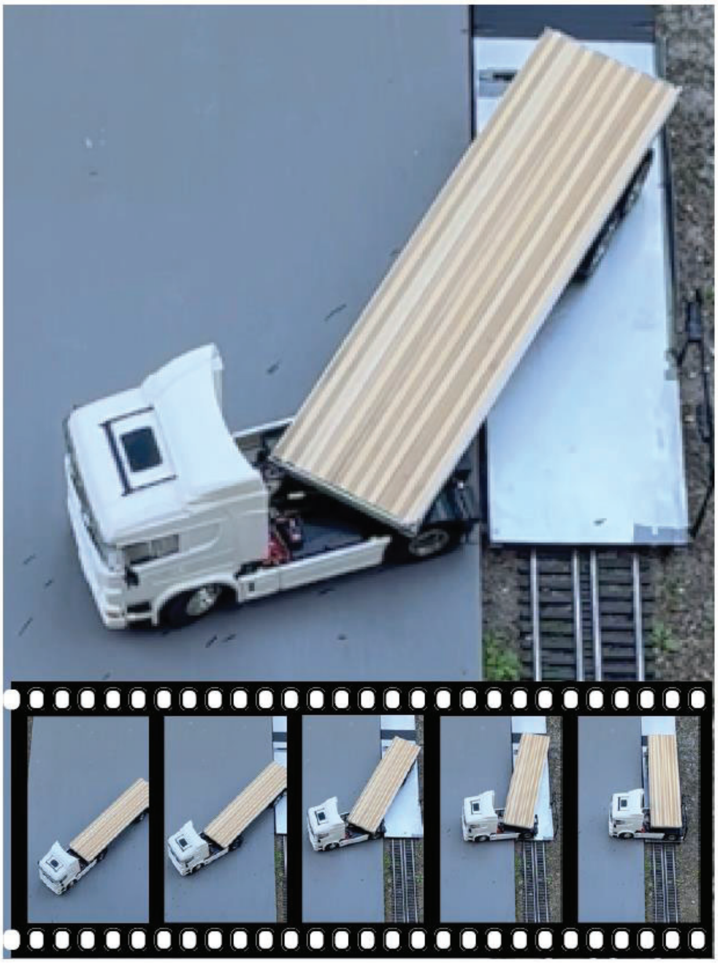
A pre-study for a new efficient transshipment technology for combined transports

Public report



Project within Accelerera omställningen till hållbara vägtransporter
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Contents

1 Summary

The project addresses the need for green end-to-end long-distance transportation over land and the need to shift more cargo from road to rail. The overarching target is to shift a considerable part of present long-distance road transports to combined transportation, by providing seamless transshipment between road and rail, with the aim to accelerate the shift from energy-consuming fossil transportation to a combination of energy-efficient and fossil-free long-distance transportation on rail and flexible and fossil-free short-distance trucking.

Combined transport (CT) of semi-trailers combines the sustainability (electrification & energy efficiency) of rail with the flexibility of road, enabling green transport chains. The availability and competitiveness of CT is however limited by inefficiencies related to the transshipment, as most trailers cannot be managed by present methods, as CT terminals are capital intensive and therefore typically few and far apart, and as large part of transport costs and time are related to the transshipment.

The proposed solution "Assisted RoRo Transshipment" is an innovative & competitive way for loading trailers onto railway wagons at terminals, through horizontal loading (Ro-Ro) of trailers onto flat railway wagons by the use of assisted precision driving. The trailer can be pushed onto the railway wagon directly by the tractor bringing it to the terminal, or alternatively by a terminal tractor.

One objective of the pre-study project has been to achieve a deeper understanding of the fit within the transport system in Sweden, including relevant market, and the needs of all relevant stakeholders. Another objective has been to review the feasibility of the technology in different implementations. A further objective has been to identify relevant use cases, and propose an actionable project plan for a full scale demo project.
The following general research questions were addressed:

- How well does the concept fit in the present system and market?
- How feasible is the concept in relation to risks and regulations?
- How should a suitable full scale demo project (FSDP) be designed and planned and what should be considered regarding technology?

To review the fit of the new concept in present systems and market, a review has been made from the perspectives: system, behaviour and application. A thorough review of the market mechanics has been made and the different components of the intermodal transport system have been addressed. Simulations of effects by the introduction of the Assisted RoRo Transshipment concept in various environments was carried out.

As a summary, the conclusion is that Assisted RoRo Transshipments have the potential of bringing relevant improvements to the marked in various situations. The costs for transshipment are estimated to be considerably lower than present alternatives and new

opportunities are created for the establishment of intermediate terminals along a railway line. Faster transshipments together with the possibility to use also non-liftable trailers in CT provides opportunities to grow the CT market. Based upon these conclusions, further development and demonstrations are suggested, as well as further research.

In the study regarding the feasibility of the concept, various risks related to CT and an implementation of Assisted RoRo Transshipments were reviewed and analysed. Applicable legislation and requirements related to intermodal railway transports were also reviewed and analysed in view of various levels of implementation. The main conclusions from the feasibility study are that the Assisted RoRo Transshipment concept appears to be feasible for implementation in an FSDP as well as in large scale and that the risks involved in transshipments and transportation call for focus on safety and reliability in all implementations.

Various alternatives for an FSDP were simulated and analysed. The technology concept has been tested from different perspectives. The conclusions were that there is a number of variations as to how a demonstration and pilot project can be set up in various stages of the development of the concept. The suggestion is however to set up a limited FSDP, with one or a few wagons in commercial pilot traffic between two terminals as part of an existing intermodal shuttle. The railway wagon should be adapted for Assisted RoRo Transshipments. Temporary platforms for Assisted RoRo Transshipments should be arranged on or close to the terminals. The project also proposes a project plan for such FSDP.

2 Sammanfattning på svenska

Projektet tar upp behovet av gröna långväga transporter över land och behovet att flytta mer gods från väg till järnväg. Det övergripande målet är att flytta en avsevärd del av nuvarande långväga vägtransporter till kombitransporter, genom att tillhandahålla sömlös omlastning mellan väg och järnväg, med målet att påskynda övergången från energikrävande fossila transporter till en kombination av energieffektiva och fossilfria långväga transporter på järnväg och flexibla och fossilfria, korta vägtransporter.

Kombitransporter av semitrailers kombinerar hållbarheten (elektrifiering och energieffektivitet) hos järnväg med vägens flexibilitet, vilket möjliggör gröna transportkedjor. Tillgängligheten och konkurrenskraften för kombitransporter begränsas dock av problem relaterade till omlastningen, eftersom de flesta trailers inte kan omlastas med nuvarande metoder, eftersom kombiterminaler är kapitalintensiva och därför vanligtvis är få och långt ifrån varandra, och eftersom en stor del av transportkostnaderna och -tiden är relaterade till omlastningen.

Den föreslagna lösningen "Assisted RoRo Transshipment" är ett innovativt och konkurrenskraftigt sätt att lasta semi-trailersläp på järnvägsvagnar vid terminaler, genom horisontell lastning (Ro-Ro) av släp på plana järnvägsvagnar med hjälp av assisterad precisionskörning. Släpet kan rullas över på järnvägsvagnen direkt av dragbilen som tar den till terminalen, eller av en terminaltruck.

Ett mål med förstudieprojektet är att nå djupare förståelse för hur metoden passar i transportsystemet i Sverige, inklusive relevant marknad, och behoven hos alla relevanta intressenter. Ett annat mål är att identifiera relevant första tillämpning och föreslå en projektplan för ett fullskaligt demoprojekt.

Följande generella frågor har varit utgångspunkt för arbetet:

- Hur väl passar konceptet i nuvarande transportsystem och på marknaden?
- Hur påverkas konceptet och den nya tekniken av risker och regleringar?
- Hur planerar och genomför man en lämplig fullskalig demonstrations pilot av konceptet?

För att undersöka hur väl det nya konceptet passar med nuvarande transportsystem och marknad, har de olika perspektiven system, beteende och användning studerats. En grundlig genomgång har gjorts av marknadsmekanismerna och av de olika komponenterna i det intermodala transportsystemet. Simulering av effekterna av införandet av konceptet Assisted RoRo Transshipment i olika miljöer har genomförts.

Sammanfattningsvis är slutsatsen att Assisted RoRo Transhipments har potential att leverera relevanta fördelar i ett flertal situationer. Kostnaden för omlastning uppskattas bli väsentligt lägre. Nya möjligheter skapas för etablering av mindre terminaler utmed en järnvägslinje. Möjligheterna till snabbare omlastning och omlastning av trailers som ej är lyftbara, kan leda till att marknaden för kombitransporter växer. Baserat på dessa slutsatser föreslås att vidare demonstrationer genomförs och att konceptet görs till föremål för vidare forskning.

Vid studier av konceptets tillämplighet har olika risker relaterade till kombitransporter och till implementation av Assisted RoRo Transshipments studerats och analyserats. Tillämpliga lagar och regler relaterade till kombitransporter har också studerats och analyserats i förhållande till olika hög grad av implementation av konceptet. En slutsats är att varken identifierade risker eller regler bör förhindra implementation av konceptet, varken i en större demopilot eller i en fullskalig implementation. En annan slutsats är att de risker som föreligger föranleder ett starkt fokus på säkerhet och tillförlitlighet vid såväl större som mindre implementationer.

Olika alternativa implementationer av ett demopilotprojekt i full skala har simulerats och analyserats. Teknikkonceptet har även testats ur olika perspektiv. Slutsatsen är att det finns ett antal olika varianter på hur ett demonstrations- och pilotprojekt kan genomföras under olika skeden av konceptets utveckling. Det föreslås emellertid att ett begränsat fullskaligt demonstrationspilotprojekt genomförs, för bästa balans mellan kostnader och nytta. En sådan begränsad pilot skulle lämpligen utgöras av en eller ett fåtal vagnar i kommersiell trafik mellan två kombiterminaler som en del av en redan existerande intermodal pendel. Järnvägsvagnen utgörs lämpligen av en befintlig lågbyggd vagn som anpassas för Assisted RoRo Transshipment. Tillfälliga plattformar anordnas på eller i närheten av terminalerna. Projektet har även tagit fram en projektplan för genomförande av ett sådant begränsat fullskaligt demopilotprojekt.

3 List of abbreviations and acronyms

Abbreviation / Acronym	Definition
AsBo	Assessment Body
CT	Combined transport
DeBo	Designated Body
ERA	European Union Agency for Railways
EU	European Union
FSDP	Full scale demo project
ITCM	Intermodal Cost Model
LU	Loading Unit
MSEK	million Swedish kronor
NoBo	Notified Body
RoRo	Roll-on, Roll-off
SE	Sweden
TEU	Twenty-foot Equivalent Unit
TOFC	Trailer On Flat Car
TSI (*sv.* TSD)	Technical Specification for Interoperability (*sv.* Tekniska Specifikationer för Driftskompatibilitet)
TTC	Total Transport Cost
US-TOFC	United States-Trailer On Flat Car

4 Background

Combined transport (CT) of semi-trailers combines the sustainability (electrification & energy efficiency) of rail with the flexibility of road and tackles the negative climate impact of longhaul truck transportation. However, there are today many inefficiencies related to the transshipment at CT terminals:

- both costs and time involved in transshipment are substantial
- only a minor share of presently used trailers can be lifted and thus be transshipped by the presently dominant transshipment method, using cranes or reach stackers
- CT terminals are capital intensive, to a large degree due to costly lifting equipment, and therefore typically few and far apart.

The problems are well described in various reports, e.g. Trafikverket (2019, 2021) and Trafikanalys (2019), and the value of the benefits has been verified with various players in the transport ecosystem.

A new concept for transshipment of trailers onto or off from railway wagons, "Assisted RoRo Transshipment", has been suggested by Assisted RoRo Transshipment AB, with the purpose to address present drawbacks regarding cost, time and availability. This is concept is subject to this pre-study.

The concept, which is illustrated in sequence in the Figure 1, is based on a horizontal loading technology (RoRo). At loading, a semi-trailer is rolled onto a flat top railway wagon through assisted precision driving by a tractor pushing the trailer. The tractor is during the loading movement pushing the trailer onto the railway wagon from a platform beside the wagon in an innovative trajectory similar to the parallel parking of a car, whereby the tractor during the movement is ending up in a direction 90 degrees from the longitudinal direction of the trailer. The loading can thus also be performed by the tractor bringing the trailer to the terminal.

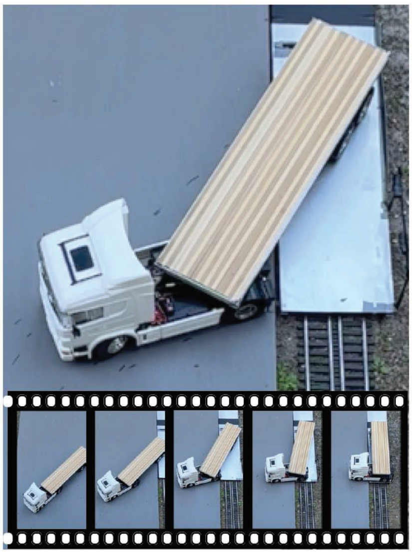

Figure 1 Model view of boarding with "Assisted RoRo Transshipment"

The core of the concept "Assisted RoRo Transshipment", see Figure 2, is an assistance system providing a driver with information facilitating the precision manoeuvring of the trailer onto the railway wagon. The assistance system may comprise an information means, e.g. in the form of a screen inside the tractor, providing the driver with precise information/instructions for the precision manoeuvring of the trailer. The information means is connected to an assistance software providing the driving instructions. The software is further connected a vehicle database, holding information related to the manoeuvring specifics of the different vehicles, and to a sensor setting, providing the software with precise information on the present position of the trailer and possibly also of the truck.

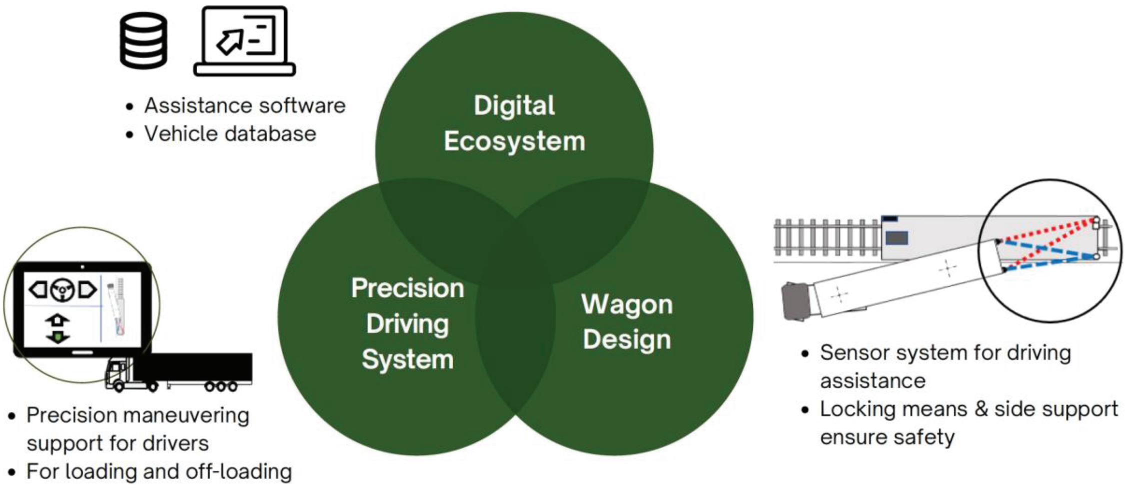

Figure 2 Overview of the concept "Assisted RoRo Transshipment"

A schematic view of a railway wagon suitable for “Assisted RoRo Transshipment” is illustrated in the front page as well as in Figure 3. During transshipment, the trailer and tractor are moving on a horizontal platform beside the tracks and the railway wagon, and on a loading area on the railway wagon. The railway wagon is typically a quite straight-forward flat wagon with a low loading area. The railway wagon may be equipped with sensors communicating with the assistance software. The wagon may also have safety supports to prevent the trailer from rolling of the wagon during loading, as well as a front side support to prevent the front end of the trailer, and the pushing tractor, to move past the side of the railway wagon. A removable kingpin holder is also arranged in the loading area of the railway wagon, to be out of the way for the tractor when connected to the trailer, and to be transformed to an erected position for locking engagement with the kingpin of the trailer during railway transport.

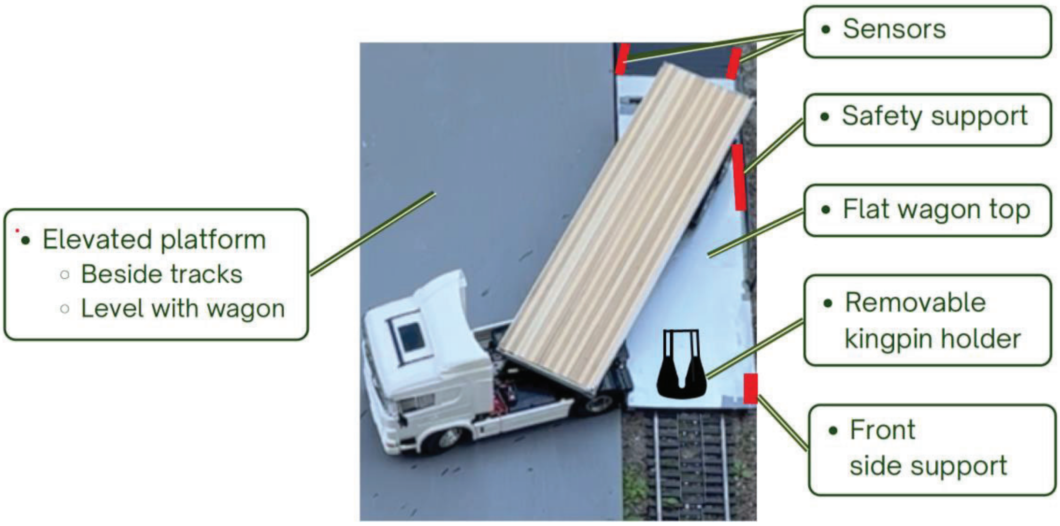

Figure 3 Important components in the concept “Assisted RoRo Transshipment”

5 Purpose, research questions and method

The general purpose of the project is to accelerate the shift to zero carbon emission transportation, in particular by competitive combined transports. In line therewith, the specific the purpose is to evaluate the Assisted RoRo Transshipment concept.

The following general research questions were addressed:

- *How well does the concept fit in the present system and market?*
- *How feasible is the concept in relation to risks and regulations?*
- *How should a suitable full scale demo project (FSDP) be designed and planned and what should be considered regarding technology?*

The project is divided into three work packages, each focusing on one of the questions. The methods used in the work packages are described below.

WP 1: Validating the concept's fit in system and market including the characteristics of the system and the associated behaviour, application of the concept in the that system and identification of further research needed. This part has aimed at identifying suitable scenarios for both demo project and commercial implementation. In order to explore the system and behavioural aspects associated with implementing the concept, literature review was the prime method and for the application of the concept, transport modelling was carried out in order estimate costs for identified scenarios. Identified research gaps and methodological developments are identified as topics for further research.

WP 2: Various risks related to CT and an implementation of Assisted RoRo Transshipments were reviewed and analysed. Applicable legislation and requirements related to intermodal railway transports were also reviewed and analysed in view of various levels of implementation. Interviews and discussions have been held with terminal operators, transport operators and wagon manufacturers. Various workshops were carried out in different constellations, within the team and with reference group, and with other experts in arrangements by TripleF.

WP 3: Various alternatives for an FSDP were simulated and analysed. The technology concept has been tested from different perspectives. Tests with precision maneuvering of trailers were conducted with different tractors and drivers for validation and analysis. Development options and technology choices and cost for various activities have been reviewed with technology experts, in particular for review of and planning of development of assistance software and sensor arrangements. Railway wagon requirements have been reviewed with technology experts. Railway wagon technology has been developed, including the filing of patent application. In addition, suitable workshops, conferences and similar have been attended.

6 Objective

The overarching goal of the project is to accelerate the transition to green end-to-end long-distance transportation over land. By addressing the competitiveness of combined transport (CT), in particular the transshipment of trailers, we can enable more goods to be shifted from road to rail. The focus is on truck transports exceeding 300 km, which amounts to 60% of the truck transport work (Eurostat, 2023). The owner of the transshipment technology, Tructric AB, has the target to enable a shift of ca 10% of this market to CT by 2035, through the application of more efficient transshipments.

The objectives of the pre-study project are to:

- achieve a deeper understanding of the fit within the transport system in Sweden, including relevant market, and the needs of all relevant stakeholders,
- gain thorough understanding about the feasibility and risks of the technology,
- identify a relevant use case and propose an actionable project plan for a full scale demonstration project.

7 Results and deliverables

This section presents the results from the three work packages:

- WP 1: Validation of fit in system and market
- WP 2: Feasibility study
- WP 3: Full scale demo project (FSDP) planning

The deliverables of WP1, WP2 and WP3 are presented in chapter 7.1, 7,2 and 7.3.

7.1 WP 1: Validation of fit in system and market

This section presents the three aspects: System, Behaviour and Application. Further research needed is identified.

7.1.1 System - Understanding of how the solution fits the current system

The intermodal system consists of three parts; road transports for pre- and post-haulage to and from intermodal terminals, transshipment of standardised unit loads i.e. containers, swap bodies and semi-trailers, between modes at the terminals, and for the main haulage rail transports. Conventional intermodal transshipment technologies consist of rather large-scale terminals using reach-stacker or portal cranes. These technologies enable transshipment for all standardised containers and swap-bodies, however they cannot handle all types of semi-trailers, only those equipped with attachments for transshipment, also sometimes called liftable or cranable semi-trailers. In the European market, it is estimated that approximately 20-35% (Godstransportrådet Skåne & Blekinge, n.d; UIC, 2020) of the European semi-trailers are cranable and thus can be transhipped using conventional transshipment technologies. Hence, the market for intermodal transports can extended if innovative novel transshipment technologies are developed that can handle non-cranable semi-trailers as well. Something that could be achieved with the Assisted RoRo Transshipment concept.

Moreover, if intermodal transports want to be competitive for smaller flows and on relatively short distances, reducing the transshipment cost is a key factor. Several novel transshipment technologies have been developed in recent decades, both horizontal and vertical. Horizontal technologies enable transshipment under the catenary and commonly require less force, on the other hand they often require customization of loading units and/or chassis and can be technically complex. Some of the technologies evaluated in earlier studies (Kordnejad 2016) are illustrated in Figure 4.

Figure 4 Examples of novel transshipment technologies from left: The Light-Combi System; Megaswing and ACT.

7.1.2 Behaviour

There are several factors associated with large-scale conventional intermodal terminals based on gantry-cranes or heavy reach-stackers that make them unsuitable for all freight flows and thus limit the competitiveness for combined rail road transport. Albeit the operational marginal transshipment cost achieved may be relatively low, a main obstacle for intermodal transport is still the associated transshipment cost, as high investment costs and high utilization rate are prerequisites for the efficiency of these terminals. Some of the underlying reasons for the inefficiency of conventional intermodal terminals are (Kordnejad, 2016):

- The terminals are designed for the heaviest LUs i.e. semi-trailers and heavy containers
- They require large areas that need to be hardened for high axle loads
- Majority of semi-trailers (~80% in Sweden) can still not be transshipped using conventional transshipment technologies as they are not lift on- lift off (LOLO) trailers.
- In electrified rail networks, many terminals are not fully electrified – thus requiring additional diesel driven shunting engines and thus time-consuming shunting movements where track capacity is limited.
- Limited flexibility in time as opening hours are limited.
- The number of intermodal terminals is commonly scarce and their network scattered.

Hence, there is a need also for cost-efficient and small-scale intermodal terminals and operationally utilizing cost-efficient transshipment technologies. The break-even distance between an intermodal transport chain and unimodal road is best described by a schematic illustration of the relation between cost and distance as represented by Figure 5.

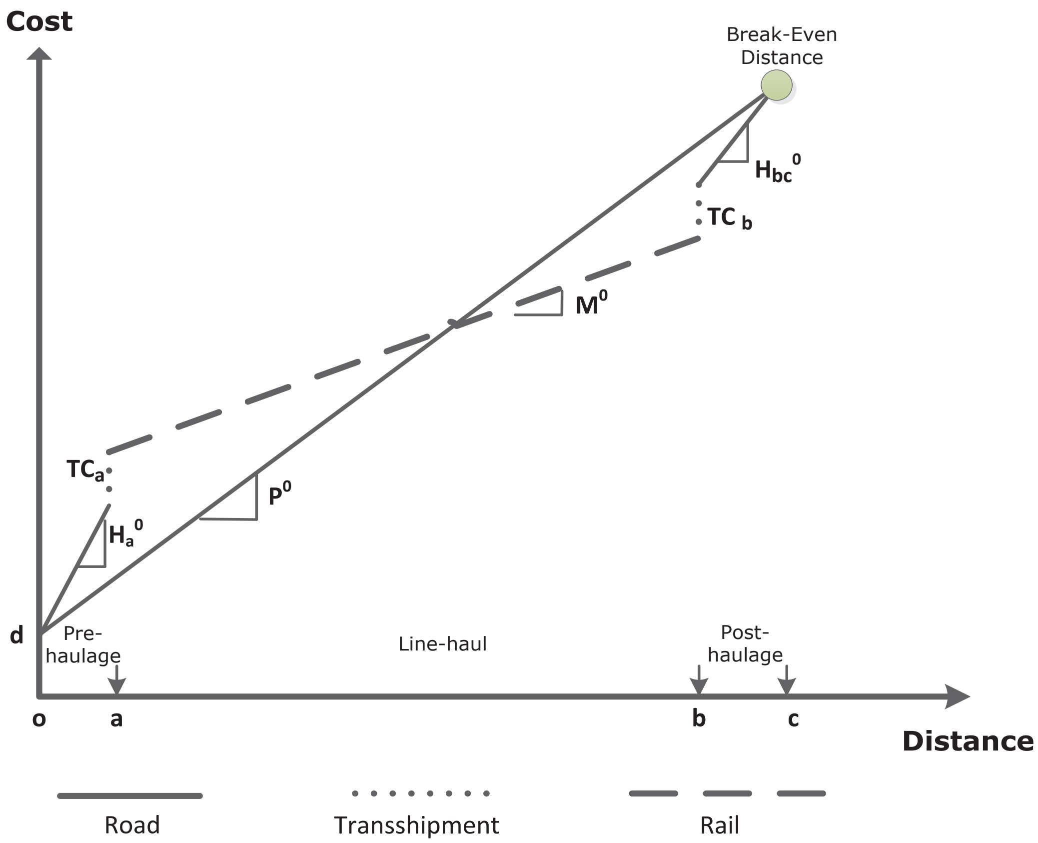

Figure 5 The cost structure of the break-even distance between a road-rail intermodal door-to-door transport chain and unimodal road.

The main cost elements in the intermodal transport chain are the following: pre- and post-haulage by road, the line-haul as well as transshipment at terminals connecting the pre- and post-haulage by road with the train run on the main line. As the transshipment cost is dependent on time and not distance, this cost component composes a larger share of the total cost as the total distance is reduced. A linear relation between cost and distance is commonly observed for unimodal road haulage. The fixed costs for road are represented by $\overline{\boldsymbol{od}}$.The running costs for rail are lower than road i.e. $\mathbf{P°} > \mathbf{M°}$, hence there is break-even point between intermodal rail and unimodal road for the door-to-door transport chain. Albeit the running costs are lower - the volume requirements on the other hand are obviously higher for rail in order to achieve cost-effectiveness, as the capacity of the train is higher. This commonly implies lower frequencies and flexibility for rail freight services compared to road haulage. Principle strategies for making intermodal rail more cost competitive towards road haulage are:

1. Reducing transshipment cost ($\sum_a^n TC$)
2. Reducing the cost for pre- and post-haulage on road ($\mathbf{H_a{}^0}$, $\mathbf{H_b{}^0}$)
3. Reducing rail transport cost on the line-haul ($\mathbf{M^0}$)
4. Increasing costs for road haulage ($\overline{\boldsymbol{od}}$, $\mathbf{P^0}$)

The inclinations of the angles $\mathbf{P^0}$, $\mathbf{M^0}$, $\mathbf{H_a^0}$ and $\mathbf{H_b^0}$ could be reduced as higher degree of cost-effectiveness is achieved by undertaking a range of operational measures e.g. higher degree of loading space utilization and backhauls. Hence conventional rail freight is commonly competitive on long distances and in line-haul relations between two nodes. Obviously, this distance differs between different markets but as indicative number the B-E distance in the Swedish freight market is approx. 350 km. Thus, reducing the transshipment cost is essential for reducing the break-even distance and make intermodal rail competitive on shorter distances. Transshipment is however a sensitive matter, as it is also required to be reliable and uncomplicated in order to reduce the disturbance sensitivity of the intermodal chain, thus testing and validation in demonstration projects are essential when considering novel transshipment technologies.

For rail and intermodal transports to regain market share on shorter distances it will have to achieve this despite the fact that road hauliers are market leaders in this segment; providing shippers service attributes such as cost-leadership, accessibility and flexibility. A number of studies have been conducted regarding shippers' requirements and their stated preferences. (Lundberg, 2006; Crainic & Bektas, 2007) The study of Lundberg (2006) based on survey and data analysis of 99 shippers in Sweden, states the following shipper requirements regarding transportation and ranks them accordingly:

1. Cost
2. Transport time
3. Reliability
4. Punctuality
5. Flexibility
6. Frequency
7. Environmental impact

However, intermodal rail transport suffers for lack of cost competitiveness over short and medium distances as described above. Improvement of the cost-quality ratio of intermodal transport is also needed, due to factors such as lack of reliability, long lead times, low frequencies and limited slots in the timetable. Nevertheless, there are also factors in favour of short haul intermodal rail transport systems e.g. the congestion on the road network, the environmental impact of transportation and the fact that road haulage may require unimodal transshipment for cross-dock activities due restricted road vehicle dimensions in urban areas. However, it is not only certain requirements that shippers base their choice upon - the perception of the performance of the modes and services can have an even higher impact on the overall decision making process (Crainic & Bektas, 2007). Thus, the quality of intermodal transport, in specific regarding reliability and punctuality, has to be ensured for it to be regarded as a feasible alternative, no matter what price is offered. Showcasing once again the need for testing and validation in demonstration projects when considering novel transshipment technologies

7.1.3 Application

<u>*Scenario development and evaluation*</u>

To evaluate the competitiveness of the Assisted RoRo Transshipment concept, a horizontal transshipment technology, the Intermodal Cost Model (ITCM) developed in the studies Kordnejad (2016), (2014) has been updated and used for scenarios defined for the route between the two major cities in Sweden, Stockholm and Gothenburg, with no intermediate stop. The model constitutes of three integrated cost modules; rail operations, road haulage and terminal handling and fully elaborated in (Kordnejad, 2016). In this study ITCM aims at investigating the cost competiveness of Assisted RoRo Transshipment concept.

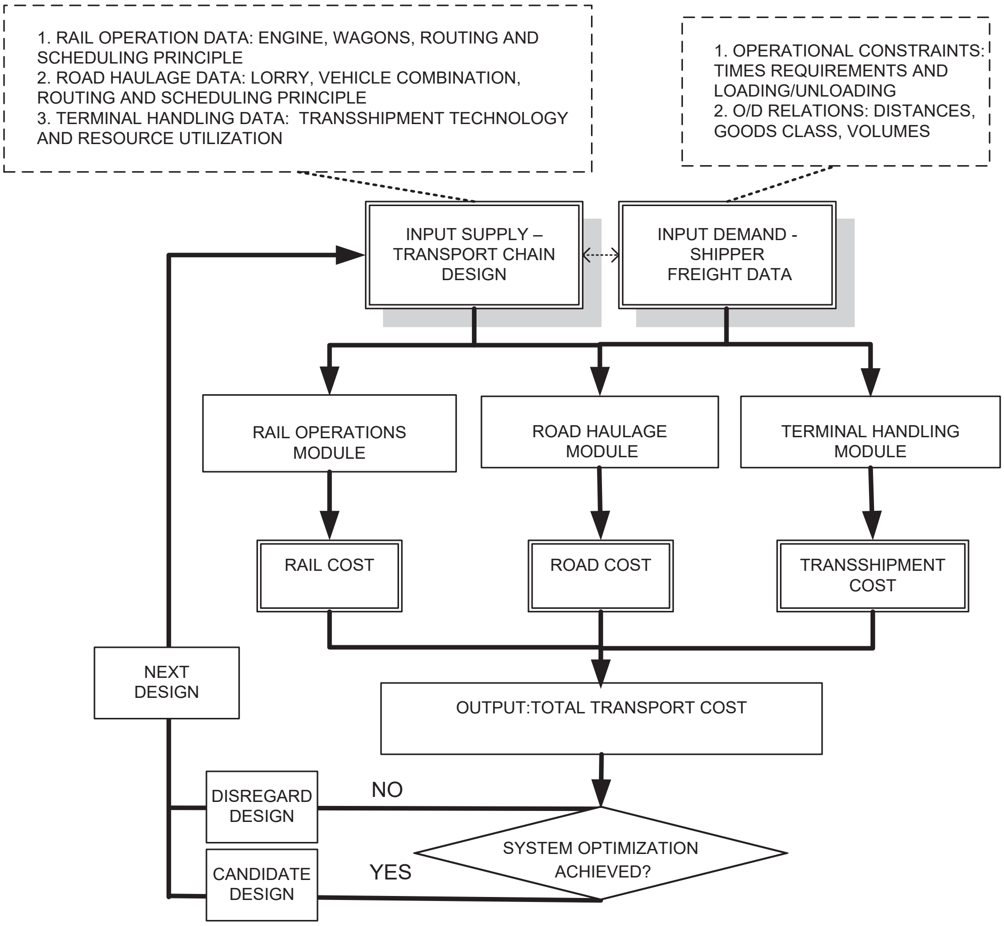

Figure 6. The conceptual framework of 'Intermodal Transport Cost Model' (ITCM).

Figure 6 presents the conceptual framework for the proposed model ITCM – consisting of parallel and serial processes involved with assigning the shipper's transport demand to a given transport chain design. This process consists of two main phases: generating an initial plan that matches the constraints of the demand and to process the demand and supply in the three integrated cost modules. The output generated is the total transport cost for the given transport assignment under the modelled conditions. The intermodal assignment based on route tree would consist of the following basic steps:

1. Generation on direct route legs between all origin and destinations using a unimodal search.
2. Generation of route legs between transfer points using a unimodal search.
3. Construction of route tree.
4. Calculation of costs for all routes and transfer points
5. Distribution of demand on routes.

The total transport cost (TTC) for a combined transport chain would take the following general form:

(TTC) =RC+HC+TC

- RC is the total cost generated by the main haul i.e. rail operations.
- HC is the total cost for road haulage consisting of pre- and post-haulage to terminals.
- TC is total cost for terminal handling, which is mainly derived from the cost per transferred unit associated with the type of terminal.

The system perspective on the logistics processes is a prerequisite in order to avoid sub-optimization on specific business functions or processes, in the case of this study the transport cost. Hence, the impact that the regarded solution has on other processes should be evaluated in order to achieve system optimization for stakeholders. Thus, further studies such as in-depth surveys and interviews with shippers and operators are essential for assessing the feasibility of the concept.

The cost structure calculated in the terminal cost module is based on a model developed in the studies of Nelldal et al. (2012) and Kordnejad, (2016), which has been modified to incorporate the Assisted RoRo Transshipment concept and updated with current values. The basic model is on a highly detailed operational level, however for the sake of clarity only a schematic structure of the categories is illustrated in Table 1. The transshipment cost for three terminal types have been estimated as illustrated by Figure 7. Firstly a conventional reach-stacker based medium-sized intermodal terminal (handling 50 000 TEU's/Year), secondly the Assisted RoRo Transshipment concept has been implemented at an existing intermodal terminal, and thirdly a new small-scale terminal located at a siding using the Assisted RoRo Transshipment concept (handling 15 000 TEU's/Year):

1. Conventional Intermodal Terminal - Medium sized, using reach-stacker.
2. Conventional Intermodal Terminal - Medium sized, using reach-stacker and Assisted RoRo Transshipment at the existing intermodal terminal
3. New small scale Assisted RoRo Transshipment terminal

Table 1 The main structure of the terminal handling module.

Infrastructure
Annuity
Maintenance
Transloading Resources
Annuity for transloading equipment
Operator
Maintenance
Energy Consumption
Shunting
Annuity for shunting engine
Operator
Maintenance
Energy Consumption
Overhead
Total Cost → Transshipment cost/LU

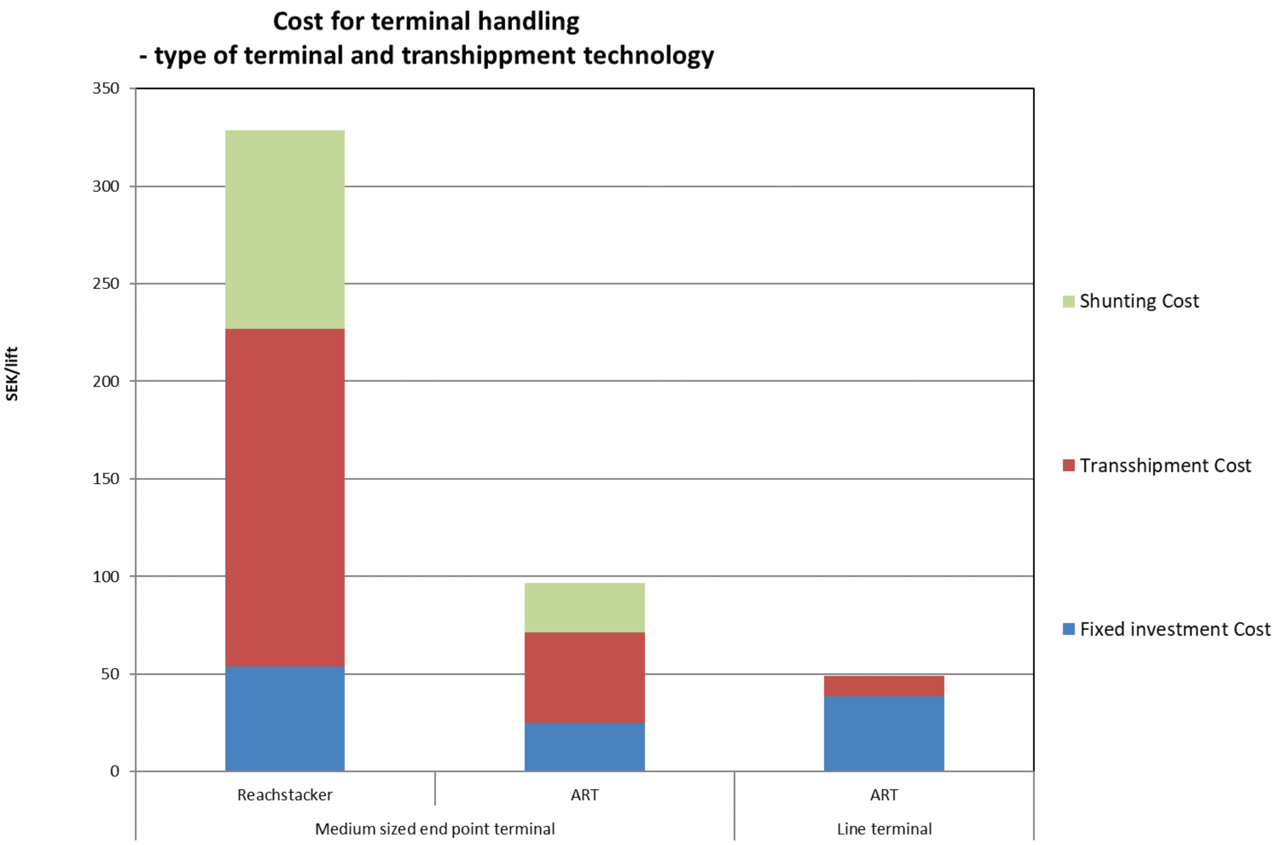

Figure 7 The aggregated cost per transshipment for three types of terminals.

Figure 7 illustrates the results of the compared types of terminals and transshipment technologies, the cost components are categorized as shunting cost, transshipment costs and fixed investment according to Table 1. The left column in Figure 7 illustrates the costs estimated for conventional intermodal terminal using reach stackers, where you commonly have to shunt the wagons to and from the terminal area. The cost for transshipment is relatively high both considering investment and operations as the reach stackers require an operator and imply running costs e.g. fuel, maintenance etc. The associated investment costs are relatively high, both considering the reach-stacker itself, but also the infrastructural costs of the terminal. The second column represents the Assisted RoRo Transshipment concept at an existing intermodal terminal. Here it was assumed that the overhead administrative cost and shunting cost are proportional to share of the area of terminal that the concept would require and thus is assumed to correspond to 25% of the total costs of the terminal. It should be noted that with the Assisted RoRo Transshipment concept, there is no transshipment equipment required apart from the platform the needs to be build, thus resulting in less the 1/3 of the cost of the conventional terminal.

The final scenario is a line terminal located at a siding along the main line. Here you would reduce the cost for shunting and administration compared to having it in an existing terminal, however you would need higher investment costs to implement the terminal. In all, the costs would be further reduced approximately by 50% if the terminal would be standalone line terminal.

Results for Identified Transport Chain Scenarios

The introduced model ITCM has been applied in order to evaluate the transport cost associated with a set of conceptual transport chain designs under Swedish conditions in a route between the two major cities in Sweden, Stockholm and Gothenburg with no intermediate stops planned. The transport assignment of the reference train consists of the distance of 446 km, of which 396 km is transported by rail. The loading factor of the train in terms of number of trailers is assumed to be of 80%. The road distance for the case study corresponds to 470 km and is expected to take 5,5 hours. As input data for estimating the costs for road haulage, data provided by ASEK 2017 (Trafikverket, 2023) has been used. Figure 8 illustrates the results from ITCM for the compared transport chain scenarios.

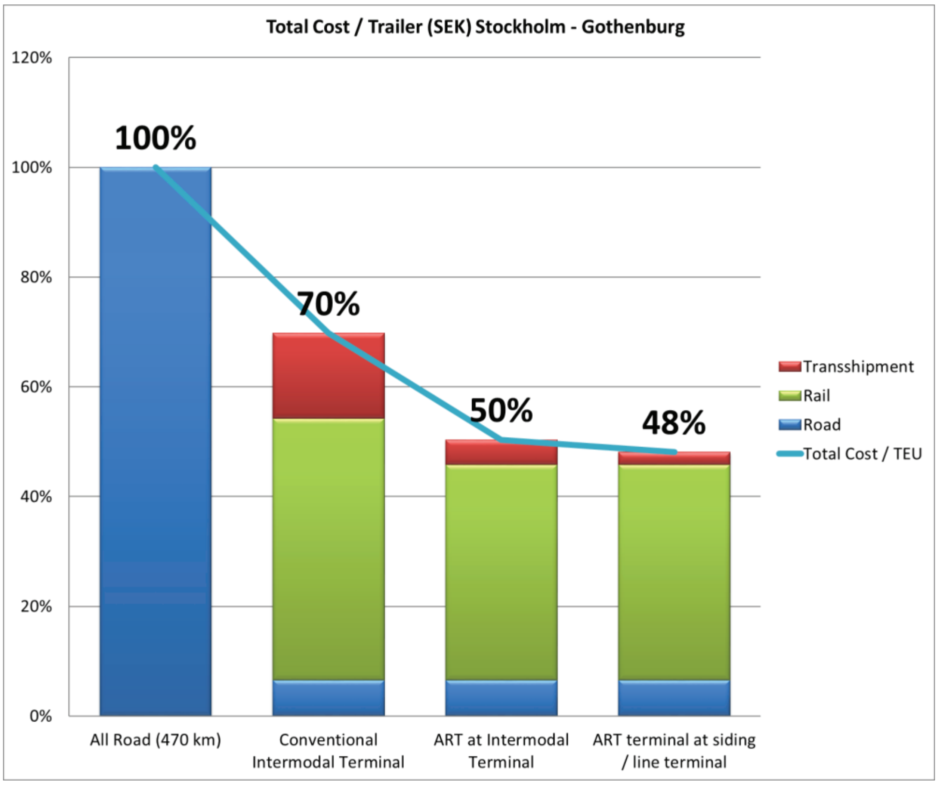

Figure 8 The results from the model on four transport chain scenarios.

The results from the model on the identified transport chain scenarios indicate that the costs for road haulage (estimated to 4209 SEK/Trailer) would be reduced by 30% if using conventional intermodal terminals, 50% if using the Assisted RoRo Transshipment concept in existing terminal and 52% in a standalone line terminal. Note that for scenarios including the Assisted RoRo Transshipment the rail cost is slightly lower compared to the conventional scenario, this due to different types of wagons. For the conventional scenario the wagon Sdggmrss (TWIN) was chosen, a six-axle combined trailer and container wagon with the capacity of two trailers. For the scenarios including the Assisted RoRo Transshipment, where a flat wagon needs to be customized (further described in chapter 4), the wagon corresponding mostly to the requirements of the concept was chosen; a flat two-axle container wagon, Lgnss, assumed to have the capacity of one trailer.

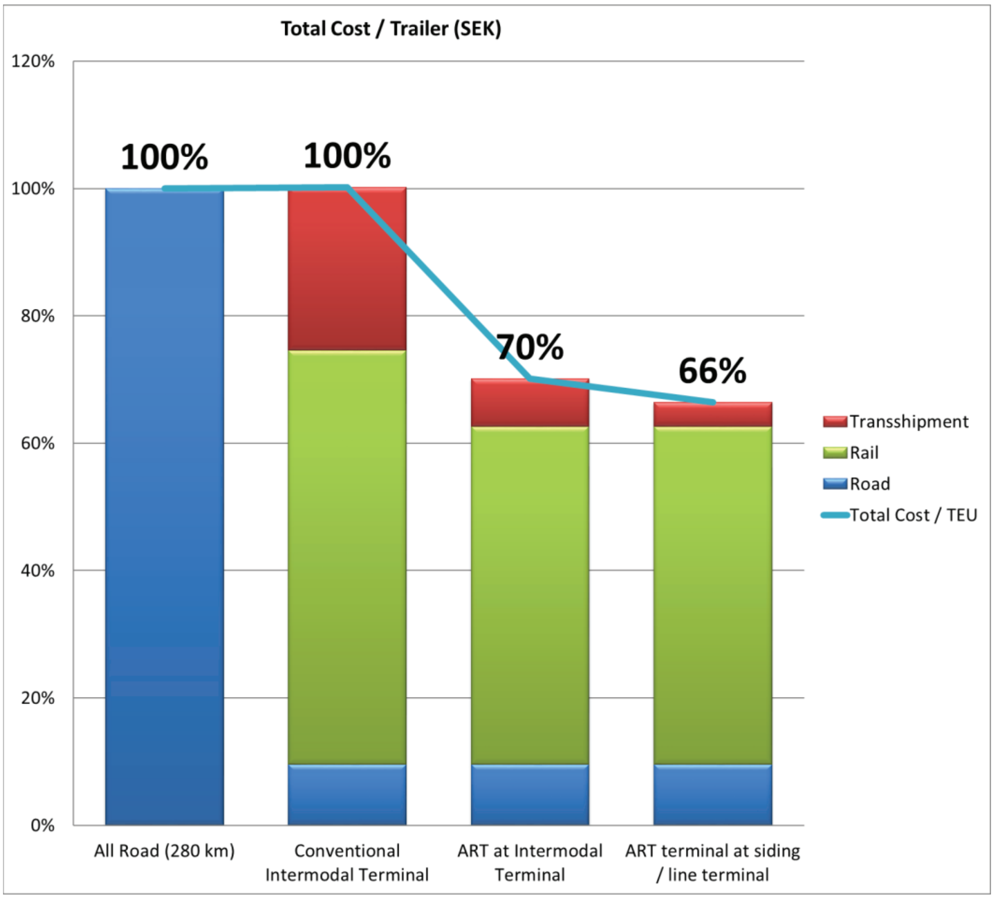

Figure 9 The results from the model on four identified transport chain scenarios at the Break-Even distance between road and conventional intermodal transports.

As a way to validate the results of the model, a break-even distance was searched. As illustrated by Figure 9 the break-even distance between road and conventional intermodal transports corresponding to 280 km, illustrated by Figure 9. This validates the results of this study satisfactorily when compared to previous studies where the break-even distance has been estimated to be around 350 km. Further calibration in particular, updated estimation of wagon costs can improve the accuracy of the results. Note that the break-even distance is subject to multiple design choices such as route choice and type of vehicles (truck, locomotive and wagon type) as well as the considered the loading unit, in this case semi-trailers.

7.1.4 Identified further research needed

In WP1, the components of the intermodal transport system have been addressed and how the concept could widen the market of intermodal transports through enabling transshipment of non-cranable trailers at relatively very low cost. However, further studies are recommended in order to fully address the concept's compatibility with present transport flows.

As for the behavioural aspect, this study has relied on literature review and previous studies regarding shipper's preferences when it comes to mode choice. Further studies could design surveys specifically for this concept. This can also be complemented with further in-depth interviews with experts. Thus, the scenario evaluations and the reference group workshop carried out within this study can be complemented extended in-depth expert interviews and market survey. The scenario assessment could also be further improved and calibrated through feasibility studies and working further on the assumptions made, e.g. regarding the split of cost if the concept is implemented at an existing terminal and the cost for the customization of the wagon.

As for the application of the concept, the quality of intermodal transport, in specific regarding reliability and punctuality, has to be ensured for it to be regarded as a feasible alternative for shippers, no matter what price is offered. This shows the need for testing and validation in demonstration projects of novel transshipment technologies. Hence, a full scale demonstrator in order to investigate the operational stability of the system would be recommended.

7.2 WP 2: Feasibility study

This section presents a feasibility study primarily related to risks, approvals and authorization needed for an FSDP as well as for a final full implementation. In the below, relevant risks from different perspectives are discussed in view of implementations of the concept for Assisted RoRo Transshipment. Further, a review of applicable regulations and approval processes for the implementation of new technology related to CT is made. In particular regulations and processes related to a temporary adaption of railway technology for a limited time demonstration is discussed.

7.2.1 Risks to consider in view of full scale demo project

Risks are inherently involved in the transshipment of trailers between rail and road, as well as in the transport of trailers on railway wagons. In the paragraphs below, the risks to consider in view of an FSDP are reviewed from various perspectives, in particular risks of accidents related to technology and operations. Also risks related to other perspectives are discussed briefly. Relevant measures to mitigate various risks are proposed in the end of this section.

Risks related to new technology

As mentioned above, risks and in particular risk of accidents are inherent in CT handling. Much of the risks related to the established technology that is applied in CT operations today has been subject to "the test of time" and safety standards and relevant processes are well established. The introduction of new technology thus introduces new risk that initially have not been subject to the same tests and empirical learnings. The essential technology introduced with Assisted RoRo Transshipment can be split into: Assistance system, Trailer securing system and low loading area on the wagon acting together with a transshipment platform beside the railway tracks to form horizontal manoeuvring surface.

The assistance system comprises high tech components with assistance software, sensors, driver presentation and connectivity. To avoid misalignment, incidents and accidents during transshipment it is essential that the assistance system delivers easy to use high precision manoeuvring assistance in all situations and with durability over time, despite a sometimes demanding environment. These risks are relevant both for an FSDP and for a full implementation.

The trailer securing needs to be reliable to avoid accident risks. Retractable kingpin holders of the type needed for Assisted RoRo Transshipment is not common in Europe. The technology has however been used extensively in the US since several decades. The solution needs to be developed and adapted for use in a European environment and well-integrated in a new railway wagon structure. From a technical perspective this is one of the most critical items to be well executed.

A platform beside railway tracks is not a totally new structure, but the purpose and use suggested are unusual at present CT terminals. There are two basic ways of designing a suitable loading platform beside the tracks, either a) an elevated platform rising above the surrounding terminal area, or b) railway tracks lowered in relation to the surrounding terminal area. It should be noted that the ground carrying capacity needed for a tractor and trailer combination is considerably than the requirements for a much heavier reach stacker. At terminals where transshipments by reach stackers and Assisted RoRo Transshipments are to be used in parallel, it is of essence to 1) either prepare the ground all over for reach stacker requirements, or 2) if the elevated platform close to the tracks is only prepared for the limited requirements of tractor-trailer combinations, to make sure that reach stackers do not enter areas with too low carrying capacity, in particular close to the tracks.

Operational risks including transshipment process risks:

From the perspective of the transport process the following potential risks have been identified. The risks are treated in process order. 1) Tractor and trailer moving to loading platform through terminal, 2) loading of trailer on railway wagon, 3) transport of trailer on railway wagon, 4) off-loading of trailer from railway wagon, 5) tractor and trailer leaving train through terminal.

1) *Tractor and trailer moving through terminal:*
   There is a specific risk, in particular on larger terminals, with having persons (here truck drivers) not trained in terminal safety risks and procedures and not used to local procedures and terminal lay out moving in a terminal area without restrictions.
2) *Loading of trailer on terminal wagon:*
   The loading procedure is a risky process in a sensitive environment with risks. If the loading process is not performed carefully and correctly and if suitable assistance and safety means are not present, a number of incidents may occur.
   a) The trailer may interfere with other wagons and trailers loaded during the loading procedure.
   b) The trailer may be misaligned and not centrally mounted on the wagon. Thereby problems of correct securing of the trailer may be prevented and/or the trailer may extend outside of the loading gauge.
   c) The trailer may even be rolled over the wagon and rolled off the wagon on the "other side" of the wagon.
   d) There is also a jack-knifing risk for the tractor and trailer combination.
   e) A further risk is also that the tractor is run backwards over the wagon past the intended position for parking the trailer, to partly or fully fall off it and thus also cause the trailer to fall off the wagon.
   f) Any incidents involving tractor or trailer fully or partly falling off a railway wagon could also cause the railway wagon to loose horizontal stability sideways or even tip over and/or cause damages to connected wagons and their load.

g) After disconnecting the tractor from the trailer, with the tractor fifth wheel still present under the trailer further a risk that the fifth wheel engages with the lower part of the trailer.

3) *Transport of trailer on railway wagon:*
   The two main risks are trailer interfering with any objects or structures beside the rail or even falling off the wagon. This may as indicated above be caused by mistakes in the loading process or securing equipment not properly working.
4) *Off-loading of trailer from railway wagon:*
   The off-loading of trailers comprises risks similar to the risks at loading. A particular risk is related to the connection procedure, where the tractor is moving backwards on the wagon in transversal direction engage the tractor fifth wheel with the corresponding king pin of the trailer. During the engagement a sideways force is exercised on the front portion of the trailer causing risks for tractor and trailer to jackknife, move outside of the wagon or even fall of.
5) *Tractor and trailer leaving train through terminal:*
   Risks when leaving through terminal are similar as for arriving via terminal.

Other risks

In addition to the above financial as well as legal and regulatory risk have been identified. Connected to the above mentioned risks related to damages at terminal/loading or damages during train transport there is of course a financial risk, which can be translated to a corresponding insurance cost. There is also a corresponding risk related to legal and regulatory requirements. If requirements for putting a railway wagon on rail, for securing a trailer on a railway wagon are not fulfilled, legal and financial risks may also be considerable. Any failure in ensuring that staff involved are well educated in handling according to the tested concept, may have similar consequences.

From a general business risk perspective, it should also be recognized that all investments in capital intensive industries are related to specific risks. This applies in particular to railway investments, such as in rolling stock and railway infrastructure, that need to be productive over long time to provide a relevant return on investment. Any successful implementation of new concepts in railways requiring such investments, must take this into account and secure good business prospects for any stakeholders expected to make substantial investments.

How to mitigate the identified risks

Given the above overview of risks involved related to a full scale demo project, it is critical to:

1) Secure that the technology for Assisted RoRo Transshipments provides precision, safety and reliability in all situations and is well tested.
2) The process is well tested and that all stakeholders are well trained in relation to all potential risk involved.
3) Secure that all legal and regulatory requirements are fully understood and are always adhered to.

Even though it is noted that an FSDP, as well as a full scale implementation, entails risk, it should also be noted that no risks of a magnitude that would prevent the feasibility of an FSDP have been identified.

7.2.2 Regulations, approvals and authorizations

As noted above it is of essence to secure that all legal and regulatory requirements are understood and adhered to. In this section a brief overview of applicable legislation and regulations, important authorities and bodies, processes for approvals, and relevant safety requirements are described and discussed in the perspective of an implementation of the Assisted RoRo Transshipment concept.

Applicable laws and regulations and relevant authorities

Railway traffic in EU is regulated by EU regulations and by national laws. In Sweden railway traffic is regulated by the Swedish Railway Law, *Järnvägslagen* (SFS 2004:519) and the Swedish Railway Regulations, *Järnvägsförordningen* (SFS 2004:526).

Within the EU common directives and regulations are present, which is also apparent in national law and regulations, to secure commons standards and interoperability cross national borders, e.g. the *EU directive on the interoperability of the rail system within the European Union* (Directive 2016/797), the *EU regulation concerning the technical specification for interoperability relating to the subsystem 'rolling stock — freight wagons' of the rail system in the European Union* (Regulation 321/2013) and the *EU regulation establishing practical arrangements for the railway vehicle authorisation and railway vehicle type authorisation process* (Regulation 2018/545). In particular Technical Specifications for Interoperability, TSI, related to rolling stock provide relevant regulations and specifications relevant for the implementation of Assisted RoRo Transshipment in the EU.

The European Union Agency for Railways, ERA, manages railway matters and act as the European Authority issuing vehicle (type) authorisations and single safety certificates. In Sweden, the Swedish Transport Agency (Transportstyrelsen) is responsible for regulations and approvals in relation to railway matters.

Introduction of new technology in railway traffic

In the following a high-level overview of relevant processes for the introduction of new technology such as a new or amended railway wagons. The Swedish Transport Agency provides a good overview of relevant regulations and requirements on its website, including instructions related to technical approvals (Transportstyrelsen, 2023).

Applications to put a new, remodelled or modernized wagon in operation are as a general rule filed with the European Union Agency for Railways, ERA:s , workshop "One-stop-shop", but for certain situations concerning only Sweden, the Swedish Transport Agency may also be an option. The application is filed, together with necessary certificates. These certificates are used to point out the fact that the wagon should be approved and follows the rules and laws.

In view of introducing a new type of vehicle it is preferable that the applicant starts the process, before the formal application, by handing in an application for advance handling to the Swedish Transport Agency, ideally in the early stages of the project. The result of the pre-handled application will be a comment, statement or opinion from the ERA or the Swedish transport agency.

The authorities, ERA & the Swedish Transport Authority, have authorized Designated Agencies to review new solution and provide certifications of conformity with requirements.

Notified Body, NoBo, is a review agency specializing in reviewing products and infrastructure, in hope of approving and certifying them for use in EU. NoBo reviews and examines how the product agrees with TSI in EU.

Designated Body, DeBo, is a reviewing agency which examines how the product agrees with the Swedish Law.

Assessment Body, AsBo, reviews how the CSM, common safety methods, is implemented.

It is the responsibility of the applicant to request the certifications needed from the relevant designated Bodies to complete the application. When the review agencies have made their assessment the applicant can send the complete application to the ERA:s One-stop-shop. If the wagon only will be in used in Sweden and on the Swedish railway, the choice to have the application handled and approved by the Swedish Transport Agency is made in One-Stop-Shop.

Specific rules are applicable for test driving of vehicles. To be able to test-drive the wagon or vehicle in Sweden, an application for test-drive should be filed with the Swedish Transport Agency. The applicant will receive technical requirements and how the application should be complemented. The Swedish transport agency does charge the applicant for the application. Thereafter, the applicant should hire designated agencies, to review the project.

To add new or remodelled infrastructure, which may be applicable for platforms/loading quays beside the railway tracks, to the Swedish railway one must apply for approval to the Swedish Transport agency. The application is to be filed during the early stages of the project, and can be complemented step by step.

Conclusions in view of an FSDP

What does this mean in relation to an FSDP regarding the Assisted RoRo Transshipment concept? In relation to a potential use of an existing railway wagon provisionally adapted for transport of trailers, there is an opportunity to rely on the rules regarding test driving for an FSDP. The level of approval efforts needed is difficult to fully predict at this stage and will be related to a number of factors related to the change of use of the wagons and the adaptions performed.

7.2.3 Safety Requirements for inter modal traffic

Requirements for loading an inter modal unit

In the Instruction for Loading Inter modal Units (Tågföretagen, 2020), the Swedish railway industry and employer organization Tågföretagen describes how to load an Inter modal Unit including which safety regulations to follow. The instructions correspond to instructions from UIC, the international union of railways.

The report includes among other instructions for loading of trailers. In summery different types of inter modal units come with their own safety measures.

Requirements on transshipment personnel

The Swedish Transport Agency has the supervising responsibility the area of loading and securing the load of semitrailer on railway wagons, therein relying on recommendations from ERA. Transport companies have the responsibility to secure that everyone involved and working with transport of goods on the railway have both theoretical and practical knowledge. In Sweden the driver of a truck is responsible that the goods are safety loaded. In several European counties the responsibility for the loading security is divided between the sender, transporter and or the driver. When securing the trailer on a railway wagon the person responsible for loading the trailer is responsible for the safe securing of the trailer.

Conclusions in view of an FSDP

In relation to an FSDP regarding the Assisted RoRo Transshipment concept, it is underlined that clear process description are needed, in line with ERA's recommendations, and that all staff involved in an FSDP has all relevant theoretical and practical knowledge.

7.3 WP 3: Full scale demo project (FSDP) planning

7.3.1 Defining the scope of the FSDP

There are various opportunities available for full scale testing, involving different investment levels and different opportunities to test from different perspectives. In one end of the demonstration spectrum would be providing a test environment where the transshipment method can be tested in full scale with a trailer being loaded onto or off from a mock up railway wagon top, equipped with necessary means for assistance and safety. In another end of the demonstration spectrum would be an implementation of full train with 35 or more wagons as a shuttle between to end terminals and having one or more in-line terminals in between. There are then also various alternatives in between these two extremes, as will be discussed below.

Perspectives of system innovation

For best evaluation and demonstration, we suggest all components related to systems innovation, as defined by Vinnova (2023), are reviewed for best evaluation and understanding of opportunities to implement in large scale, i.e. a) technology, products & processes, b) business models & procurement, c) policy & regulations, d) behaviour, culture & values and e) infrastructure. Below relevant topics to demonstrate and test are discussed for each of the perspectives.

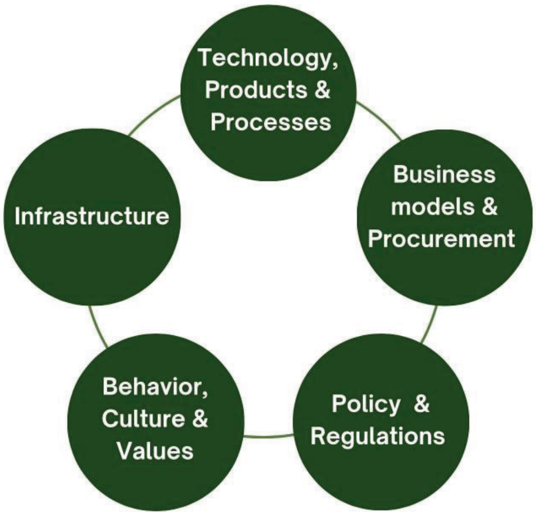

Figure 10 Perspectives of system innovation:

Technology, Products & Processes

In this perspective it is relevant to test and demonstrate various aspects of the technology. Specific items to demonstrate would be:

- Applicability of assisted precision driving used for the loading and off-loading of trailers onto or off from railway wagons. –
- Applicability for different tractors and drivers.
- Will the correct positioning of a trailer be achieved consistently, safely and with relevant speed?
- Will the railway wagon design interact with a trailer being loaded or off-loaded as expected?
- Can all risks at terminal and on rail be managed and mitigated effectively?

Business model and procurement

Even though CT is a well-established practice, in relation to a present long distance truck transport, the shift to CT is in itself another business model with higher administration as more actors and transport modes are involved. Also in relation to present combined transport offerings on the market, Assisted RoRo Transshipments, with its opportunities to connect different vehicles and actors may impact the suitability of different business models. Perspectives to evaluate include:

- How can the concept be integrated in present purchasing models?
- How can the connection of actors and relevant data be used for new business models to increase efficiency in the procurement of combined transport services?
- What is a suitable chain of cost transactions in a combined transport chain?
- For which goods and transport needs is the concept suitable?
- To what extent can the concept increase the attractiveness of combined transport for various goods and situations?
- How large is the market for non-liftable trailers

Policy and regulations

Regulations have been discussed above. An evaluation from this perspective would in particular consider:

- What specific challenges are provided for implementation of the new concept?
- What are the specific requirements for securing trailers on railway wagons?
- Can implementation of more competitive CT increase the general attractivity of railway transports?

Behaviour, culture and values

Trucking is in many ways the norm for long distance transportation today. Combined transports are in many situations – and for different reasons - not even considered. With that background, relevant questions to evaluate would include:

- Are present buying behaviours and perceptions related to railway transports a problem to overcome?
- How well are railway and trucking transports connected?

Infrastructure

Infrastructure is an extremely important perspective to evaluate. Key questions would be:

- What demands are to be put on terminals?
- How can the system integrate in present terminals? –
- How can new low-cost terminals change the attractiveness of CT?
- What impact does the need for new railway wagons have on implementation and scalability.

<u>Options and evaluation</u>

In the following options for perform an FSDP are described and evaluated.

Railway wagon options

The railway wagon design has large impact of the implementation of Assisted RoRo Transshipments. The loading gauge available in Europe sets limits on the height of a loaded railway wagon. The maximum loading floor height for CT transports of Trailers in Sweden is 830 mm. No suitable wagons with a low flat loading area open for horizontal loading from the wagon side and with suitable means for securing a trailer on the wagon during transport are to our knowledge available in Europe.

One railway wagon design for horizontal loading longitudinally from wagon short end has been designed by TrailerTrain Niart AB, see Figure 11. The wagon has suitable measurement for running on Swedish rail, including a loading height of 800 mm, and is prepared for holding a loaded trailer during transport. The wagon is however not yet on the market and would need final product development and manufacturing to be available for implementation or demonstration.

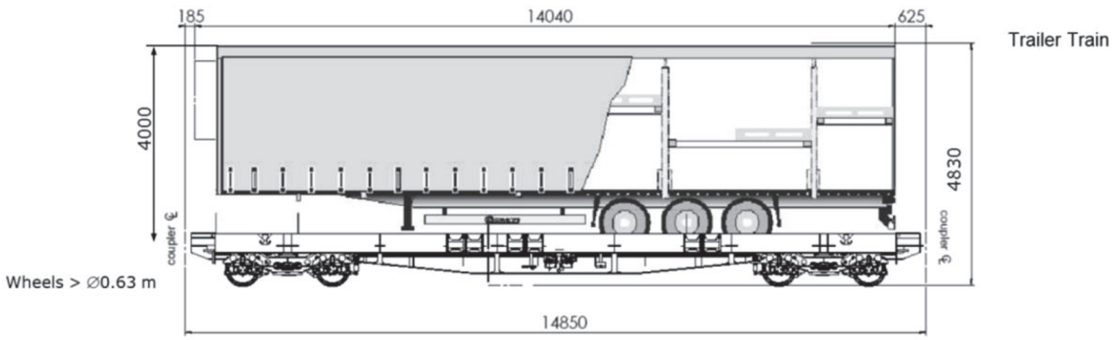

Figure 11 TrailerTrain wagon with a loaded trailer. Source: Bärthel, 2011

Various other low built wagons are available on the market and can likely be adapted for test and demonstration. Below are some options available on the market presented.

Greenbrier, FKA 2 x 50´, 8-axle container wagon (megafret) (Greenbrier 2022), presents an intermodal wagon with loading height 820 mm and a loading length well exceeding trailer length (13,6 m).

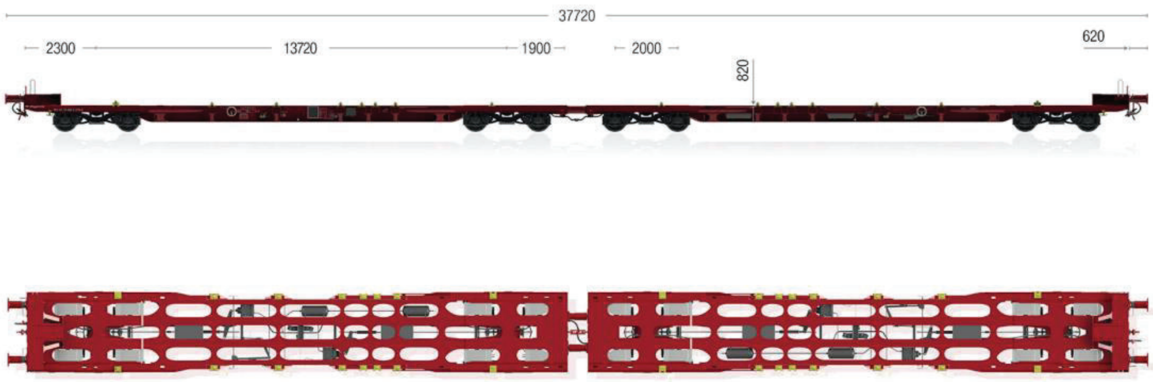

Figure 12 FKA 2x50. Source: Greenbrier, 2022

Greenbrier, Sffggmrrss, 8-axle short coupled intermodal wagon (Megafret) (Greenbriar, 2023a), represents a wagon similar to the one above. The wagon has a loading height of 825 mm and a loading length that should be enough for two trailers, even though it is somewhat shorter than the example above.

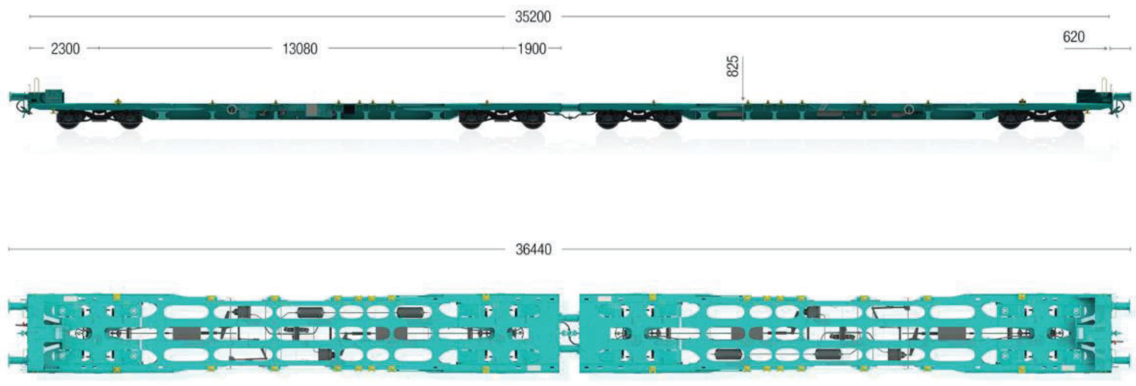

Figure 13 Sffggmrrss 8-axle short coupled intermodal wagon (Megafret). Source: Greenbriar, 2023a

Greenbrier, Laads L09A, 2×2-axle flatbed wagon with lowered floor (Greenbrier 2023b), is a wagon designed for special vehicle transports with a loading height of 800 mm that would likely work to transport one single trailer.

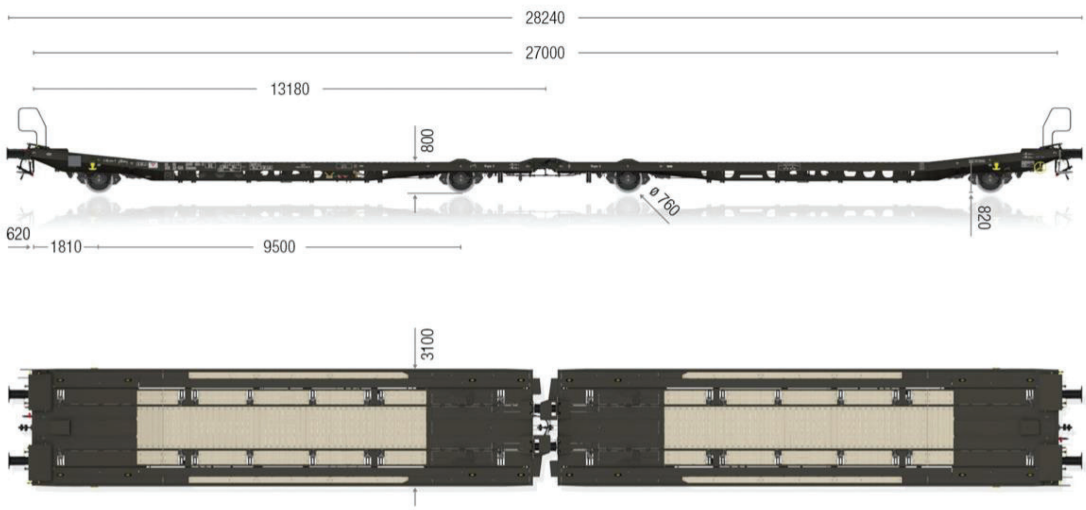

Figure 14 Laads L09A | 2×2-axle flatbed wagon with lowered floor from Greenbrier. Source: Greenbrier, 2023b

Tatravagónka, Laados 6 axle, 3 segment wagon (Tatravagónka, 2023) is wagon designed for transport of truck tractors, having a loading height of 700 mm, providing a possibility to carry two trailers.

Figure 15 Laados 6 axle, 3 segment wagon from Tatravagónka.. Source: Tatravagónka, 2023

In the US, there is since long a practice of transporting trailers on flat railway wagons, TOFC (Trailer On Flat Car), (Troche & Carrillo Sanuy 2010). These wagons have a flat loading area and means for holding the trailer secured during transport. Presently transshipment is performed through lifting, similar to the European practice related to pocket wagons.

Figure 16 TOFC (Trailer On Flat Car) in US. Source: Troche & Carrillo Sanuy, 2010.

7.3.2 Different FSDP options

It is easily realised that a number of opportunities are available and that a suitable cost/benefit relation should be sought. The demonstration options analysed have been:

1) A “mock up” railway wagon top/loading area beside a platform/area on the same level as the “wagon top”. The “wagon top” would be adapted with all objects such as side supports and sensors. A tractor would be equipped means to receive assistance during precision maneuvering of a trailer. The demonstration would demonstrate the performance of the assistance.
2) “Minor full scale”: One (or possibly a few more) wagon (-s) adapted (possibly temporarily adapted) for the concept and put into traffic in an existing intermodal shuttle, with two terminals adapted for horizontal transshipment.
3) “Full scale”: A full intermodal shuttle ca 35 wagons, established between two endpoints, full terminals, and having at least one intermediate terminal.
4) “US-TOFC”: A demonstration in the US using one or more existing wagons adapted for the transportation of trailers (Trailer On Flat Car). This would require adapting one or more wagons for assisted transshipment from the side and adapting one or more terminals.

The demonstration options 1)-3) may also be regarded as demonstrations on different readiness levels, in relation to technology as well as other perspectives, see illustration in Figure 14. Demonstration option 4) may also be regarded as an alternative to demonstration option 2). Even though results from option 4) are more relevant for a US market than for a European market, the results therefrom may be relevant for both markets and may be a cost efficient alternative to option 2).

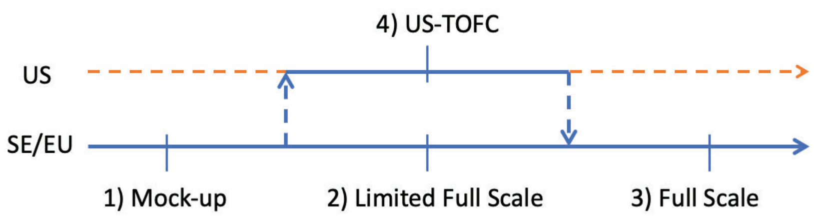

Figure 17 Alternative demonstration options on the path to implementation

Evaluation

Each of the demonstration options 1-4 has been evaluated in relation to each of the five perspectives as described above. An overview of the outcome is indicated in the table below. The expected outcomes of each of the demonstration options are also discussed below, in relation to the different perspectives as well as high level estimations of expected cost.

Table 2 Evaluation of FSDP alternatives

Evaluation Matrix		Mock up	Limited Full scale	Full Scale	US TOFC
Technology, product & process	Assistance system	Tested	Tested	Tested	Tested
	Wagon top design	Tested	Tested	Tested	Tested
	Wagon on rail	Not Tested	Tested	Tested	Tested
	Risks at terminal	Not Tested	Partly Tested	Partly Tested	Partly tested
Business model & Procurement	Integration of CT business model	Not Tested	Partly Tested	Tested	Partly tested
	Increased efficiency in procurement	Not Tested	Partly Tested	Tested	Partly tested
	Suitable chain of cost transactions	Not Tested	Partly Tested	Tested	Partly tested
	Suitable for which needs	Not Tested	Partly Tested	Tested	Partly tested
	Ability to increase CT attractiveness	Not Tested	Partly Tested	Tested	Partly tested
	Market for non liftable trailers	Not Tested	Partly Tested	Partly Tested	Partly tested
Policy and Regulations	Challenges for implementation	Partly Tested	Tested	Tested	Partly tested
	Requirements for securing trailer	Party Tested	Tested	Tested	Partly tested
Behaviour, Culture & Values	Overcoming present perceptions	Not Tested	Partly Tested	Tested	Partly tested
	Integration trucks - trains	Not Tested	Partly Tested	Tested	Partly tested
Infrastructure	Demands on terminals	Partly Tested	Partly Tested	Tested	Partly tested
	Integration on existing terminals	Partly Tested	Partly Tested	Partly Tested	Partly tested
	Importance of low cost terminals	Not Tested	Partly Tested	Partly Tested	Partly tested

A demonstration on a Mock up of a railway wagon is expected to give a good test and demonstration of the assistance technology (software, sensors, connectivity) as well as physical interaction between trailer and wagon top. The demonstration may also give some relevant information regarding the physical installations from a policy and regulations perspective. Requirements on the terminal at wagon side is also expected to be tested, but not regarding other requirements on terminal. It does neither test nor demonstrate any perspectives related to business model & procurement, nor any perspectives relating to behaviour, culture and values. The development costs for providing relevant demonstrations on a mock up is expected to be in the range MSEK 2-5.

A demonstration with a limited full scale implementation is, in addition to learnings from a “mock up” also demonstrating technology and behaviour on rail and to some degree (depending on the execution) trailer management on terminal. To some degree also the business model and procurement will be demonstrated, as the service would be subject to commercial transactions, even though in limited scale. Behaviour, Culture and Values will in a similar way partly be demonstrated. The perspective policy and regulations will partly be demonstrated as the system will be in commercial use and regulations and safety requirements will have to be handled.

In addition to development costs of at least MSEK 5 for the technology, the costs for a limited full scale demonstration is expected to be ca MSEK 4-5.

A full scale implementation would over time enable demonstration out of all perspectives. The extent to which various perspectives related to terminals are tested will depend on which types of terminals are included in a first full scale implementation. Also, the degree of demonstration of the concept in the perspective behaviour, culture and values depend on where and how the concept is implemented.

The costs involved in a full scale implementation including development cost and costs for 35 wagons is expected to be in the range MSEK 80-100

A demo implementation on one or more existing wagons (TOFC) in the US can be compared to demo option "Limited full scale implementation". Some perspectives relevant to Europe may be missed, but the cost for an implementation is expected to be possible at lower costs, as less technology development and approvals are needed for trailer securing and allowance of wagon in traffic. A rough estimation is that the cost, in addition to the initial tech development in the first phase would be in the range MSEK 1-2.

Given the above discussion, the proposed most suitable FSDP level is option 2) Limited full scale implementation, as the cost/benefit ratio appears to be most favourable. The focus for the project planning below will be on a limited full scale implementation. As a preceding mock up demo and a succeeding full scale implementation are relevant steps, general costs and activities related thereto are also indicated. It should also be noted that variations can be made and that perspectives that are not directly tested may be subject to parallel survey and similar on the back of the FSDP, to broaden the learnings.

Further demonstration option – simulation

Rail freight transports a vital component of the worldwide logistics business, requiring efficient and secure operations. Advanced technologies such as simulation can be used to improve these activities and test specific parts of concepts and systems without or before a full- scale real life demonstration. Tools such as AnyLogic simulation software can be used to improve rail freight movements and enable comparisons of between theoretical scenarios and concepts.

AnyLogic is a simulation program that is commonly used for modelling and evaluating transportation systems. In modern simulation modelling there are three main approaches: system dynamics, discrete event and agent-based modelling. All three modelling approaches have their own tool set, unique features, strengths, and weaknesses. The choice of method should be based on the system under study and the purpose of the modelling. However, due to the fact that most real-world cases are too complex to be modelled with one method, it is often convenient to describe different parts of a system with different modelling approaches. A combination of approaches provides the opportunity to create an accurate and multi-functional model of a system without any workarounds. Thus, researchers and decision makers can create and test models of various system designs and answer a range of "what-if" questions, all by virtually experimenting in a risk-free environment. Thus, users may effectively model, simulate, and visualize the operations of rail yards and rail transit of any complexity and size thanks to the AnyLogic Rail Library. This library can be used to model classification yards, railway stations, rail wagon maintenance facilities, subway stations, airport shuttle trains, and even tram networks. Additionally, it aids users in fleet management, maintenance scheduling, and operations planning. Its multi-method modelling methodology enables the development of models that capture the intricacies of rail operations. (AnyLogic, 2023).

7.3.3 Project resources planning

This section presents an overview of a project plan for implementation of an FSDP related to a Limited Full scale Implementation together with a discussion of relevant considerations. The purpose of the plan is to serve as a relevant starting point for a future FSDP detail planning and execution.

The suggested starting point for the project plan is that the technology is sufficiently developed to be demonstrated on a mock up railway wagon top. As an FSDP alternatively could start already with development of technology, a brief overview of a preceding technology development project is also presented. Similarly, as the ultimate goal is a full scale implementation, some thoughts on requirements for such an implementation are also shared below.

Overview of a suggested FSDP project plan

The suggested project is split in three phases, a preparation phase, an execution phase and a restoration phase. The suggested time frame is 8 months, 3 months of preparation, 3 months of execution and 2 months of restoration. A visual overview is presented in Figure 18 below.

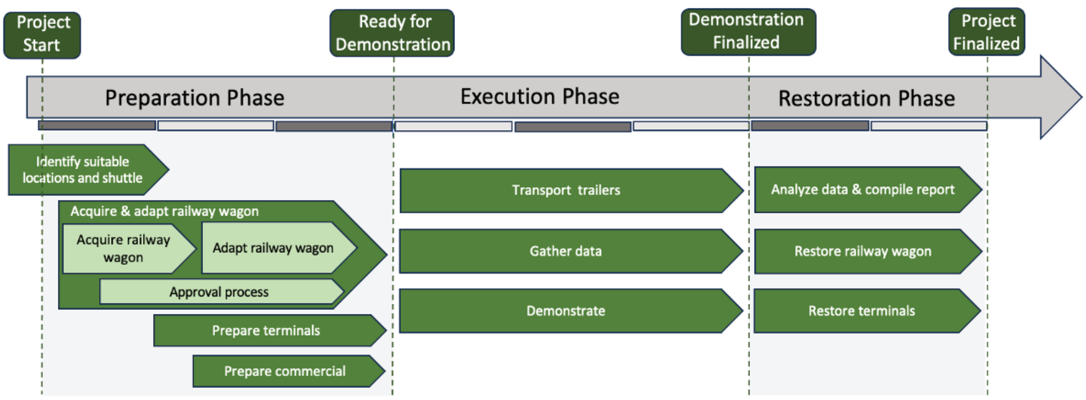

Figure 18 Overview of FSDP plan

The suggested project outline comprises four key milestones, project start, ready for demonstration, demonstration finalized and project finalized, as will be described in more detail below.

Overview of the preparation phase

The preparation phase has as its purpose to secure that the execution can start and be run as smooth as possible. Requirements for starting is apparent from Figure 19 below. Two of the most critical requirements are that the technology, the assistance system, has reached a certain readiness level, and that relevant stakeholders, in particular a railway operator, shows interest in pursuing the FSDP.

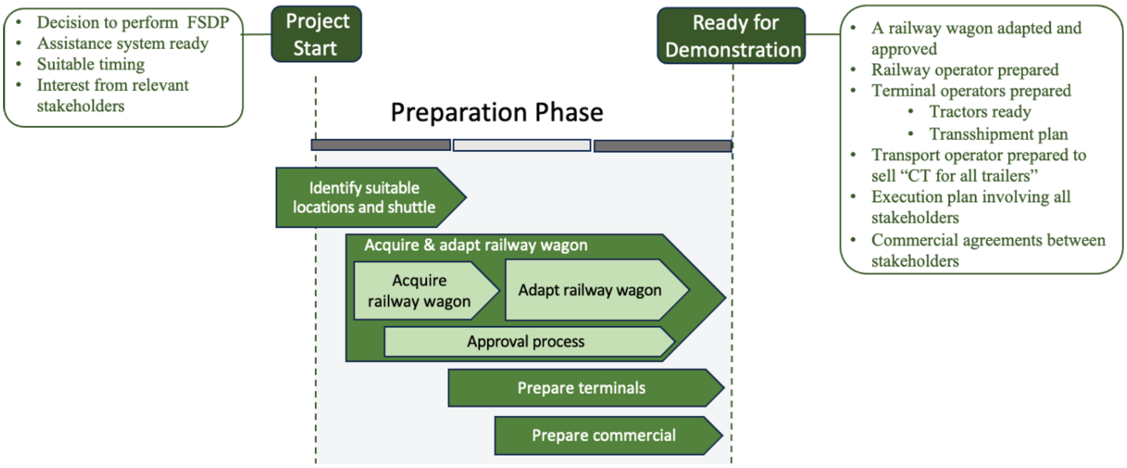

Figure 19 Overview of the preparation phase

The deliverables are of course technology and infrastructure ready for Assisted RoRo Transshipment. Due to the risks and cost involved, it is in particular critical that all processes are in place and that there are clear agreements between all stakeholders involved, before any execution is started.

Overview of the execution phase

In the execution phase the main activity is to load, shipped and off-load trailers. It should be noted that, there is likely to be an added cost and time involved in the Assisted RoRo Transshipment, as negative impact on the regular transshipment of trailers should be avoided. The extra efforts involved may differ, depending on how and where the platform for Assisted RoRo Transshipment is placed on or near the terminal.

In addition to the "regular" transshipment and transport of trailers, two other activities are relevant to perform. The transshipment process performance needs to be logged and measured throughout the execution phase, by the persons involved regularly as well as through specific studies. The demonstration also needs to take place, which in addition to general communication activities is suggested to be performed through scheduled demonstration events and good opportunities for visits.

As is visible in Figure 20 below, at the end of the execution phase, the value gained lies in the fact that the concept has been demonstrated, which in itself should have lead to raised knowledge, and in the data and experiences gathered. There is however also "waste created" in a specific demonstration railway wagon and temporary loading platforms, which are likely not useful after the execution phase.

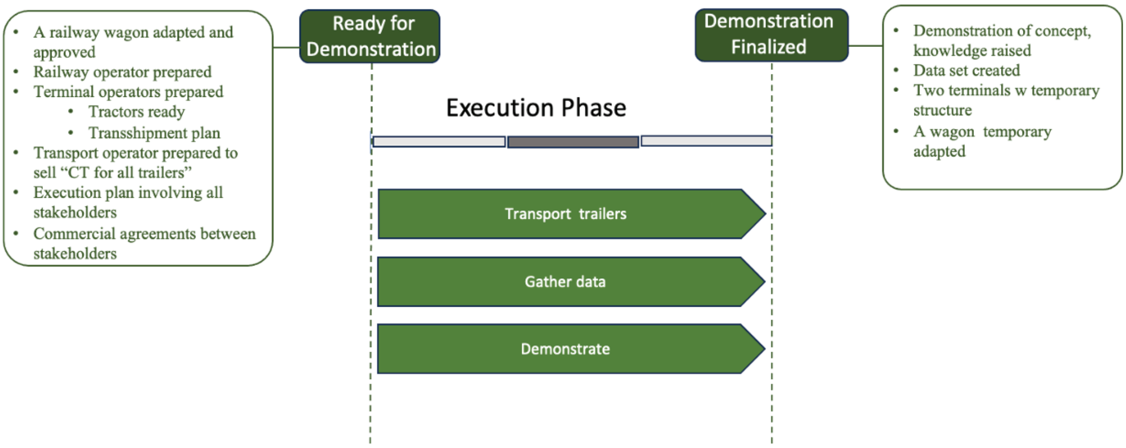

Figure 20 Overview of the execution phase

Overview of the restoration phase

The final phase, see Figure 21 is directed to analysis of the data and learnings from the FSDP, and to restore railwagon and terminal infrastructure.

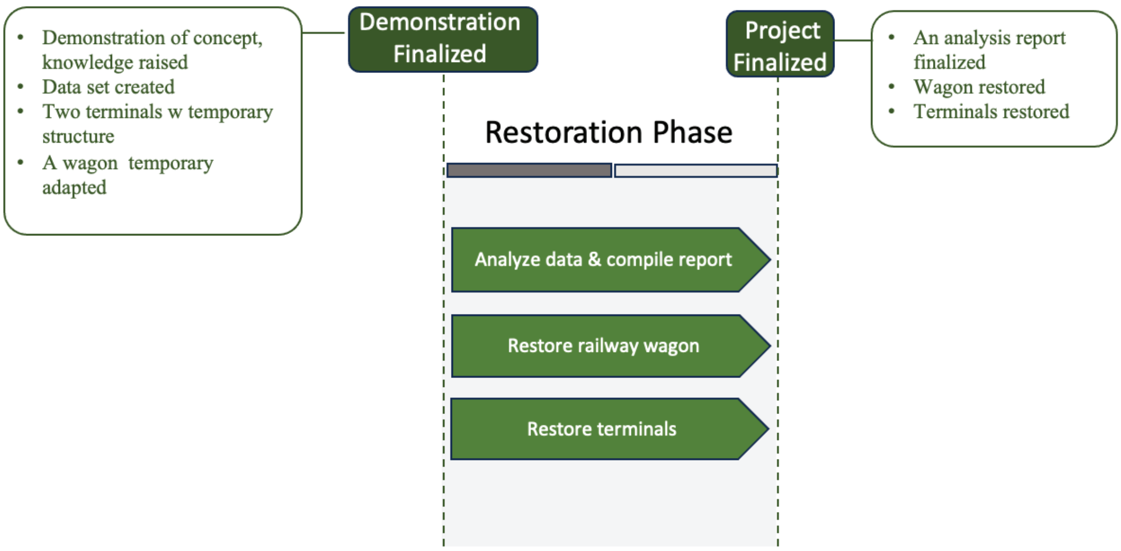

Figure 21 Overview of the restoration phase

Key cost drivers

The total cost for performing a FSDP according the project plan as outlined above is estimated to be in the range of 4-5 MSEK. The major parts of the costs are related to the preparation phase. The largest cost item is the preparations of temporary loading platforms, which in such a pilot setting with only one trailer and need for extra margins, is difficult optimize. The cost for creating and restoring such platforms could amount to almost half of the total amount. The cost for acquiring and suitably adapt such a railway wagon is a bit difficult to scope as the adaption needed vary between different options, which in turn may have large impact on the efforts and cost for wagon approval. A total cost of 500 KSEK to 1 MSEK.

During the execution phase, added costs per transshipment can be expected, but considerably less than the costs of the preparation phase.

Other specific considerations in view of a suggested FSDP project

King pin holder

A key component for a railway wagon suitable for Assisted RoRo Transshipments is the king pin holder, locking the trailer in position during transport. As assisted RoRo Transshipments require a kingpin holder that is moved out of the way for a tractor loading or off-loading the trailer, and moved into locking engagement with the king pin with the tractor removed. As the kingpin holder is critical for transport safety, the technology used is critical. Such king pin holders are however since long used in North America on TOFC. Figure 22 illustrate such typical king pin holders, trailer hitch stanchions.

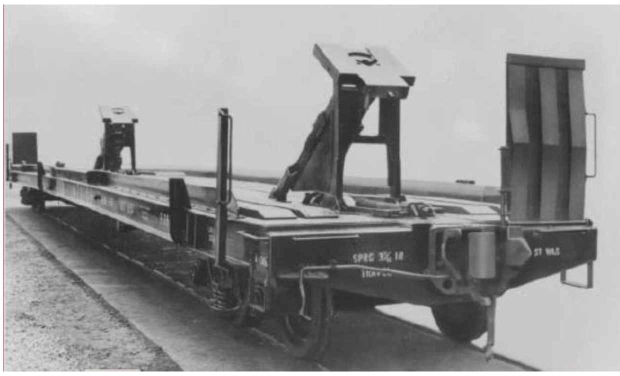

Figure 22 Early king pin holder Source: Ron Sucik (2023)

Geography

The Assisted RoRo Transshipment concept has, as indicated above, benefits of being comparably more competitive on shorter distances, where the advantages of lower transshipment costs and faster transshipment have larger relative impact. For the FSDP, where costs may not be optimized in the same way, it is rather advisable to demonstrate with a shuttle on a longer distance, as extra measures and costs for special treatment for the demonstration would have lower impact on the total transport cost.

Development of the assistance technology

An important prerequisite for initiating a suggested FSDP is the assistance technology being ready for use. A plan for developing this technology includes the steps of developing the assistance software, sensor arrangement, connectivity, driver presentation and railway wagon top in parallel processes with repetitive tests being run on a mock up railway wagon top. For demonstrations and pilots, the system has to deliver safety precision and reliability. Cost and design optimizations are not prioritized in a first stage, but rather the priority in a second stage.

First full scale implementation

As a full scale implementation is a suitable next level pilot after the suggested limited FSDP, it is relevant to touch the pre-requisites for early full scale implementations and suitable implementation strategies.

A first prerequisite for an implementation in Europe is the development and launch of a flat railway wagon optimized for Assisted RoRo Shipping, i.e optimising the parameters low loading area, short wagon without sacrificing suitable wheel size.

Where would a suitable first implementation be made? To answer this question, the comparable strengths of the Assisted RoRo Transshipment concept need to be considered. As described above some of the expected benefits lie in low cost transshipment which is particularly competitive on shorter distances. Another advantage is the opportunity for low cost terminals and in line terminals with transshipments. Given this, the concept may beneficially be implemented along a railway line one or more intermediate stops can be integrated. This could be applicable on a number of alternatives. In reviewing such geographical alternatives, the special case of the Swedish inland line, Inlandsbanan, is an interesting one, as the low cost terminal options provided by Assisted RoRo Transshipments offers a unique opportunity to enable green transport chains with semi trailers.

8 Dissemination and publications

8.1 Dissemination

How are the project results planned to be used and disseminated?	Mark with X	Comment
Increase knowledge in the field	X	The results will be published on the Tructric website and announcements will be made on LinkedIn. Various opportunites to share the knowledge will be explored
Be passed on to other advanced technological development projects		
Be passed on to product development projects	X	Results from the project forms a base for future development of assistance system as well as of railway wagons
Introduced on the market	X	The results may be used in discussions with stakeholders in view of future cooperations
Used in investigations / regulatory / licensing / political decisions		

8.2 Publications

No publications have been published during the pre-study.

9 Conclusions and future research

The main conclusions from the work carried out in WP1 are categorized according to relevance in the freight system, behaviour aspects of the freight market and the application of the concept. As for the relevance in the freight system, the components of the intermodal transport systems have been addressed and how the concept could widen the market of intermodal transports through enabling transshipment of non-cranable trailers at a very low cost. However, further studies are recommended in order to fully address the concept's compatibility with present transport flows and market demands.

As for the behavioural aspect, this study has relied on literature review and previous studies regarding shipper's preferences when it comes to mode choice. Further studies could design a survey specifically for this concept. This can also be complemented with further in-depth interviews with experts. The scenario assessment and the reference group workshop carried out within this study can be complemented with extended in-depth expert interviews and market survey. The results of the scenario assessment are promising as the scenario including the Assisted RoRo Transshipment technology, resulted in 50% cost reduction compared to pure road if using the Assisted RoRo Transshipment concept in an existing intermodal terminal and 52% in a standalone line terminal. The reduction is primarily due to reduced transshipment cost as no transshipment technology nor dedicated operator are required. Although a platform is required for the truck driver to be able to tranship the semi-trailer on and off the train. Furthermore, the scenario assessment could be improved and calibrated through studies on parameters identified as significant. The assumptions made in the assessment could also be further investigated e.g. regarding the share of total costs if the concept is implemented at an existing intermodal terminal and the cost for the customization of the wagon.

As for the application of the concept, the quality of intermodal transport, in specific regarding reliability and punctuality, has to be ensured for it to be regarded as a feasible alternative for shippers, no matter what price is offered. This shows the need for tests of novel transshipment technologies and validation in demonstration projects. Hence, a full scale demonstrator in order to investigate the operational stability of the system would be recommended, as elaborated by WP3.

The main conclusions from the feasibility study of WP2 are the Assisted RoRo Transshipment concept appears to be feasible for implementation in an FSDP as well as in large scale and that the risks involved in transshipments and transportation call for focus on safety and reliability in all implementations. The overview of risks and the increased understanding of applicable regulations and process in various steps of the continued development, will be used in relation to future development, demonstrations and commercialization of the concept.

The conclusions from WP3 are that a number of variations as to how a demonstration and pilot project can be set up in various stages of the development. Further steps have been taken in validating the technology related to Assisted RoRo Transshipments, in particular regarding development of the assistance system and an optimized railway wagon. An in-depth understanding of various alternatives and challenges has been gained, which will be a good basis for the planning and execution of future demonstrations and commercialization.

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