orient-East Med	DE	Dresden - Prag (only German part)	Construction of a new rail line including Erzgebirge tunnel.	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	01/2020	12/2035	1541,00
Construction of new single railway line Kalambaka-Ioannina – Igoumenitsa	OSE S.A.	Orient-East Med	EL	Ioannina – Kalambaka, Igoumenit a - Ioannina	Construction of the new single railway line (V=160 km/h), with two-way signalling, telecommanding and electrification, connecting the Igoumenitsa port with the remaining railway network in Kalambaka (global project).	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	01/2025	12/2030	1729,00
Connection to the Rubí Operations Center and Workshop	Ferrocarrils Generalitat de Catalunya (FGC)	Mediterranean	ES	Castellbisbal agujas Llobregat - Bif. Nudo Mollet	Connection of the line of FGC El Vallès to the Castellbisbal - Mollet section of the Mediterranean Corridor and specifically the FGC Operations Center of Rubí (maintenance services).	Electrification, Track gauge 1435 mm, Intermodal gauge	04/2018	12/2023	12,50

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Modernization of railway access to the port (electrification, P 400 gauge, ERTMS)	Port Autonome de Strasbourg	Atlantic, North Sea-MediterraneanRhine-Danube	FR	Strasbourg	Study and Work on the upgrade of the south railway access to the port (electrification, P400 gauge, ERTMS, maintenance of railway line).	Intermodal gauge, ERTMS implementation	01/2023	12/2025	10,00
Extension of multimodal Strasbourg South terminal (works)	Port Autonome de Strasbourg	Rhine-Alpine, Atlantic, North Sea-MediterraneanRhine-Danube	FR	Strasbourg	Works on the extension of the multimodal Strasbourg south terminal.	Intermodal gauge, ERTMS implementation	08/2023	12/2028	40,00
Treviglio – Brescia: Construction of a new HS line	RFI S.p.A.	Mediterranean	IT	Treviglio – Brescia	New HS line between Treviglio and Brescia (comprehends PRG and ACC Brescia)	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones	05/2011	12/2018	2050,00
Brescia - Verona: Construction of a new HS line	RFI S.p.A.	Mediterranean	IT	Brescia - Verona	New HS line between Brescia and Verona	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones	07/2018	07/2028	3430,00
New HS line Vicenza - Padova	RFI S.p.A.	Mediterranean	IT	Vicenza - Padova (HS)	New HS section (26 km), the intersection with the existing line will be realized through two interconnections in Vicenza and Padova. Resolution of physical bottleneck	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones	unknown	> 2030	1316,00

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Maas system/ Platform for intermodality and integrated mobility from/to Airport	Bologna Airport	Baltic-Adriatic, Mediterranean, Scandinavian-Mediterranean	IT	Bologna Airport	Bologna Airport will work on extension of the MaaS to a Regional MaaS, including other transport modes available (taxi / bike sharing / etc), all to be integrated in the existing ROGER app. (Costs: 2,20, Timing: 2022-2024. Financing: own funds)	Intermodal gauge	12/2022	12/2024	0,20
Upgrading of the railway link to the port of Ravenna	RFI S.p.A.	Baltic-Adriatic, Mediterranean	IT	Ravenna Port	Railway works on tracks connected to the port area. Elimination of the road interference in Via Canele Molinetto and upgrade to gabarit P/C80 of the link. Resolution of a physical bottleneck	Intermodal gauge, Train length ≥ 740m	12/2017	12/2026	77,10
New HS line Verona - Vicenza	RFI S.p.A.	Mediterranean	IT	Verona-Vicenza (HS)	New HS section Verona - Bivio Vicenza (50km), it will run in parallel to the conventional line and the A4 highway;	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones	09/2020	12/2028	3945,00
Upgrading of the national line sections in connection with the New line Turin-Lyon: (Bussoleno-	RFI S.p.A.	Mediterranean	IT	Torino node	Connection of Torino belt to the new line Torino-Lione, priority interventions: line section Avigliana-Orbassano and Torino Orbassano marshalling yards (1^ phase) Upgrade existing	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	03/2022	> 2030	1900,15

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Avigliana-Orbassano)					conventional line (Bussoleno-Avigliana)				
Railway works inside and outside the port area of Trieste	RFI S.p.A.	Baltic-Adriatic, Mediterranean	IT	Trieste Port	Upgrading of Trieste Campo Marzio station (PRG and ACC) and of the railway line “Linea di cintura” to Campo Marzio/Trieste Aquilinia. Intermodal integration. Upgrading Trieste Servola e Trieste Aquilinia (PRG ed ACC)	Intermodal gauge, Train length ≥ 740m	09/2017	12/2026	112,00
Firenze node - HS Railway by-pass and Belfiore HS station	RFI S.p.A.	Scandinavian-Mediterranean	IT	Firenze	Upgrading Firenze HS node (including construction of the new HS station Firenze Belfiore)	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h	07/2001	12/2024	1612,06

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Upgrade to P/C80 gauge of CNC lines	RFI S.p.A.	Scandinavian-Mediterranean	IT	Various lines	Upgrading of the railway line to P/C80 gauge for the lines: Bologna – Firenze; (Firenze) - Pisa - La Spezia; Bologna - Ancona + (Ancona - Foggia) + Foggia – Taranto; Faenza/CastelBolognese – Ravenna; Pisa - Civitavecchia - Roma (not on CNC line); Taranto - Paola - Rosarno - Gioia Tauro (not on CNC line); Roma – Napoli – Via Cassino (not on CNC line); Napoli – Rosarno (Gioia Tauro); Roma – Pomezia; Milano – Piacenza – Bologna(Not on CNC line); Rosarno (Gioia Tauro) – Villa San Giovanni; Messina – Catania – Bicocca;	Intermodal gauge	04/2015	12/2030	530,00*
Rail connection Napoli - Foggia - Bari	RFI S.p.A.	Scandinavian-Mediterranean	IT	Napoli - Bari	Construction of a HS/HC railway connection between Napoli and Bari.	Structure gauge, Intermodal gauge, Axle load ≥ 22.5 tones Train length ≥ 740m	11/2018	06/2027	5523,60

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Rail connection Napoli - Foggia - Bari	RFI S.p.A.	Scandinavian-Mediterranean	IT	Napoli - Bari	Construction of a HS/HC railway connection between Napoli and Bari (Infrastructure and technological upgrading on section belonging to the line Caserta-Foggia: doubling of the section Bovino-Cervaro)	Structure gauge, Intermodal gauge, Axle load ≥ 22.5 tones Train length ≥ 740m	05/2008	06/2017	263,40
Southern access line to Brenner; Lotto/lot 1: Fortezza/Franzenfeste - Ponte Gardena/Waidbruck	RFI S.p.A.	Scandinavian-Mediterranean	IT	Fortezza - Verona	Upgrading of Brennero southern access lines: - quadrupling Fortezza-Ponte Gardena (lotto 1 - including ACC and PRG di Ponte Gardena)	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	03/2014	12/2028	1521,60
Southern access line to Brenner; Lotto/lot 2-4: Bolzano/Bozen; Trento/Trient; Pescantina - Verona	RFI S.p.A.	Scandinavian-Mediterranean	IT	Fortezza - Verona	Upgrading of Brennero Southern access lines (Fortezza - Verona): - Bolzano bypass (lotto 2) - Trento and Rovereto bypass (lotto 3) - Northern access to Verona node (section Pescantina - Verona) (lotto 4)	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	11/2022	08/2035	3404,40
Upgrade to PC80 loading gauge on railway access from Novara to Domodossola e from Milano to	RFI S.p.A.	Mediterranean, Rhine-Alpine	IT	Domodossola - Novara/Milano Chiasso - Milano	Upgrading to PC80 loading gauge of the railway connecting line to the passes (Gottardo via Chiasso and Sempione via Arona)	Intermodal gauge	03/2014	12/2028	231,30

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Chiasso/Domodossola				Nodo di Milano					
Upgrading of Novara Node	RFI S.p.A.	Mediterranean, Rhine-Alpine	IT	Novara node	Phase 1) Terminal Upgrading. Phase 2) Completion of planned works in Vignale, Boschetto and “Novara Centrale”. Development of traffic management system. Resolution of physical bottlenecks.	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, Train length ≥ 740m	03/2023	06/2027	183,10
Upgrade to 4 tracks on the section Pavia - Milano Rogoredo	RFI S.p.A.	Rhine-Alpine	IT	Pavia - Milano Rogoredo	Upgrade to 4 tracks between Milano Rogoredo and Pavia (26 km), with the construction of the Pieve Emanuele station.	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones	07/2022	03/2028	900,00
Upgrade to PC80 loading gauge on railway access from Milano/Novara to Genova	RFI S.p.A.	Mediterranean, Rhine-Alpine	IT	Novara - Alessandria - Novi Ligure Milano - Pavia - Tortona	Upgrade to PC80 loading gauge of the connecting line to the Terzo Valico from Novara and Milano to Genova.	Intermodal gauge	01/2019	12/2024	35,80
Nodo di Genova e Terzo valico dei Giovi	RFI S.p.A.	Mediterranean, Rhine-Alpine	IT	Genova node - Tortona/Novi Ligure	1. Project “Voltri-Brignole Infrastructural Upgrading”. 2. High speed railway link “Terzo valico dei Giovi”. 3. Campasso station upgrade and Campasso-	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h,	01/2010	12/2026	6853,03

Project Name	**Project Promoter**	**TEN-T Corridor**	**Member states**	**Section or Node**	**Description**	**KPI target achieved**	**Project start date**	**Project end date**	**Total Cost [M€]**
					Port connection restoration.	Axle load ≥ 22.5 tones, Train length ≥ 740m			
New rail link between Livorno Darsena and Interporto Guasticce	RFI S.p.A.	Scandinavian-Mediterranean	IT	Livorno	New rail link which allows a direct connection between Livorno Darsena and Interporto Guasticce with an overpass of Tirrenica railway line	Track gauge 1435 mm, Structure gauge, Intermodal gauge	06/2019	12/2021	27,00
Cross-border section of new Lyon Turin railway line	TELT	Mediterranean	IT, FR	FR/IT Border	The project regards: the base tunnel, the railway stations of Susa and Saint Jean de Maurienne will be built and the interconnections with existing railway lines. The realization of this railway link will meet all the TEN-T technical requirements.	Electrification, Track gauge 1435 mm, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones.	01/2017	12/2029	8609,70
Works on main passenger lines (E 30 and E 65) in Śląsk area, phase I: line E 65, section Będzin – Katowice – Tychy – Czechowice Dziedzice –	PKP Polskie Linie Kolejowe S.A.	Baltic-Adriatic	PL	Warszawa - Katowice - state border (towards Ostrava)	Complex modernisation of dual track electrified lines on sections Most Wisła - Czechowice Dziedzice - Zabrzeg including Czechowice Dziedzice station. The Action is a part of the project on the Będzin - Zebrzydowice section.	Intermodal gauge, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones, Train length ≥ 740 m	10/2019	09/2023	336,08

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
Zebrzydowice; lot C									
Rehabilitation + new line of Railway line Craiova - Caransebes (226 km)	Romanian National Railways Company "CFR" S.A.	Orient-East Med, Rhine-Danube	RO	Craiova - Caransebes	Increase of the maximum designed speeds from 120 km/hour to 160 km/hour for passenger trains and 120 km/hour for freight trains); full interoperability through the implementation of technical specifications for interoperability; upgraded electrification along the length (in 25 kV power system) and improved facilities for people with reduced mobility.	Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	09/2022	12/2026	2.424,57 *
Modernisation/ Rehabilitation rail line Caransebeş - Timişoara (93,72 km)	Romanian National Railways Company "CFR" S.A.	Orient-East Med, Rhine-Danube	RO	Caransebes - Timisoara	Increase of the maximum designed speeds from 120 km/hour to 160 km/hour for passenger trains and 120 km/hour for freight trains); full interoperability through the implementation of technical specifications for interoperability; upgraded electrification along the length (in a 25 kV power system) and improved facilities for	Electrification, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	06/2022	07/2025	804,12*

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
					people with reduced mobility.				
Modernisation/ Rehabilitation rail line Timișoara - Arad (68,72 km)	Romanian National Railways Company "CFR" S.A.	Orient-East Med, Rhine-Danube	RO	Timisoara - Arad	Increase of the maximum designed speeds from 120 km/hour to 160 km/hour for passenger trains and 120 km/hour for freight trains); full interoperability through the implementation of technical specifications for interoperability; upgraded electrification along the length (in 25 kV power system); improved facilities for people with reduced mobility.	Electrification, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones Train length ≥ 740m	06/2022	07/2025	978,39*
Modernizing and rehabilitation of TEN-T corridor network on RO territory, section Predeal-Brasov	Romanian National Railways Company "CFR" S.A.	Rhine-Danube	RO	Brasov - Predeal	Measures included the rehabilitation and new construction for maximum speed of 160 km/h, signalling improvements and ERTMS.	Electrification, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones, Train length ≥ 740m	03/2023	03/2027	497,42*
Railway line modernisation Bucureşti-Videle-Roşiori-Caracal-Craiova	Romanian National Railways Company "CFR" S.A.	Rhine-Danube	RO	Bucuresti - Craiova	Increase of the maximum designed speeds from 120 km/hour to 160 km/hour for passenger trains and 120 km/hour for freight trains) and rehabilitation for existing double-tracks electrified railway on 74.73 km;	Electrification, Structure gauge, Intermodal gauge, ERTMS implementation, Line speed ≥ 100 km/h, Axle load ≥ 22.5 tones, Train length ≥ 740m	09/2024	09/2028	2.265,76 *

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	KPI target achieved	Project start date	Project end date	Total Cost [M€]
					full interoperability through the implementation of technical specifications for interoperability; upgraded electrification along the length (in a 25 kV power system) and improved facilities for people with reduced mobility.				

TEN-T CNC PROJECT LIST 2021 – CHAPTER 4.10

Table 3: TEN-T CNC 2021 Project List – Task 3.10 Capacity growth trend analysis

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	Project start date	Project end date	Total Cost [M€]
Terminal Graz Süd Expansion	Steiermärkische Landesbahnen / Cargo-Center-Graz	Baltic-Adriatic	AT	Graz Werndorf Railroad Terminal	Terminal Graz Süd: rail-road container-terminal with a capacity of 4.200 TEU storage and 230.000 TEU handling per year (current utilisation at its limit), located south of Graz on the Baltic Adriatic Corridor; upgrade to increase capacity in two phases: Phase 1: supplementation of existing terminal by a third gantry crane, expansion of the workshop and track elongation, electrification and safety technology in the transfer station Wundschuh. Phase 2: new terminal site (terminal B) with four additional tracks in parallel to the Koralm railway line, equipping with two gantries cranes, expansion of the second container storage area to 4200 TEU including new road access (FW6). Total future capacity of 500.000 TEU handling per year.	01/2018	12/2026	72,44
Trimodal Port of Linz - Rail connection and	Linz Service GmbH für Infrastruktur	Rhine-Danube	AT	Linz	Remove main bottleneck of rail connection of the inland port of Linz to the main rail corridor of the Core Network Corridor Rhine-Danube	07/2017	12/2023	122,90

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	Project start date	Project end date	Total Cost [M€]
port enhancement	und Kommunale Dienste				Remove main bottleneck of road connections of the port to the higher system road and within the port. Increase of railway capacity by creating 1 new track and prolonging all rail tracks in the port area and to full train length to discharge more trains in parallel, saving tranship movements, transferring them into embedded rail tracks, to improve truck moving between rails. Improve inland shipping and rail transfer capacity (to 450,000 TEU/y) creating additional storage space and capacities, by adding a rail mounted gantry crane and reorganising and modernising the rail tracks in the container terminal Increase of transfer and storage capacity to 10.126 TEU for all trimodal transport modes by installing 3 storage facilities for in and outbound traffic (pre- and post-transhipment) Improve efficiency and safety of truck transport from and to the port. Improve the safety and security of railway transport by electrification of tracks and switches and installation of new signalling system and modern rail crossings from the port railway station into the port. Decrease the carbon footprint of the port.			
Investing in the upgrade of the RSC terminal Rotterdam servicing combined transport operations across Europe	Rail Service Center Rotterdam B.V.	North Sea-Baltic, Rhine-Alpine, North Sea-Mediterranean	NL	Rotterdam	With the investment of the here presented Action, the handling operation of the RSC terminal will be more cost-effective and efficient. Even more important, the RSC terminal can growth with the transhipment capacity by 14%, from currently 350,000 to 400,000 loading units per year. However, RSC terminal will need to invest a significant amount of €9.155 million in achieving the upgrade of the existing combined terminal infrastructure, such as: 1) Enhancing the terminal operating system, 2) Upgrading terminal transhipment facility 3) Modernising terminal ICT Equipment, such as "video gates". 4) Modernisation of existing crane gantries, and purchase of a 5th gantry crane	10/2018	12/2022	8,80

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	Project start date	Project end date	Total Cost [M€]
Extension of the combined transport terminal Clésud Miramas.	Aix-Marseille-Métropole	North Sea-Mediterranean	FR	Marseille Node	This project aims to extend Clésud terminal. This combined rail-road transport terminal now offers a processing capacity of 50,000 ITUs. The objective of the extension project is to create a new way to increase this capacity of 25,000 additional ITUs to ensure the development of the site. This extension is consistent with the development of the Avignon terminal and with the installations of the Fos basins of the GPMM, as well as those of Marseille. This project also meets the objective of reducing the environmental impact of freight transport by reinforcing the modal shift	01/2019	12/2023	10,50
Shunting locomotives purchase for the intermodal terminals in Kutno, Brzeg Dolny and Gliwice	PCC Intermodal S.A.	Baltic-Adriatic	PL	Intermodal Container Terminal in Brzeg Dolny	The project includes purchase of 3 modern locomotives for operational activities on the intermodal terminals in Brzeg Dolny, Kutno and Gliwice. These devices will replace the outdated locomotives which are currently used by the company. The main aim of this project is increasing the capacity of the terminals (aprox. 5% on each terminal). Furthermore project will improve overall manoeuvrability and increase the company's competitiveness on the intermodal transport market in Poland and EU.	06/2019	10/2021	2,59
Upgrade Cargo Center Wien South - Phase 2	ÖBB-Infrastruktur AG	Baltic-Adriatic, Orient-East Med, Rhine-Danube	AT	Wien (node)	Second phase of upgrade of Cargo Center Wien South - Since 2016, the Vienna South Terminal has been the main railway station for freight traffic in the eastern region. At present, 210,000 Intermodal Transport Units (ITE) can be handled annually at the terminal as containers, semi-trailers or swap bodies. The expansion will increase the handling capacity to 315,000 ITE. In addition, there is an additional storage capacity of 940 TEU (20-foot standard containers).	01/2022	12/2023	19,60
Increase the efficiency of current Alcantara container terminal	LISCONT (APL Concessionaire)	Atlantic	PT	Port of Lisboa	This project will increase the Terminal's annual handling capacity from 576.641 to 662.347 TEU and allow the reduction of CO_2 emissions through the installation of modern electrified equipment, generating the creation of around 285 jobs.	06/2021	12/2038	122,00
Enlargement of the container terminal at quay VII increasing	Autorità di Sistema Portuale del	Baltic-Adriatic, Mediterranean	IT	Port of Trieste	Enlargement of the container terminal at quay VII to increase the capacity up to a maximum of 1,200,000 TEU (length: 200 m, depth: 18 m).	06/2019	12/2021	187,00

Project Name	Project Promoter	TEN-T Corridor	Member states	Section or Node	Description	Project start date	Project end date	Total Cost [M€]
the potential up to a maximum of 1,200,000 TEU (dimension 200m, 18m depth)	Mare Adriatico Orientale							
Container berth upgrade in the Port of Dunkerque	Dunkerque Port authority (GPMD)	North Sea-Mediterranean	FR	Dunkerque	The extension of the existing container berth (extension of quays, platforms, upgrade of road and rail infrastructures) will enhance operational capacity of the terminal, allowing the latest generation of ships (400m long, 18 000TEU) to call in. Thus, it will support both the development of transshipment to feedering or short-sea services and improve inland access and multimodal transfer to rail and river services. Nominal throughput capacity is expected to grow from 600 000 to 900 000 TEU by 2017.	07/2016	06/2018	65,00
Expansion of Deepwater Container Ter-minal DCT Gdansk - Construction of T2 Terminal	DCT Gdansk S.A.	Baltic-Adriatic	PL	Gdańsk RRT	The port of Gdansk is an important port in the Baltic Sea and a starting point of Baltic - Adriatic TEN-T Core Corridor. The Action aims to expand existing container terminal DCT Gdansk S.A. in the Port of Gdansk (Poland). The Action includes construction of a new deep-water berth and purchase of specialist equipment such as STS cranes, RTG cranes, container trailers and tractors. The action will increase capacity and efficiency of TEN-T Network by increasing capacity of DCT Gdansk terminal to 2.5 million TEU per year.	Unknown	Unknown	157,81

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