C4R

Capacity for Rail

Towards an affordable, resilient, innovative and high-capacity European Railway System for 2030/2050

Co-modal transshipments and terminals (Final)

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Deliverable 23.2

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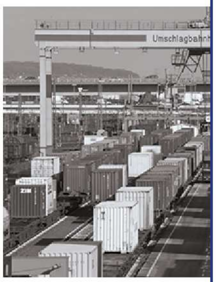

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Lead contractor for this deliverable:

- DICEA

Project coordinator

- International Union of Railways, UIC

Executive Summary

This Deliverable is based on the general aims of CAPACITY4RAIL (C4R): to pave the way for the future railway system, delivering coherent, demonstrated, innovative and sustainable solutions.

The deliverable objective is the conceptual design of transhipment technologies and Interchanges of the future 2030 and 2050 (rail yards, intermodal terminals, shunting facilities, rail-sea ports, etc.), according to their role in co-modal transhipment to influence freight demand distribution, both by operation improvements and logistic advantages.

Indeed, European rail freight has not progressed in parallel with the European economy: during the last century, the single wagon was the core business of railways; today, in contrast to the decline of conventional rail freight, combined transport has shown signs of growth.

Currently, rail freight transport consists of two main typologies: conventional rail freight services (wagonload) and combined transport services, which include the notion of transhipment and the flow of goods from an origin to an intermediate destination, and from there to another destination.

Terminals are a key element of transport services and, in this study, the main goal has been to suggest suitable methods to evaluate the performance of different types of rail freight terminals, which are applicable to various families of terminals:

- Rail to road for shorter range units transfer;
- Rail to waterways for rail feeding from ports.
- Rail to rail for shunting wagonloads;

The evaluation of the performances of the terminals concerned and the influence on them of innovative operational measures and technologies is based on a selected combination of tested analytical methods based on sequential application of algorithms (e.g. from queuing theory) and discrete event simulation models, capable to quantify different KPI. The implementation of new technologies and operational measures lead to a general increase of the terminals performances when measured by KPI.

The first case study selected for the pilot application of methods and models and the evaluation of future scenarios is the terminal located in Munich Riem, operated by the DB owned company DUSS.

The set of road-rail terminals considered as case studies includes three intermodal terminals located in Antwerp: Combinant, Hupac and Zomerweg.

The Port of Valencia's Principe Felipe Railway Terminal has been the selected as a case study for sea-rail terminals.

Finally, Hallsberg case study is the largest marshalling yard in Sweden, both in the number of wagons handled and surface extension.

For each case study, the identification of suitable innovations allows migration towards a consolidated future scenario which is affordable.

The assessment of future terminals, including the effects of innovative technologies and operational measures on performance, is the basis to calculate the variations in operational and investment costs of newly designed terminals, both in terms of business case and cost-benefit social assessment, carried out based on a consolidated methodology.

The activities performed in WP2.3, provided a large set of results concerning typical terminal operation in the present situation and in selected future scenarios which provide interesting and original results, particularly concerning:

1) Achievable operational standards of intermodal and wagonload terminals, detailed in sections 4.1, 4.2 and 4.3;
2) Financial results concerning the business case of intermodal and wagonload terminals, detailed in section 5.7.
3) Economic results from a societal viewpoint, which are useful to pilot future European actions in the freight transport and rail systems fields, detailed in section 5.9.

Business economic calculations for conventional terminals, with reach-stackers and gantry cranes, show that the cost is in the range of 20-30 €/TEU, also a common market price for terminal handling. This includes both the operating costs and the capital costs for the technical equipment, which often the terminal operator is responsible for. The total cost including basic investments is in the range of 30-50 €/TEU, which is the long-term cost for building new terminals.

Technical measures such as fast transtainers, horizontal and parallel handling, automated gates, automatic couplings on locos and automatic ITU, vehicles control and data exchange provided with given better KPI. These measures are also profitable in a cost benefit calculation.

Linear traffic makes it possible to have more terminals to cover a larger market. While horizontal transfer makes it possible to have terminals on an electrified siding so the train can make short stops on intermediate stations. This means that there will be no need for shunting with diesel and parking of wagons and full automation of transfer of loading units will be possible. The total cost for a small-scale automatic linear terminal has been calculated to 14 €/TEU. The low cost for the linear terminal is mainly due to the absence of shunting engine and personnel meaning that it has a very high benefit/cost ratio.

The operating cost for handling wagons at a marshalling yard in Sweden is about 15 € per wagon, but adding the maintenance cost for the infrastructure manager increases this to 50 € per wagon. The whole cost, including building the yard, for this example would be 100 € per wagon.

For marshalling yards, automatic couplers, automatic brakes on wagons, automatic wagon identification, duo locos and driverless locos were tested and the KPI improved.

In this case, the cost-benefit analysis gives a negative result because of the huge investments. However, the yard is a prerequisite for the rationalization of wagonload's transport system.

Automation of terminals and terminal functions seems to be the most efficient way to reduce costs and increase benefits in future terminals. There are many ideas how to implement this, but not many of the systems are ready for market use today.

That means that strong effort is required (i.e. in Shift2Rail) to implement automated systems in real operation.

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Abbreviations and acronyms

Abbreviation / Acronym	Description
BAU	Business As Usual
CBA	Cost Benefit Analysis
CCT	CarCon Train
C4R	Capacity4Rail
DCF	Discounted Cash Flow
DUSS	Deutsche Umschlaggesellschaft Schiene-Straße
EU	European Union
FA	Financial Analysis
FNPV	Financial Net Present Value
FRR	Financial Rate of Return
GHG	Greenhouse Gas
ITU	Intermodal Transport Unit
ITS	Intelligent Transport System
KPI	Key Performance Indicator
KTH	Kungliga Tekniska Hogskolan
LU	Loading Unit
MMM	Multimodal Marshalling
NPV	Net Present Value
RMG	Rail Mounted Gantry
RTG	Rubber Tyred Gantry
SDR	Social Discount Rate
SEK	Swedish Kroner
SWL	Single Wagon Load
TEU	Twenty Equivalent Unit
TL	Trainload
TOFC	Trailer on Flat Car
VOT	Value Of Time
WL	Wagon Load
WP	Work-package

1. Background

This deliverable is based on the general aims of CAPACITY4RAIL (C4R): to pave the way for a future railway system, delivering coherent, demonstrated, innovative and sustainable solutions.

Sub-Project 2 Freight will develop the rail freight systems of the future, its objectives are:

- Design of a modern fully integrated rail freight system to meet the requirements for 2030/2050;
- GAP analysis for vehicles, intermodal systems and operation principles;
- Specification of rail freight system development to be implemented;
- Identification of today's and future demand for rail freight, by existing forecasts;
- Description of freight flows, up to 2030/2050;
- Adoption to existing and expected future customer requirements for different goods segments.

Sub-Project 2 includes a first Work-package (WP2.1), which outlined the progress beyond the state of the art by investigating the innovations emerging from research-based experimental results concerning both technologies and operational measures.

Market trends analyses were undertaken to focus on the future requirements of the freight transport market at the 2030 and 2050 time horizons.

The EU reference standards, referred to these time horizons, depicted an incremental change by 2030 and a system change by 2050, which represent the starting milestones to develop a stepwise improvement of rail system based towards the satisfaction of future freight transport market needs.

System improvements encompass the system as a whole, including both the infrastructural and operational components, which WP2.3 is dealing with, as well as the vehicles, specifically approached by WP2.2.

Namely, WP2.3 focus is on "Co-modal transhipment and interchange/logistics" and is organised into the following Tasks:

- 2.3.1 Conceptual terminals design methodology for different markets;
- 2.3.2 Identification of functional requirements of future terminals;
- 2.3.3 Application of design methodology for terminals innovative technologies;
- 2.3.4 Application of design methodology for terminals innovative operational measures;
- 2.3.5 Operational costs of newly designed terminals: business cases and cost-benefit analyses;
- 2.3.6 Validation of terminals' conceptual design and WP synthesis.

The present Deliverable summarises the main activities and achievements developed in the period from Month 25 (October 2015) to Month 30 (March 2016) in the Tasks 2.3.3-2.3.6.

Tasks 2.3.3 and 2.3.4 include the application of methodological framework setup in Task 2.3.1 for the terminal typologies defined by the requirements identified in Task 2.3.2.

Tasks 2.3.3 and 2.3.4 started in April 2015, jointly led by DICEA and TRV.

The largest part of activities, completed by September 2015 populated Deliverable 2.3.1.

A set of results for typical terminal operation in the present situation and in selected future scenarios available in D2.3.1.

An extension of this work including a larger set of case studies and an additional future scenario achieved over the past few months are included in the present Deliverable.

Task 2.3.5 deals with operational costs of newly designed terminals and includes the development of business cases and cost-benefit analyses.

The work focused on the assessment of effects on costs associated with performances of future terminals. These activities started in October 2015 and are now complete.

Finally, Task 2.3.6 deals with the validation of terminals' conceptual design throughout the assessment of scenarios and the synthesis of the whole WP2.3, further summarised in the Executive Summary.

2. Objectives

The objectives of this Deliverable are to validate technically feasible scenarios for standard rail freight terminals of the future targeted to contribute to rail freight systems in 2030 and 2050.

It provides consolidated answers to the following questions, first approached in Deliverable 2.3.1.

- Expected performances and requisites = what the terminals should do;
- Key Performance Indicators (KPI) = how the terminal performances can be measured;
- Integration of innovations = what the terminals can take on-board;
- Future scenarios = How the terminals could work in the future;
- Methods and models to assess innovations = how to assess scenarios;
- Assessment of scenarios = to what extent will the expected performances be achieved?

In addition to these questions, issues concerning the economic and financial feasibility of the proposed solutions are:

- Will future terminals be viable for Society = how future terminals will affect the social cost?
- Will future terminals be viable for the operators = how future terminals will affect the cost of freight operators along the logistic chains?

The analysed typologies of terminals and corresponding case studies are:

- Rail-Road: freight interchange
    - Munich Riem in Germany;
- Rail-Sea: port rail terminal
    - Valencia Principe Felipe in Spain.
- Rail-Rail: marshalling yard
    - Hallsberg in Sweden;

Additional case studies, identified during the research work will extend the analysis and the validation of the methodological framework.

- Rail-Road: freight interchange
    - Antwerpen Combinant, HUPAC and Zomerweg in Belgium;
    - A typical innovative linear terminal

Moreover, specific analysis has targeted the operation of transport and integrated logistics services along a typical intermodal chain, including road, rail and maritime sections, focussing on the role of each terminal typology and the effects of improvements and innovations on each analysed scenario.

This affects the operational cost of the terminals and the results of business cases analysis.

3. Terminals typologies, KPI, case studies and future scenarios

3.1 From European goals to terminal typologies selections

On 28th March 2011, the European Commission published a White Paper entitled "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system".

The EC has a vision of a long-term-sustainable transport system with the aim of attaining the goals to reduce the transport sector's emissions.

The goal for rail freight is that 30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than it should be 50% by 2050.

In the EC vision, freight terminals play a primary role in an efficient and competitive supply chain: they are the connection point between the various transport nodes and the nodal points where the freight services are handled, stored and transferred between different modes to final customers.

In the current state, terminals often represent the bottlenecks of freight network, where goods are often stored for long periods and trucks and trains experience delays in comparison with the time schedule.

For these reasons, to meet the requirements from the European Union, to contribute to the establishment of the future supply chain and to gain new market share, new terminals need to improve their performances in terms of operational times, reliability, flexibility and monitoring and information exchange.

In conventional freight transport, the loading/unloading terminals operation and facilities for the handling of goods are closely dependent upon goods type, though it does not need integration with other modes.

Combined transport offers the possibility of a rapid transhipment of goods, since this is transported in loading units (container, swap bodies, semitrailers, even truck itself, in case of accompanied transport).

This implies the shipment of goods from an origin to an intermediate destination and from there to another destination.

The transhipment takes places in terminals or hubs where the freight is consolidated or deconsolidated and allows the change of the transport modes during the journey without handling the goods.

Among these terminal types, a set of case studies was identified, as discussed below.

The criteria adopted for the choice of terminal was based on both economic and functional considerations.

Intermodal rail transport is the only sector of rail freight which has grown, in line or in some cases, even higher than the growth of gross domestic product.

Moreover, it is also the type of transport best suited to international transport, integrating several transport modes, from road, to rail, to waterways, to sea and is the system that benefits most by the interoperability process undertaken on the European rail network.

The same considerations led the single wagonload to be given less importance, since this type of transport is in steady decline.

However, wagonload does have a capacity advantage compared to intermodal traffic. It is possible to load more freight in a railway wagon than in a container because the road vehicle dimensions and weight, restrict the container dimensions.

Wagonload can handle both higher volume in m^3 and more tonnes in general. It can also be increased more by higher axle loads and wider loading gauge. Containers and trailers can also be increased but mostly by the length.

Wagon load also uses the same technical system as trainload, which has increased in many countries. Here the economy of scale is more evident with even higher axle loads, loading gauges, train length and weights on special lines adopted to the industry needs.

However, in order to increase rail market share, actions, also supported by EU, are in place in order to revitalize wagonload transport.

Finally, it was preferred to deal with medium to large installations, operated through complex processes in which the possible interactions of the innovations make their evaluation more representative, though less evident.

Based on these considerations, the identified case studies are:

- In intermodal traffic:
    - Rail - Road (inland freight interchanges),
    - Rail - Sea (port terminals);
- In wagon load traffic:
    - Rail - Rail (marshalling yards).

Inland freight interchanges

Rail - Road terminals are the place on a railway network where you handle, store and transfer goods between different modes to the final customer; it is normally equipped with costly technology based on high complexity technological procedure demanding a high degree of coordination and control skills.

Therefore, great effort is required to find an optimal configuration of infrastructure to exploit extensively technical resources and to organize technological procedures. Evaluation of technological processes and their development in railway terminals enables successful functioning of transport, thus guaranteeing reliability, independency and quality for the consignee. Generally terminals can be classified by location in the logistics chain (e.g. Hub and Spoke, Linear, Gate terminal), by dimensions (Large, Medium and small) or transfer mode (Vertical or Horizontal).

Port terminals

Ports are the interface between: land based and water based systems. While the maritime domain can involve vast geographical coverage, the land domain relates to the port's region and site location. Ports handle the largest amounts of goods by accommodating transhipment activities and modern container ports commonly act as pioneers in automation and innovation of terminal operations.

Moreover, in comparison with land based terminals, the operation and the information flows are more complex: in port terminals, the ITUs tranship at least twice (ship to store and store to train). Ship-to-shore cranes, harbour cranes, straddle carriers, reach stackers and empty container trucks are the main equipment used for handling containers at both port and connected inland terminals. A ship-to-shore Rail Mounted Gantry (RMG) crane (Portainer) is a specialized version of the gantry crane allowed to move along the quay. Another type of crane, common at large ports, is the Rubber Tired Gantry (RTG) crane, a mobile gantry crane used for loading and unloading of railcars and road trucks and for stacking containers. It can cover several tracks simultaneously and containers can be stored aside the tracks. RTG cranes are most effective to handle a high numbers of railcars and can move between rail and yard operations. However, when higher flexibility is required, the reach stacker is the preferred transhipment equipment.

Marshalling yards

Different groups of tracks characterize this terminal typology. Trains arrive in sidings, where wagons documents are checked. They split into groups of wagons, according to their final destination; the line loco moves away, while the hump loco takes place behind the groups of wagons to shunt. The wagons move, pushed by a manoeuvring loco, over a hump in a direction group, where they are braked using hump retarders placed along the tracks, finally reaching departure sidings where they cumulate to reach the critical mass for a departing train. There train documents are checked, the line loco is coupled to the wagons, the brakes are tested and the train is ready to depart.

3.2 Innovations across intermodal logistic chains

The function of a terminal

Terminal handling is an interruption in the transport chain and has no value in itself. However, it is possible to optimise the transport chain through a combination of the best modes on each link of the transhipment, to minimize costs and to reduce energy consumption and GHG. The aim of terminal handling is to be as smooth and cheap as possible, so it will be easy to change mode if requested.

Terminals can add value to the goods if they can offer logistic functions like warehousing and freight administration, acting as an agent for the customer. Nevertheless, the fact that trucking does not require so much terminal handling is one reason that it has been so successful. For rail, there is also an internal terminal system for the production of rail transport with no interface to the customers like marshalling yards and shunting areas, building and splitting trains of wagons and for optimize the train system especially for wagonload.

Innovations in terminal handling must reduce cost, shorten the time, lower energy consumption and GHG, reduce damages and make administration and control of the transport chain more streamlined. It will be measured as a success if the terminal handling does not stand out as anything special to the customer.

In this section, the terminal is a part of the complete logistic chain (figure 1).

Logistic trends

Current logistics trends are *outsourcing*, *offshoring* and *centralisation*. The resulting design of the logistics network is mainly basing on a cost perspective. *Outsourcing* of production activities means to subcontract a process to a third party who can take advantage of economies of scale.

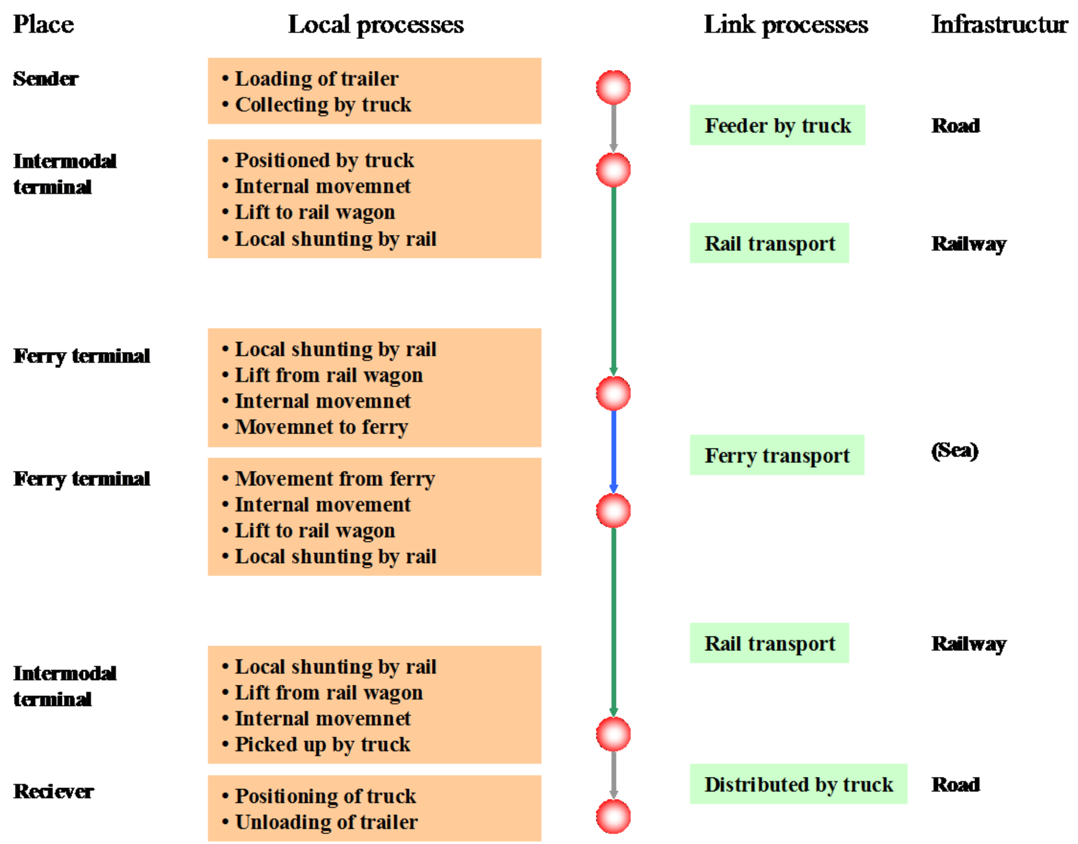

FIGURE 1: INTERMODAL TRANSPORT CHAIN WITH DIFFERENT TERMINAL HANDLING SYSTEMS

Offshoring describes the dislocation of a production activity to a far-distant country in order to reduce operational costs. Physical *centralisation* means that the number of production, procurement or distribution sites is lower, whereby the main goal is to pool risk, reduce inventory and exploit economies of scale. For instance, offshoring can lead to a reduction of total logistics costs by 25-40%. However, important "soft" factors, like delivery time, flexibility and risks of a logistics network can lead to a considerable reduction of this cost advantage.

Furthermore, stricter regulations and increased awareness of customers with respect to the environment support a reconsideration of a company's strategy. In the case of city logistics, the evolution of the urban population in relation to congestion and pollution problems are favorable factors for rail. If areas for logistics distribution are preserved in city centers, silent trains could reach them for last mile delivery by electric road vehicles (also at night with high productivity) or using the underground network or even tramways or inland waterways. This will create innovative business models instead of the overwhelming solution of delivery by truck, which is being increasingly subject to stringent constraints.

In general, it can be said that these new logistics trends will gain importance in the future as companies' focus shifts away from a purely cost perspective to a more integrated approach that includes cost, risks and the environment. In particular, considering that offshoring no longer offers a significant cost advantage and that some companies are reducing spatial concentration, any future network should be a more decentralised one in which the amount of long-distance transport can be reduced.

Improvements in transportation efficiency are achievable by better vehicle utilization, the reduction of empty trips as well as less frequent shipments with larger lot sizes, reducing the number of trips. Moreover, using multi-modal transportation will make the supply chain more flexible.

From today's conventional system to innovative intermodal systems

Conventional large end-point terminals are relatively expensive as regards both investment and operation costs. On the other hand, they can handle all types of LUs and have a high handling capacity. However, because they use gantry cranes or reach stackers with top lift, they cannot be electrified and trains must be shunted by diesel locomotives. Furthermore, several tracks are for parking wagons waiting to be loaded and unloaded. The consequence is that they cover a relatively large area, where operate reach stackers and other lifts for high axle loads. Large intermodal terminals are therefore cost- and space-intensive and the cost per LU handled is relatively high even with large freight volumes. Therefore, new terminal and traffic concepts are very interesting.

Easy access to terminals

There are different methods to make terminal access easier with electric hauled trains. One is to let the train roll through the terminal with pantograph in down position, like in Germany. Another is to have an electrified section to the border of the terminal so the loco can push the train to loading position, like in Sweden. However, in the latter case the loco must change place first. A third method is to use duo-locomotives which both have electric and diesel propulsion. They are available on the market now but not so common.

Linear trains

A liner traffic terminal is located on a track siding, where the train can drive straight in and out onto the line again. The electrified track does not require switching the train in which in turn requires a handling technology that can function under the overhead contact wires. The train must be able to be loaded and unloaded during a stop of 15-30 minutes, which obviates the need to park wagons. The terminals can be more compact and with the right handling technology do not need dimensioning for high axle loads. They require less space and will be more cost-effective than conventional terminals.

Horizontal transfer

To use a linear terminal in an efficient way, a horizontal transfer system can operate under the catenary (figure 2).

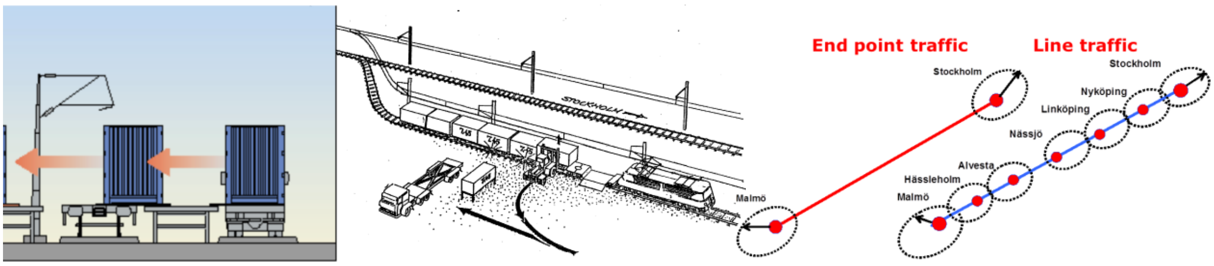

FIGURE 2: HORIZONTAL TRANSFER EQUIPMENT TO HANDLE CONTAINERS UNDER THE CONTACT WIRE. THE TERMINAL CAN BE ON A SIDING AND THE TRAIN CAN MAKE SHORT INTERMEDIATE STOPS AT MANY STATIONS. THE MARKET WILL BE WIDER AND THE FEEDER DISTANCES SHORTER

A system in operation in Switzerland is the ContainerMover system: the device is on the truck, which makes transhipment possible at every terminal or siding. Another system is the CarCon Train (CCT), which consists of a wagon that travels parallel with the track, equipped with arms for transferring freight horizontally. There are many other systems designed or planned, but many are complicated and do not seems to mean lower cost than today´s system.

With a linertrain and a system for horizontal transfer, the following is achievable in the logistics system:

- Containers and swap-bodies can be reloaded under a live catenary;
- The terminal can be located on a siding where the train make a short stop for transhipment;
- No need for a diesel shunting engine to handle the train at the terminal;
- No need to park wagons and the terminal can be very compact;
- Possibility to have more small terminals along the line to widen the market and shorten the feeder transport;
- The train and the truck can be independent of each other.

This means lower logistics costs for both customers and society.

Roll-on/roll off terminals for trailer handling

Most trailers today are not suitable to lift onto a railway wagon. The trailer market is in practice therefore very limited even at conventional intermodal terminals that have lifting equipment. It is therefore a great advantage if trailers can roll on and off the wagons: solutions where trailers do not need lift, which can thus widen the market considerably. A traditional solution is the *rolling highway*, commonly used in alpine passes. This solution is very costly, partly because the entire truck including the driver has to be loaded and partly because the railway wagon itself is expensive to buy and maintain. There are many different technical solutions for loading trailers, some of them tested on the market, some of them planned. One example is the Modalohr system in France (figure 3), which has the possibility to handle trailers without lifting; however, it needs a rather complicated wagon and special ramps at the terminal.

FIGURE 3: A) MODALOHR SYSTEM WITH SPECIAL RAMPS ON EACH WAGON. B) TRAILER TRAINS ONLY NEEDING A RAMP AT THE END BUT LOW WAGONS AND A HIGH LOADING GAUGE. C) TRAILER TRAIN MORE SPACE EFFICIENT THAN TRAIN WITH POCKET WAGONS.

Another project is Trailer Train, which is like the system used in US for Trailers on Flat Cars (TOFS). This only needs a ramp at the end of the train but a lower wagon and a high loading gauge. By this, it is also possible to achieve higher length utilization of the train because the trailers are very densely located on a rake of flat cars (figure 4).

The cost of handling units with a reach stacker at conventional end-point terminals is approximately 30 €/unit. At a liner traffic terminal with forklifts, this may be reduced to 15 €/unit if the train driver is also driving the forklifts, but is restricted to 20 ft. containers or swap-bodies. Approximately the same cost is for the ContainerMover system with the transfer system on the truck. With a horizontal transfer system like CCT the cost is estimated to be around 10 €/unit. Handling a trailer with *Megaswing* or *Trailertrain*, which do not require a special terminal costs roughly the same.

Fully automated terminals

There are already fully automated terminals in service in various ports and for inland terminals in Germany. So far, these systems are rather complex, expensive, and used on very large terminals. What rail requires are automated terminals for smaller demand, profitable on shorter distances and more relations.

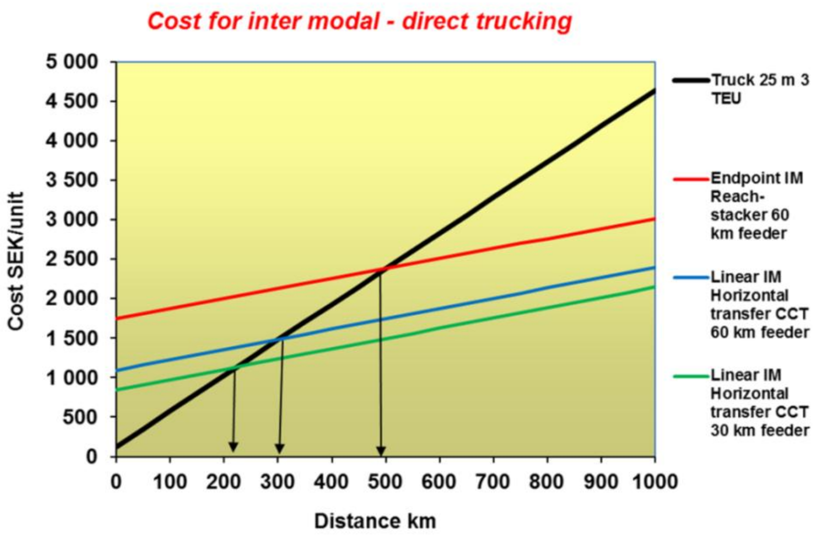

Figure 4: Cost (expressed in SEK) of conventional intermodal traffic and intermodal traffic with horizontal transfer of CCT type and with regular traffic with shorter feeder distances

Figure 4 and 5 provide an example of measurable achievements estimated for a future system for horizontal terminal handling in combination with liner trains as follows:

- Cost for terminal handling of a unit will be reduced by approximately 60%;
- Break-even point for intermodal will be reduced from 500 km to 300 km;
- Energy consumption will be reduced by 93%;
- CO2 emissions in kg per unit will be reduced by 99% with electric propulsion;
- Terminals will be cheaper and smaller so it will be possible to have more terminals which will reduce the distance for feeder transport and widen the market further

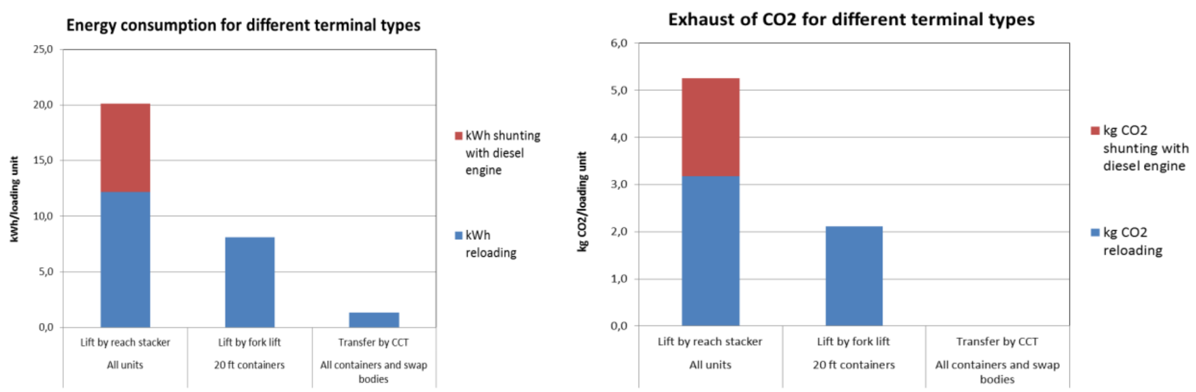

FIGURE 5: ENERGY CONSUMPTION AND GHG EXHAUST FOR DIFFERENT TERMINAL HANDLING TECHNIQUES

From today's system to Innovative wagon load systems

Today´s system has many disadvantages compared with road and has lost market share in many countries. Structural problems include closing of industrial sidings and feeder service and at the same time a more concentrated system with fewer destinations and market coverage. One reason is the terminal handling, which for SWL is crucial to handle trains to, from and between marshalling yards. Therefore, the next section deals mostly with the internal production system, techniques and traffic systems for SWL.

Duo-locomotives

In the freight transport chain, electric locomotives operates for long distance transport between the marshalling yards and diesel locos are needed to distribute the wagons to the customers because their tracks are not often electrified. However, today dual-mode locomotives, with both electric and diesel traction, can be used to run on non-electrified lines or in areas like terminals and industries.

Operators then often only need one locomotive instead of two and can save costs and make operations more flexible by shunting wagons along the line. There are two types of duo-locomotive: a regular electric loco with a small diesel engine for shunting wagons in yards or on shorter distances like "TRAXX last-mile". Moreover, there are locos capable of line haul with both electric and diesel traction (e.g. the Vossloh six-axle Euro Dual locomotive).

Liner trains instead of node systems

Instead of a conventional hub and spoke system, a system of linertrains has been proposed (Nelldal et al. 2005), where the trains run on a main route and wagons pick up and drop is managed at the stations along the way. In many cases, feeder trains are not necessary and the wagons no longer need shunting at a marshalling yard and hauling by feeder trains. The liner train system is also combinable with a hub system, so that the trains can exchange wagons at suitable places and marshalling yards can handle more relations. The left diagram in figure 6 shows a conventional wagonload system consisting of 30 nodes of which two are marshalling yards and 2 are secondary nodes.

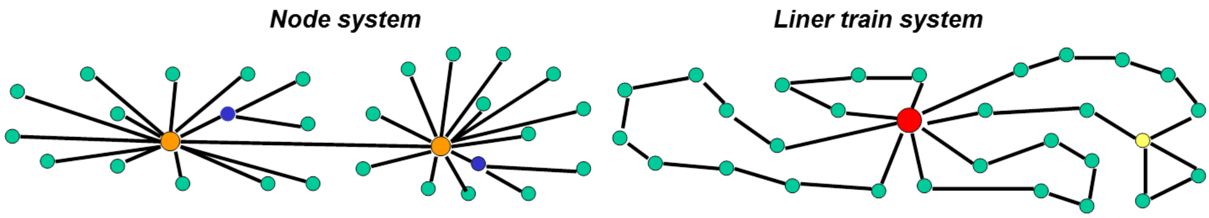

FIGURE 6: CONVENTIONAL HUB AND SPOKE SYSTEM (LEFT) AND LINER SYSTEM WITH THE SAME MARKET (RIGHT)

Automation of marshalling yards

To link terminals, at least 1 long-distance train in each direction and 26 feeder trains in each direction are required every day between the marshalling yards, which means 56 movements/day. In addition to the liner locomotives, terminal locomotives are needed at most terminal nodes. The right diagram shows a linertrain system where the trains pick up and drop wagons along the route. The system consists of five loops, four of which meet at a central marshalling yard, and one meets another at a local node. This system needs only 10 train movements in each direction each day to cover the same terminals as the node system. A calculation shows that transportation costs reduces by 17% in the case of wagonload traffic. If duo locomotives are used, the transportation costs reduces by a further 5%. With a single duo locomotive for both shunting and long haul traffic, the trains do not then need to change locomotives to enter a terminal. There are many possibilities for further automation of marshalling yards, i.e. radio-controlled hump-locomotives, primary hump and secondary-retarders, piston retarders in the sorting tracks, wagon-movers, movable stopping devices and automatic brake test equipment (figure 7).

FIGURE 7: AUTOMATION OF MARSHALLING YARDS

Complemented with an IT system to control all movements and an advanced planning system, marshalling can be automatic. There are also new network strategies, which mix full trainloads and wagonloads to achieve a unified system based on the blocking principle. This system looks at the conventional traffic as dynamic wagon blocks that are susceptible to coupling and decoupling. The new system is increasing the capacity of the trains and the frequency of the service by better coordinating the timetable and the booking system by using sophisticated IT systems. Another contradictory trend is the introduction of shunting areas without a hump. The fact is that WL nowadays include more wagon-groups than single wagons and that radio-controlled locomotives makes it relatively easy to handle. Therefore, the need of complicated hump yards to some extent has decreased.

Automatic couplers

The ultimate solution is to introduce automatic couplers. The process will demand minimum number of staff and not be so dangerous for the workers. If this is also radio-controlled, there will be further cost savings in the operations and it will widen the market for wagonloads through more efficient operations on sidings and stations. An advanced idea which does not exist in reality yet is to have self-propelled wagons which can operate themselves shorter distances on sidings or on marshalling yards.

Conclusions

Terminal handling is an interruption in the transport chain and has no value in itself. However, with terminals, the transport chain optimizes the combination of the best modes on each link to minimize costs; in addition, the terminals can bring benefit to the goods offering logistic functions, like warehousing and freight administration. Innovation in terminal handling includes; lowering the cost, shortening the time, lowering energy consumption and GHG, getting rid of damages and making administration and control of the whole transport and logistics chain better.

Duo-locomotives, with both electric and diesel traction make it possible to operate directly into intermodal terminals which cannot be electrified and also to shunt wagons into sidings or marshalling wagons on not electrified yards. For operators, which often need electric locos for long haul and diesel locos for short haul and shunting, it can save one loco. *Liner trains* in SWL means that the train can pick up and leave wagons at intermediate stops in connection to the long haul; in combination with duo-locos, this is easier and can save costs. Linear traffic makes it possible to have more terminals to cover a larger market, in combination with considered new techniques: particularly horizontal transfer makes it possible to have terminals on an electrified siding so the train can make short stops at intermediate stations. It means that there will be no need for shunting with diesel and parking of wagons, as well as full automation of driving will be possible.

Moreover, today most trailers are not suitable for lifting on, which restricts the market for intermodality, therefore, *Roll On Roll Off* techniques are interesting to enlarge market for trailers and also make it possible the loading under the electric wire. A fully *automated marshalling yard* is technically possible and has the potential of a strong impact: the automatic coupler is an ultimate solution for WL, especially if it can be radio-controlled, making longer trains easier to operate and, even if it is a big investment, it can lower long-term costs.

Finally, introduction of *IT-systems* to get total control of the consignee from origin to destination including terminal handling is a prerequisite for any future rail development.

3.3 Selected Key Performance Indicators by terminal typology

The validation of analytical method and simulation models has provided relevant feedback to select the Key Performance Indicators (KPIs), explained in Deliverable 2.3.1 and extended here, to define the most effective KPI to describe the terminal from the viewpoint of operation performances.

Moreover, the validation procedure has enabled the definition of the most reliable methodology (analytical algorithms vs. simulation) to calculate the selected KPIs. On this basis, the selected Key Performance Indicators in Tables 1÷3 refer to terminal typologies and the most appropriate calculation method.

Table 1: Selected Key Performance Indicators for Rail – Road terminals

Total Transit Time (ITU) Total Transit Time (vehicle)	$TTR = \sum_{i=1}^{n} TWi + \sum_{i=i}^{n} TOi$	Time period from the arrival of the freight unit (or vehicle) to the terminal gate from road (an external transport infrastructure) to the exit of the unit (or vehicle) from the terminal towards road or railway network. • TTR_v =vehicle total transit time (Ship and train); • TTR_{ITU} = Unit total transit time; • TW = waiting time; • TO = operational time.	Analytical Method

Equipment Performance	$Ep = \frac{n_{ITU}}{\text{h}}$	It is the potentiality of handling equipment. • n_{ITU} = number of handled intermodal transport unit; • h = hour.	Simulation model
System utilization rate	$\varrho = \frac{\lambda}{\mu}$	It is the queueing theory. It is useful to measure the correct sizing of different sidings. • ϱ = system utilization; • λ = average rate of arrivals; • μ = average rate of served.	

TABLE 2: SELECTED KEY PERFORMANCE INDICATORS FOR RAIL – SEA TERMINALS

Total Transit Time (ITU)	$TTR = \sum_{i=1}^{n} TWi + \sum_{i=i}^{n} TOi$	Time period from the arrival of the freight unit (or vehicle) to the terminal gate from road (an external transport infrastructure) to the exit of the unit (or vehicle) from the terminal towards road or railway network. • TTR_v =vehicle total transit time (Ship and train); • TTR_{ITU} = Unit total transit time; • TW = waiting time; • TO = operational time.	Analytical Method
Total Transit Time (vehicle)			
Equipment Performance	$Ep = \frac{n_{ITU}}{\text{h}}$	It is the potentiality of handling equipment. • n ITU = number of handled intermodal transport unit; • h = hour.	Simulation model
System utilization rate	$\varrho = \frac{\lambda}{\mu}$	It is the queueing theory. It is useful to measure the correct sizing of different sidings. • ϱ = system utilization; • λ = average rate of arrivals; • μ = average rate of served.	

TABLE 3: SELECTED KEY PERFORMANCE INDICATORS FOR RAIL – RAIL TERMINALS

Maximum flow through the yard	$\boldsymbol{\Phi_{max}} = \frac{\boldsymbol{N_{max}}}{\boldsymbol{T} - (\boldsymbol{t_{pr}} + \boldsymbol{t_{av}})}$	It is the maximum flow through the yard. It is useful to measure the effect of the interruptions on the maximum number of wagons daily treated. • $\boldsymbol{\Phi_{max}}$ = maximum flow through the yard • $\boldsymbol{N_{max}}$ = maximum capacity of the hump • $\boldsymbol{T}$ = time interval • $\boldsymbol{t_{pr}}$ = mean interruption time for breakdowns • $\boldsymbol{t_{av}}$ = mean scheduled interruption	Analytical Method
Mean number of wagons in the yard at the same time	$n_{cpi} = \frac{N}{T} t_{mtw}$	It is the mean number of wagons in the yard at the same time. • N = mean number of trains daily handled • T = time interval • t_{mtw} = mean wagon transit time	

Average wagon transit time	$t_{mtt} = \sum_{i=1}^{12} t_i$	It is the mean time period from the arrival of a wagon to the marshalling yard from railway network to the exit of the wagon from the marshalling yard to the railway network. • t_{mtt} = mean wagon transit time • t_i = partial time (waiting or operative time)	Simulation model
Tracks utilization rate	$A_{su} = \frac{L_{tr}}{La_{bin}}$ $D_{su} = \frac{L_{tr}}{Ld_{bin}}$ $P_{su} = \frac{L_{tr}}{Lp_{bin}}$	It is the arrival sidings track utilization factor. It is useful to measure the tracks adequacy to receive new longer trains • L_{tr} = Average train length • La_{bin} = Average arrival sidings track length • Ld_{bin} = Average direction sidings track length • Lp_{bin} = Average departure sidings track length	

3.4 Selected case studies by terminal typology

For each terminal typology, the research activities focused on case studies based on the data collected by WP2.3 partners in various countries. Table 4 reports the correspondence between terminal typologies and case studies characterised today (State of art state) by their main features.

Table 4: Case studies corresponding to terminal typologies

Terminal typology	Terminal	Main Features
Rail-Road: inland freight interchanges	Munich Riem (Germany)	• 5 arrivals tracks in the holding area • 3 operative modules • 14 loading/unloading tracks • 6 trucks lanes • 8 storage lanes • 6 RMG cranes
	Antwerp Combinant (Belgium)	• 5 tracks • 3 RMG cranes • 10-12 trains/day • 150,000 units/year
	Antwerp Hupac (Belgium)	• 3 RMG cranes; • 4 tracks • 235 trucks/3 h (6 am - 9 pm) • 4 trains/day.
	Antwerp Zomerweg (Belgium)	• 5 trains/day • 4 tracks • 2 cranes + 2 straddle carriers
	Typical small scale automatic linear terminal	• 1 track (600 m) • 2 temporary storages (200 m) • 1 trucks lane (200 m)
Rail-Rail: marshalling yards	Hallsberg (Sweden)	• Arrival sidings: 8 tracks (590-690 m) • Double Hump

		• Direction sidings: 32 tracks (374-760 m) • Departure sidings: 12 tracks (562-886 m)
Rail-Sea: containers port terminals	Valencia Principe Felipe (Spain)	• Total area: 50,000 m^2 • 4 loading/unloading tracks • Extra track to shunt locomotives • Electrified tracks until approaching loading/unloading area • Two road access • Two storage areas (9,000 + 20,000 m^2)

Future scenarios by terminal typology and corresponding case studies

Based on the innovative operational measures and technologies, described in Deliverable 2.3.1, combination of elements are made to obtain future scenarios for certain case studies, taking into account a progressive temporal implementation of some measures and technologies. Therefore, each scenario represents a different temporal step of the application of these innovations.

In addition to the temporal scenarios (1 and 2) presented in Deliverable 2.3.1, related to conventional time horizons of 2030 and 2050, for all case studies a scenario not temporarily defined (Consolidated Scenario) has been considered.

It includes elements of innovative operational measures and technologies better suited for case studies, normally temporarily located between the two above-mentioned scenarios.

Therefore, for each typology of terminal, the comparative analyses involves the following scenarios (Table 5):

- State of art;
- Scenario 1;
- Scenario 2;
- Consolidated Scenario.

For Rail - Road and Rail - Sea intermodal terminals, both innovative operational measures and technologies are included in scenarios. For marshalling yards, innovative technologies only are included. The characteristics of all scenarios are in Tables 6÷9.

Table 5: Future scenario per terminal typology

Scenario / Terminal Typology	State of art	Consolidated	Scenario 1	Scenario 2
Rail - Road Munich Riem	X	X	X	X
Rail - Road Antwerp Combinant	X	X		
Rail - Road Antwerp HUPAC	X	X		
Rail - Road Antwerp Zomerweg	X	X		
Rail - Road typical linear		X		
Rail - Rail Hallsberg marshalling yard	X	X	X	X
Rail - Sea Valencia Principe Felipe	X	X	X	X

Table 6: Innovative operational measures and technologies included in scenarios for Munich Riem

Rail - Road terminal Munich Riem					
Scenario 1		**Scenario 2**		**Consolidated Scenario**	
Innovative operational measures	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*
Faster and fully direct handling Automatic ITU and vehicles control and data exchange No locomotive change Long train (1500 m) H24 working time	Automated fast transtainer Intermodal complex spreader Duo loco Fast automated gate	Horizontal and parallel handling Faster and fully direct handling Automatic ITU and vehicles control and data exchange No locomotive change Long train (1500 m) H24 working time	Automatic systems for horizontal parallel handling Duo loco Fast automated gate	Automatic ITU and vehicles control and data exchange Partial and fast locomotive change Long train (670m) H24 working time	Fast transtainer (+30-40% RMG performances) Fast Automated gate Automatic coupling loco

TABLE 7: INNOVATIVE OPERATIONAL MEASURES AND TECHNOLOGIES INCLUDED IN CONSOLIDATED SCENARIO FOR ANTWERP COMBINANT, HUPAC AND ZOMERWEG

Rail - Road terminal Antwerp Combinant		Rail - Road terminal Antwerp Zomerweg		Rail - Road terminal Antwerp HUPAC	
Consolidated Scenario		Consolidated Scenario		Consolidated Scenario	
Innovative operational measures	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*
Automatic ITU and vehicles control and data exchange Partial and fast loco change Long train (670 m) H24 working time	Fast transtainer Duo propulsion loco Automatic coupling loco Automated gate (based on OCR and RFID)	Partial automatic ITU and vehicles control and data exchange Fast loco change Long train (670m) H24 working time	Partial Automated gate (based on RFID and manual procedure) Automatic coupling loco Long train (670 m) H24 working time	Automatic ITU and vehicles control and data exchange Fast loco change Long train (670 m) H24 working time	Automatic systems for horizontal parallel handling Automatic coupling loco Automated gate

TABLE 8: INNOVATIVE OPERATIONAL MEASURES AND TECHNOLOGIES INCLUDED IN SCENARIOS FOR VALENCIA PRINCIPE FELIPE

Rail - Sea terminal Valencia Principe Felipe					
Scenario 1		Scenario 2		Consolidated Scenario	
Innovative operational measures	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*	*Innovative operational measures*	*Innovative technologies*
Automatic ITU and Vehicle. control and data exchange No locomotive change Tracks operative length 1500 m H24 working time	Automated fast transtainer Intermodal complex spreader Duo propulsion loco Automated gate	Horizontal and parallel handling Automatic ITU and vehicles control and data exchange No locomotive change Long train H24 working time	Duo propulsion loco Automated gate	Automatic ITU and vehicles control and data exchange Long train (850-1000 m) H24 working time	Multi lift spreader handling Fast Automated gate Automatic coupling loco

TABLE 9: INNOVATIVE TECHNOLOGIES INCLUDED IN SCENARIOS FOR HALLSBERG

Rail - Rail marshalling yard Hallsberg		
Scenario 1	**Scenario 2**	**Consolidated Scenario**
Innovative technologies	*Innovative technologies*	*Innovative technologies*
Automatic brakes on wagons Self-propelled wagons Automatic coupling and uncoupling Tracks operative length1500 m H24 working time Automatic wagon identification	Driverless loco Automatic brakes on wagons Duo propulsion loco Automatic coupling and uncoupling Tracks operative length 1500 m H24 working time Automatic wagon identification	Tracks operative length till 1500 m Multi Modal Marshalling (MMM): classification tracks accessible not only via hump Automatic wagon identification Automatic coupling and uncoupling Automatic brakes on wagons Self-propelled wagons Duo propulsion and driverless loco H24 working time

4. The future terminal: analysing the effects of innovative technologies and operational measures

4.1 Rail-Road: inland freight interchanges

The evaluation of innovative scenarios in comparison with the present situation (State of art) is based on the calculation of KPIs, through analytical and simulation methods for various case studies and different scenarios (see tables 5÷9).

In Table 10 and figures 8÷11 the results for Munich Riem terminal.

Table 10: Munich Riem terminal KPIs results

SCENARIO							
KPI		State of art	Consolidated	Scenario 1	Scenario 2	*unit*	*method*
Total Transit Time (ITU)	TRUCK_TRAIN	7.69	6.62	2.56	2.44	h	A
	TRAIN_TRUCK	3.65	5.26	2.79	1.62	h	
Total Transit Time (vehicle)	TRAIN	5.3	2.15	2.89	2.63	h	A
	TRUCK	0.97	0.33	1.55	1.34	h	
Equipment Performance	CRANE	13.6	17.0	58.0	70.0	ITUs/h	S
System utilization rate	TRAIN	0.43	0.22	0.14	0.80	-	S
	TRUCK	0.38	0.31	0.64	0.66	-	

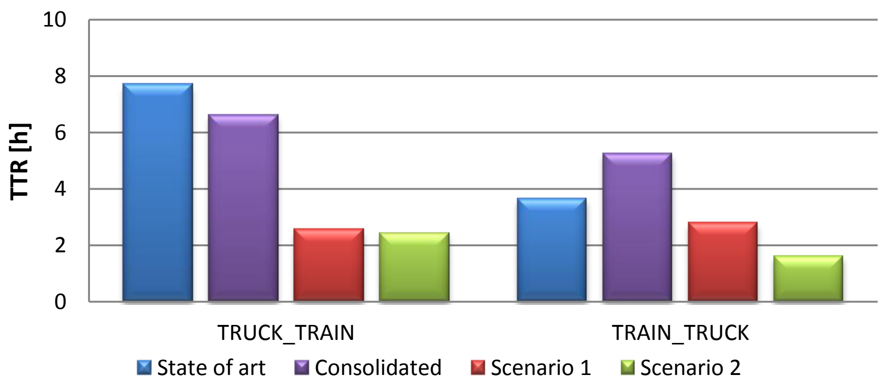

Figure 8: ITU transit time in Munich Riem freight interchange

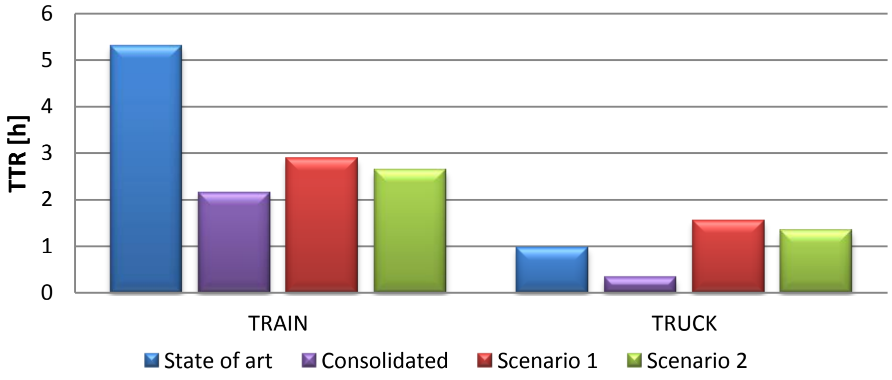

FIGURE 9: VEHICLES TRANSIT TIME IN MUNICH RIEM FREIGHT INTERCHANGE

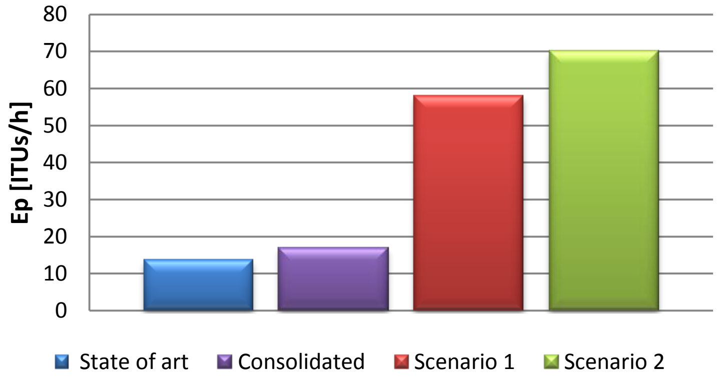

FIGURE 10: EQUIPMENT PERFORMANCES IN MUNICH RIEM FREIGHT INTERCHANGE

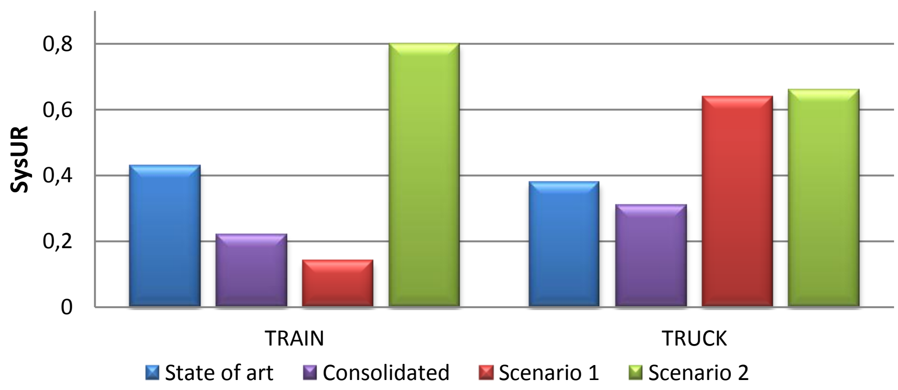

FIGURE 11: SYSTEMS UTILIZATION RATE IN MUNICH RIEM FREIGHT INTERCHANGE

The implementation of new technologies and operational measures allows a general increase of the terminal performances.

In particular:

- Reduction of ITUs transit time in truck-train direction (14% in Consolidated Scenario);
- General reduction of train transit time respect to State of art application;
- Increase of equipment performances (25% in Consolidated Scenario);
- Important decrease of trains and tracks utilization rate in Consolidated Scenario.

The innovations in handling technology which may be implemented in the future, have indicated positive effects on the speed of terminal operations and consequently on handling time per ITU.

In Table 11 and figures 12-15 the results for Antwerp Combinant terminal.

TABLE 11: ANTWERP COMBINANT TERMINAL KPIS RESULTS

SCENARIO					
KPI		**State of art**	**Consolidated**	*unit*	*method*
Total Transit Time (ITU)	TRUCK_TRAIN	7.50	6.67	h	A
	TRAIN_TRUCK	3.75	3.36	h	
Total Transit Time (vehicle)	TRAIN	3.58	2.55	h	A
	TRUCK	0.82	0.46	h	
Equipment Performance	CRANE	25	48	ITUs/h	S
System utilization rate	TRAIN	0.15	0.1	-	S
	TRUCK	0.24	0.08	-	

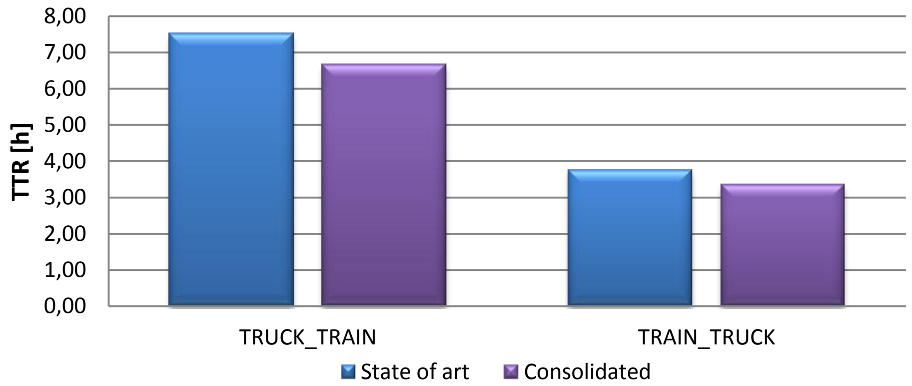

FIGURE 12: ITUS TRANSIT TIMES IN ANTWERP COMBINANT FREIGHT INTERCHANGE

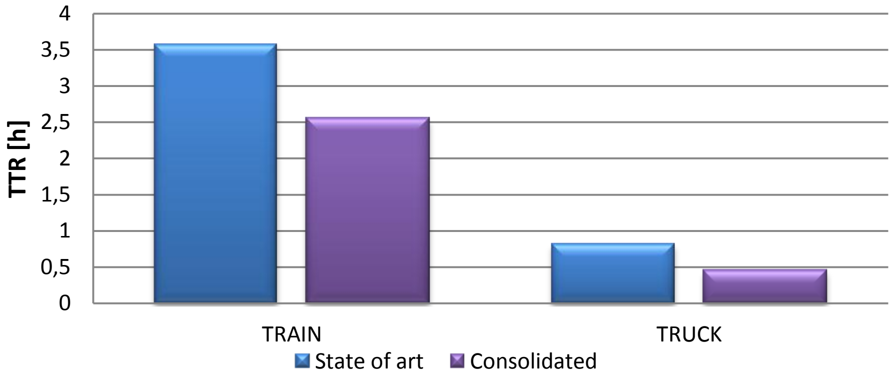

FIGURE 13: VEHICLES TRANSIT TIME IN ANTWERP COMBINANT FREIGHT INTERCHANGE

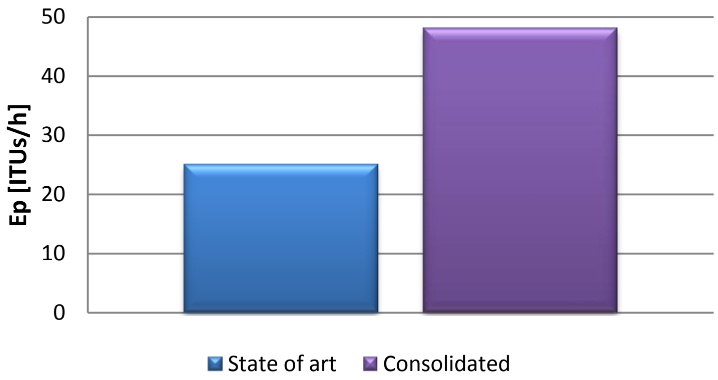

FIGURE 14: EQUIPMENT PERFORMANCES IN ANTWERP COMBINANT FREIGHT INTERCHANGE

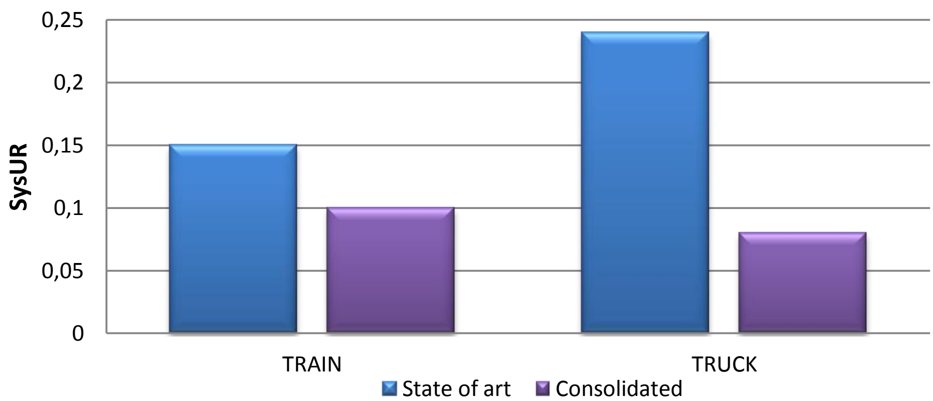

FIGURE 15: SYSTEMS UTILIZATION RATE IN ANTWERP COMBINANT FREIGHT INTERCHANGE

In Antwerp Combinant terminal, the adoption of new technologies and innovative operational measures shows an improvement of the general performances, without relevant negative effects:

- Reduction of vehicles transit time: 44% for trucks and 29% for trains;
- Reduction of ITUs transit time: 11% in truck-train direction and 10% in train-truck direction;
- Increase of equipment performances: 92%;
- Reduction of systems utilization rate: 67% for trucks and 33% for trains.

In Table 12 and figures 16÷19 the results for Antwerp HUPAC terminal.

TABLE 12: ANTWERP HUPAC TERMINAL KPIS RESULTS

KPI		SCENARIO State of art	SCENARIO Consolidated	unit	method
Total Transit Time (ITU)	TRUCK_TRAIN	6.93	3.55	h	A
	TRAIN_TRUCK	2.99	2.88	h	
Total Transit Time (vehicle)	TRAIN	5.08	2.33	h	A
	TRUCK	0.8	0.56	h	
Equipment Performance	CRANE	30	42	ITUs/h	S
System utilization rate	TRAIN	0.31	0.15	-	S
	TRUCK	0.15	0.11	-	

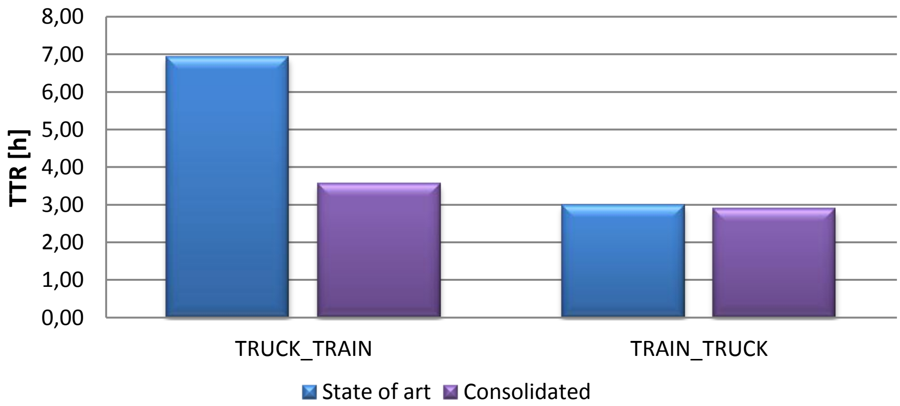

FIGURE 16: ITU TRANSIT TIMES IN ANTWERP HUPAC FREIGHT INTERCHANGE

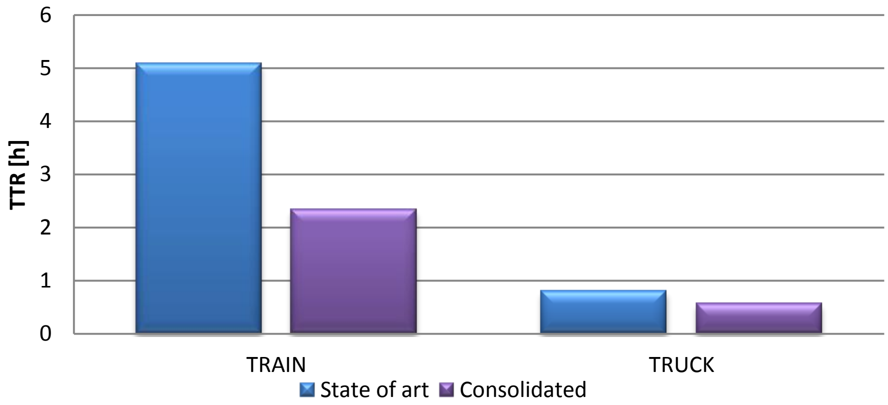

FIGURE 17: VEHICLES TRANSIT TIMES IN ANTWERP HUPAC FREIGHT INTERCHANGE

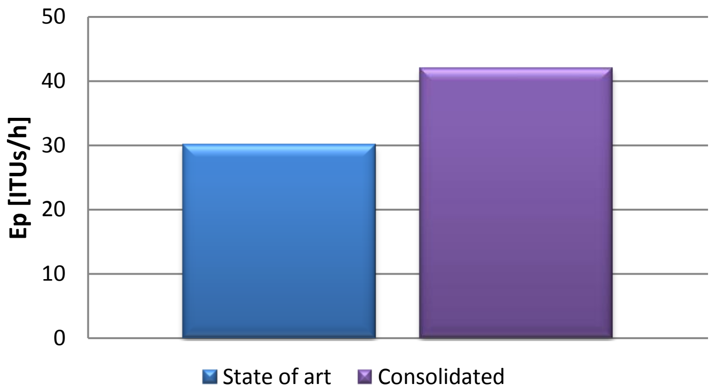

FIGURE 18: EQUIPMENT PERFORMANCES IN ANTWERP HUPAC FREIGHT INTERCHANGE

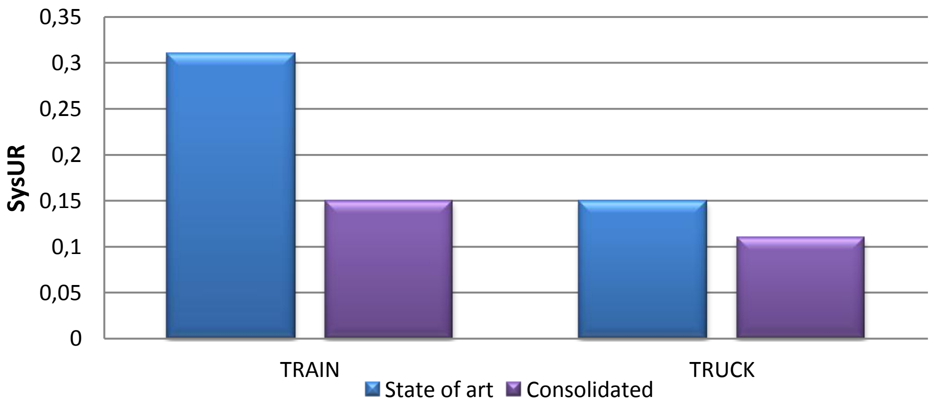

FIGURE 19: SYSTEMS UTILISATION RATE IN ANTWERP HUPAC FREIGHT INTERCHANGE

For HUPAC terminal as well, the results achieved are all largely positive.

In particular:

- Reduction of vehicles transit time: 30% for trucks and 54% for trains;
- Reduction of ITUs transit time: 49% in truck-train direction and 4% in train-truck direction;
- Increase of equipment performances: 40%;
- Reduction of system utilization rate: 27% for trucks and 52% for trains.

In Table 13 and figures 20÷23 the results for Antwerp Zomerweg terminal.

TABLE 13: ANTWERP ZOMERWEG TERMINAL KPIS RESULTS

SCENARIO					
KPI		**State of art**	**Consolidated**	*unit*	*method*
Total Transit Time (ITU)	TRUCK_TRAIN	8.39	3.15	h	A
	TRAIN_TRUCK	2.59	4.76	h	
Total Transit Time (vehicle)	TRAIN	5.09	2.58	h	A
	TRUCK	0.77	0.22	h	
Equipment Performance	CRANE	22	33	ITUs/h	S
System utilization rate	TRAIN	0.39	0.12	-	S
	TRUCK	0.19	0.25	-	

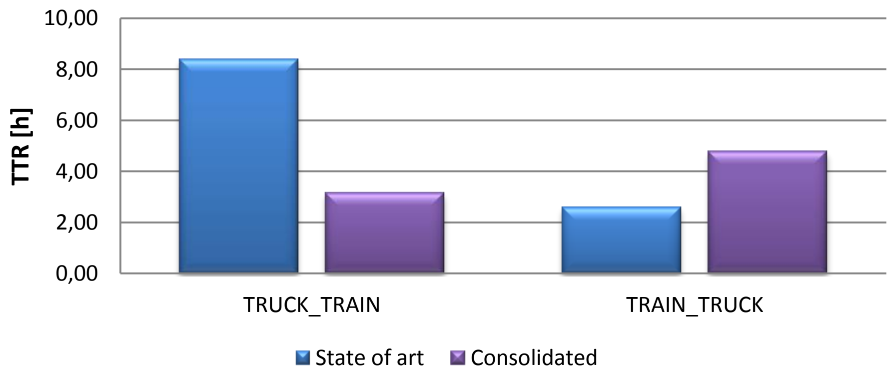

FIGURE 20: ITU TRANSIT TIME IN ANTWERP ZOMERWEG FREIGHT INTERCHANGE

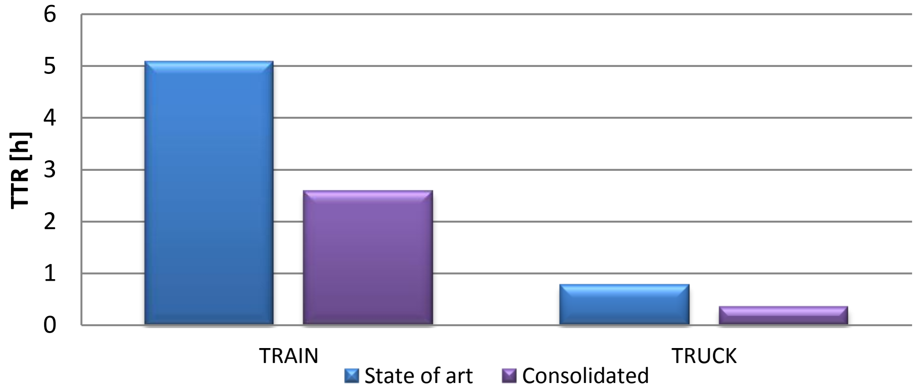

FIGURE 21: VEHICLES TRANSIT TIME IN ANTWERP ZOMERWEG FREIGHT INTERCHANGE

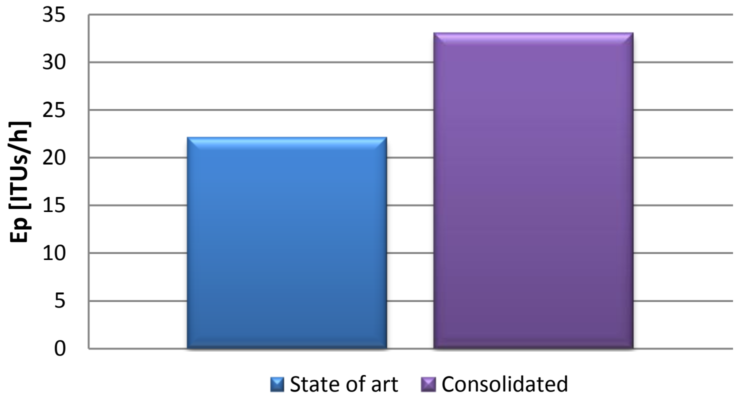

FIGURE 22: EQUIPMENT PERFORMANCES IN ANTWERP ZOMERWEG FREIGHT INTERCHANGE

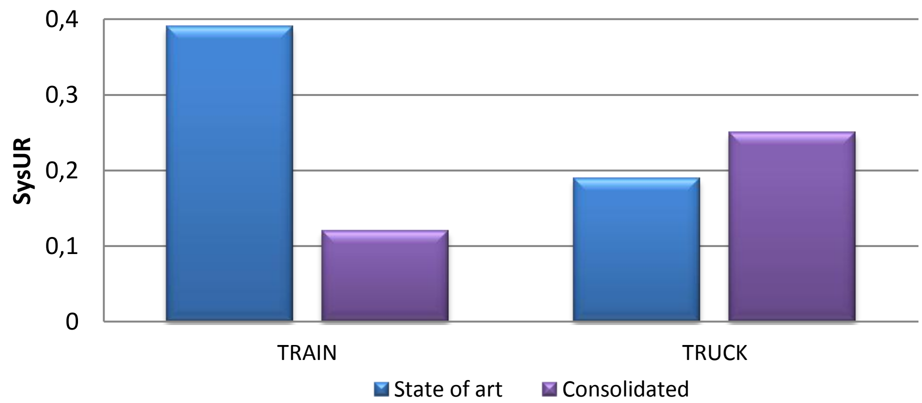

FIGURE 23: SYSTEMS UTILIZATION RATE IN ANTWERP ZOMERWEG FREIGHT INTERCHANGE

The Zomerweg terminal consolidated scenario includes a parallel horizontal handling technology. In this case, the applications of new technologies and operational measures have a largely positive effect on terminal performances.

In particular:

- Reduction of vehicles transit time: 71% for trucks and 49% for trains;
- Reduction of ITUs transit time in truck-train direction: 62.5%;
- Increase of equipment performances: 50%;
- Reduction of train's utilization rate: 69%.

The negative effects are dependent on the increased flows of trucks, in particular:

- Increase of ITUs transit time in train-truck direction: 84%;
- Increase of trucks utilization rate: 31%.

The small-scale intermodal Rail - Road linear terminal is basing on CarCon Train (CCT) horizontal ITUs handling system.

The methodological framework, including analytical method and simulation model provided results also for this typology of terminal, though a comparison with a State of art situation is not applicable in this case (Table 14 and Figure 24).

TABLE 14: INTERMODAL RAIL - ROAD LINEAR TERMINAL KPIS RESULTS

KPI		Analytical Method	Simulation Model	*unit*
Total Transit Time	ITU	3.33	6.72	h
	TRAIN	2.65	2.08	h
	TRUCK	0.47	0.85	h

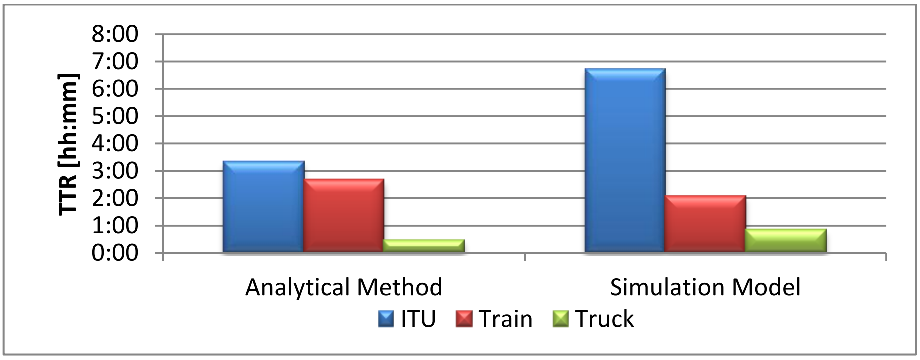

FIGURE 24: TRANSIT TIME IN AN INTERMODAL RAIL - ROAD LINEAR TERMINAL

The results are in line with other studies carried out on terminal with these features. The calculated transit time allows trains doing more than one stop during the day and serving more than a single area along a line.

Rail - Road conclusions

New technologies and innovational operational measures demonstrated their capability to improve the terminals performances.

In future scenarios, a combination of various innovations, can be effectively evaluated using different methodologies capable to deal with many types of terminal and to evaluate the influence of innovations.

The outputs obtained from key performance indicators demonstrate that innovations are able to increase the overall performance of a terminal, enabling increase in flows, of ITUs and vehicles, as well as lower duration of various operational phases, according to the objectives of the European Union.

The comparison among all case studies and scenarios is represented in table 15 with reference to positive and negative effects, which the implementation of new technologies and innovative operational measures have on terminal performances.

TABLE 15: POSITIVE AND NEGATIVE EFFECTS ON TERMINAL PERFORMANCES MEASURED BY KPIs

- *Green = Positive effect*
- *Red = Negative effect*

		SCENARIO					
		Consolidated				Scenario 1	Scenario 2
KPI		Riem	Combinant	HUPAC	Zomerweg	Riem	Riem
Total Transit Time (ITU)	TRUCK_TRAIN	Green	Green	Green	Green	Green	Green
	TRAIN_TRUCK	Red	Green	Green	Red	Green	Green
Total Transit Time (vehicle)	TRAIN	Green	Green	Green	Green	Green	Green
	TRUCK	Green	Green	Green	Green	Red	Red
Equipment Performance	CRANE	Green	Green	Green	Green	Green	Green
System utilization rate	TRAIN	Green	Green	Green	Green	Green	Red
	TRUCK	Green	Green	Green	Red	Red	Red

4.2 Rail-Sea: containers port terminals

The application of both analytical method and simulation model provided the results shown in Table 16 and in Figures 25÷28 for the selected KPIs.

Table 16: Valencia Principe Felipe KPIs results

KPI		SCENARIO					
		State of art	Consolidated	Scenario 1	Scenario 2	unit	method
Total Transit Time (ITU)	Train-Ship	40.64	36.91	37.17	38.88	h	A
	Ship-Train	15.33	10.87	11.07	12.11	h	
Total Transit Time (vehicle)	Ship	8.96	5.89	5.89	5.89	h	A
	Train	4.94	1.31	2.84	1.55	h	
Equipment Performance	Portainer	23.1	23.1	23.1	23.1	ITUs/h	S
	Reach stacker	18.5	-	-	-	ITUs/h	
	RTG	23.5	77.0	49.0	-	ITUs/h	
	Horizontal Handling	-	-	-	91.0	ITUs/h	
System utilization rate	Ship	0.57	0.61	0.76	0.76	-	S
	Train	0.96	0.47	0.83	0.80	-	

Each histogram presents a comparison between the state of the art and the scenarios proposed for the case study.

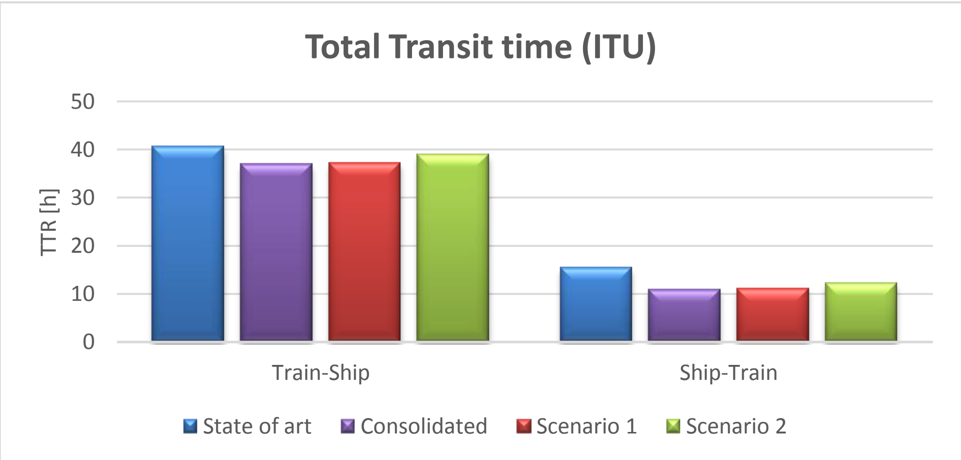

Figure 25: ITUs transit times Valencia Principe Felipe Terminal

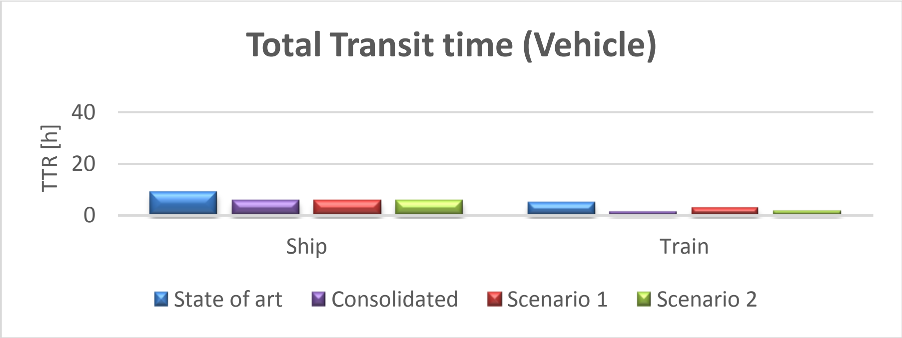

FIGURE 26: VEHICLES TRANSIT TIMES IN VALENCIA PRINCE FELIPE TERMINAL

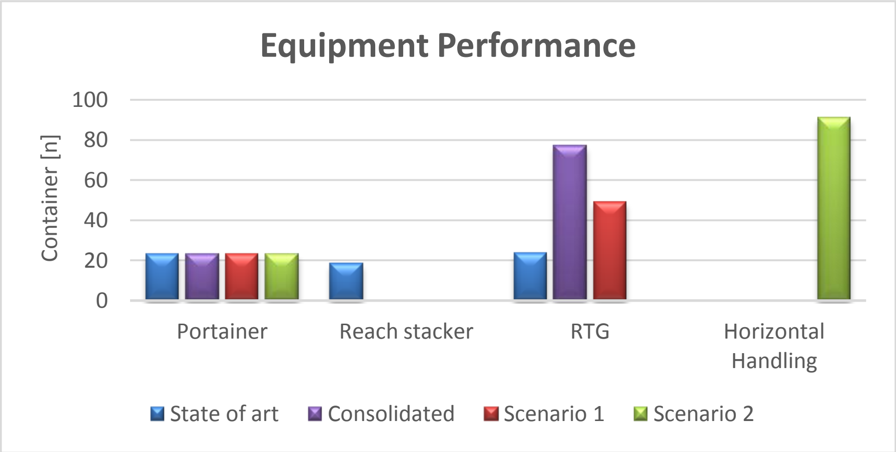

Figure 27: Equipment performances Valencia Principe Felipe Terminal

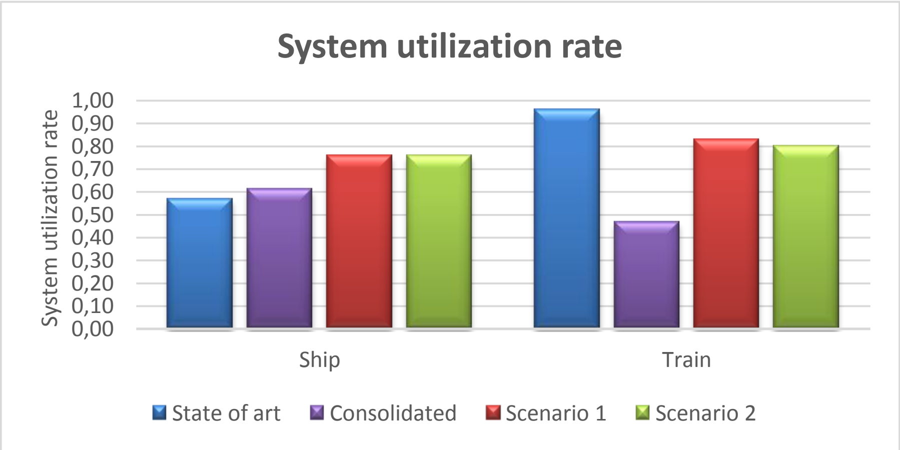

Figure 28: System utilization rate in Valencia Principe Felipe Terminal

Analysis of the results obtained for common standards, future technologies and operational measures for the Principe Felipe Terminal in Consolidated Scenario:

- Not negligible reductions of ITUs transit time in train-ship direction: about 9%;
- Important reductions of ITUs transit time in ship-train direction: about 29%;
- Reductions of vehicles transit time: 34% for ships and 74% for trains;
- Huge increase of maximum equipment performances: 230% for RTG crane;
- Moderate increase of ships utilisation rate: 7%;
- Relevant decrease of train utilisation rate: 51%.

The models and simulations developed within C4R are interesting for the Port Authority and the operators:

- To analyse the capacity and potential of rail infrastructures in port environment examining different parameters such as layouts, working periods, equipment, etc.
- To design railway infrastructures of future port extensions, where two new container terminals will double the current capacity.

The next step would be to integrate the isolated models (shunting terminal. sea-rail terminal. etc.) into a system so that the whole port-rail infrastructure (integrating different shunting and loading/unloading terminals) could be analysed as a more complex system. In table 17, the comparison among all case of study and scenarios with reference to positive and negative effects are represented, illustrating the effect of implementation of new technologies and innovative operational measures on terminal performances.

TABLE 17: POSITIVE AND NEGATIVE EFFECTS ON TERMINAL PERFORMANCES

- *Green = Positive effect*
- *Red = Negative effect*

KPI		SCENARIO		
		Consolidated	Scenario 1	Scenario 2
Total Transit Time (ITU)	TRAIN-SHIP	Green	Green	Green
	SHIP-TRAIN	Green	Green	Green
Total Transit Time (vehicle)	SHIP	Green	Green	Green
	TRAIN	Green	Green	Green
Equipment Performance	PORTAINER	Red	Red	Red
	REACH STACKER	-	-	-
	RTG	Green	Green	-
	HORIZONTAL HANDLING	-	-	Green
System utilization rate	SHIP	Red	Red	Red
	TRAIN	Green	Green	Green

In particular, there are 18 (75%) positive effects that improve terminal performances and 6 (25%) partially negative effects. Some of the negative effects depend upon the constant performances of the portainers, not upgraded in any Scenario, causing an increase of the ship utilization rate due to related congestion effects. Nevertheless, it is possible to take into account an overall positive influence of the technological and operational improvement in terminal.

4.3 Rail-Rail: marshalling yards

The application of both analytical and simulation methods provided the results summarised in Table 18 and described in more details in Figures 29-32 compared with present (State of art) situation.

Table 18: HALLSBERG MARSHALLING YARD KPIs results

KPIs		SCENARIOS						
		State of art	**Consolidated**	**Consolidated (Long Train)**	**Scenario 1**	**Scenario 2**	*Unit*	*Method*
Average wagon transit time		4.57	1.73	4.46	4.50	4.44	h	S
Tracks utilisation rate	Arrival Group	0.63	0.63	0.93	0.93	0.93	-	S
	Direction Group	0.70	0.70	0.93	0.93	0.93	-	S
	Departure Group	0.62	0.62	0.93	0.93	0.93	-	S
Maximum flow through the yard		161	161	275	203	275	Wagons/h	A
Average number of wagons in the yard		1152	607	1033	1666	1662	Wagons	A

From the histograms, it is possible to derive some considerations about the scenarios.

In particular, there is a:

- Reduction of wagon transit time (about 60%);
- Increase of sidings utilization rate (48%) in Consolidated Scenario with long trains;
- Increase of flows through yard (75%) in Consolidated Scenario with long trains;
- Reduction of the amount of wagons in the yard: 50% in Consolidated Scenario with normal trains and significant (10%) in Consolidated Scenario with long trains;
- Reduced interruption time due to breakdowns thanks to retarders' removal in all scenarios.

However, all scenarios require a re-planning of layout: longer tracks, shift or removal of hump, etc.

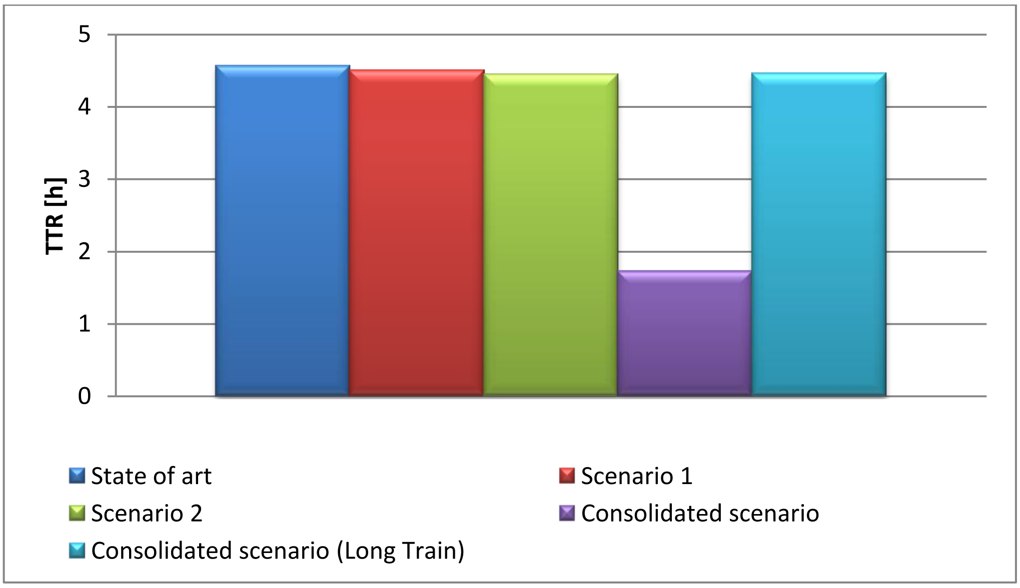

FIGURE 29: AVERAGE WAGON TRANSIT TIME IN HALLSBERG MARSHALLING YARD

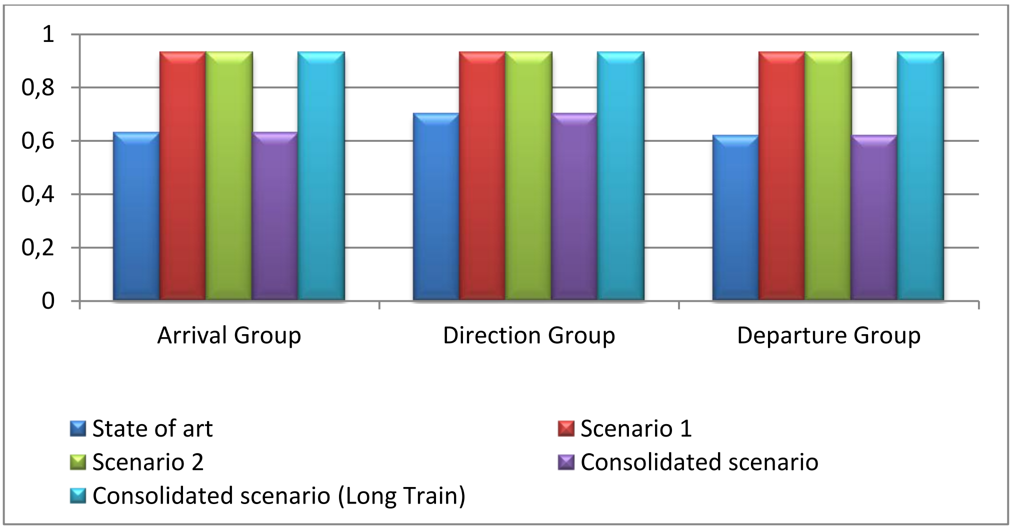

FIGURE 30: TRACKS UTILIZATION RATE IN HALLSBERG MARSHALLING YARD

Rail - Rail conclusions

New technologies and innovational operational measures demonstrated their capability to improve terminal performance. The outputs obtained in terms of Key Performance Indicators demonstrate that innovations are able to increase the overall performances of the marshalling yard, enabling an increase in flows, of both wagons and train, as well as a reduction in duration of various operational phases, in line with the objectives of the European Union.

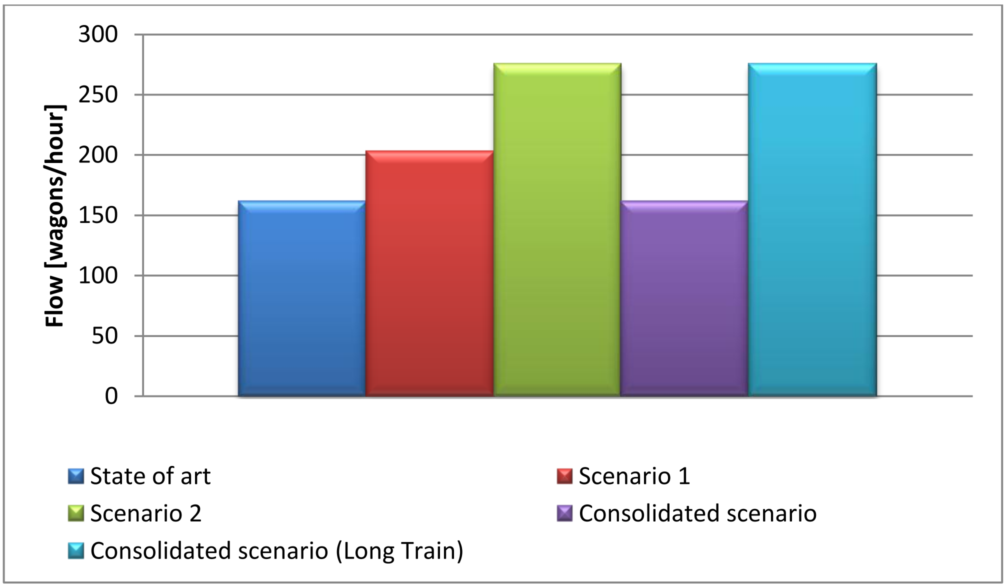

FIGURE 31: MAXIMUM FLOW THROUGH HALLSBERG MARSHALLING YARD

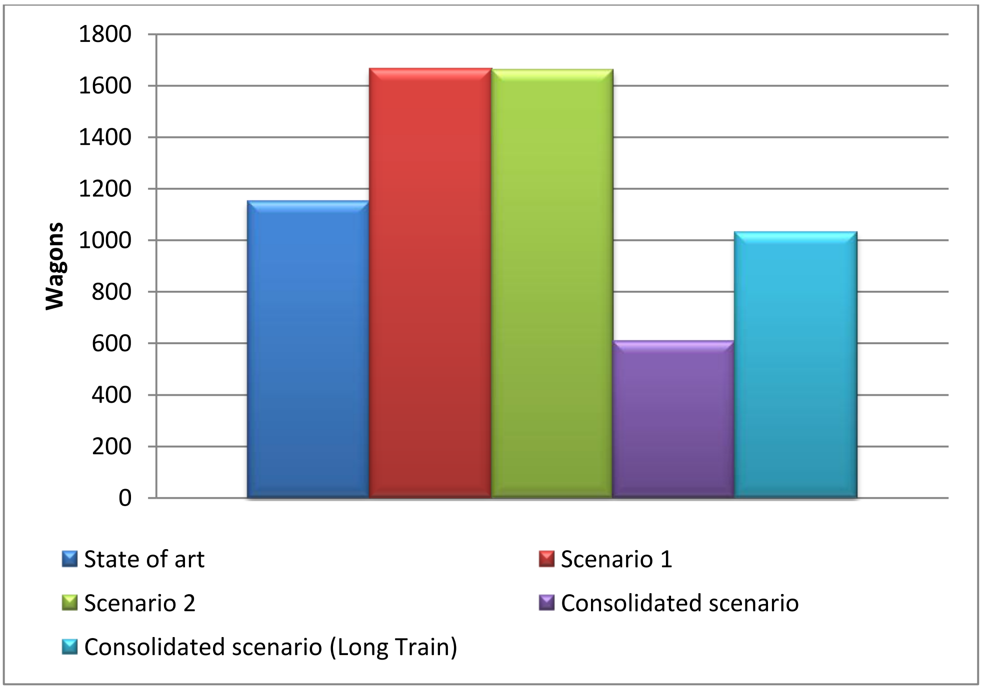

FIGURE 32: AVERAGE NUMBER OF WAGONS IN HALLSBERG MARSHALLING YARD

In table 19 is represented the comparison among all case studies and scenarios with reference to positive and negative effects produced by the implementation of new technologies and innovative operational measures.

TABLE 19: POSITIVE AND NEGATIVE EFFECTS ON TERMINAL PERFORMANCES

- *Green = Positive effect*
- *Red = Negative effect*

KPI		SCENARIO: Consolidated	SCENARIO: Consolidated (Long Train)	SCENARIO: Scenario 1	SCENARIO: Scenario 2
Average wagon transit time		Green	Green	Green	Green
Tracks utilization rate	Arrival Group	Green	Green	Green	Green
	Direction Group	Green	Green	Green	Green
	Departure Group	Green	Green	Green	Green
Maximum flow through the yard		Green	Green	Green	Green
Average number of wagons in the yard		Green	Green	Red	Red

In particular, there are 22 (92%) positive effects improving terminal performances and 2 (8%) partially negative effects. The negative effects are mainly due to the increased flows and the consequent decrease of terminal capacity due to congestion.

5. Operational costs of newly designed terminals: business cases and cost-benefit analyses

5.1 Background

This section discusses the operational cost and benefits of a newly designed terminal from two aspects: business case and socio economic. A project is defined as *an operation comprising of a series of works, activities or services intended to accomplish an indivisible task of a precise economic or technical nature; one which has well defined goals* (European Commission, 2008).

Projects in the *Port, airport and intermodal facility* sectors aim to increase accessibility and promote transport intermodality as well as linking to the national and international transport networks. In many cases, the infrastructure can support local economic development and employment through productive activities and the satisfaction of the transport needs of the local population. For the current task, the project is *the operation of newly designed future terminals to serve rail freight and other (road and maritime) operators in Europe*.

The first step in evaluating a project is to specify whether it is a new construction, extension or upgrading of an existing project and to describe its scope, objectives, technical and physical characteristics. In order to be fully exploited, the terminal will have to be appropriately connected with the inland networks (including road, rail, and inland waterways) to help towards reaching EU goals of shift from road to rail and other more environmentally friendly modes. The project identification should therefore include all the relevant investments needed to guarantee the correct functioning of the entire terminal handling system.

5.2 Introduction

The objective is to achieve improved performance of terminals in Europe, reflected in the financial soundness of their operations as well as the improved turn-around-time of the vessels (in Rail - Sea terminals) and vehicles (in Rail - Road and Rail - Rail terminals).

Factors influencing and determining the operational behaviour of the future terminals will be:

- Novel and improved technologies and equipment, where high performing automated operations of ship-to-shore cranes (Gantry crane), driverless shunting locos and self-propelled wagons, RMG cranes, direct rail-to-rail operations will play a major role;
- Operational measures including longer rail track (e.g. 1500 m), horizontal and vertical operations of automated transhipment equipment, 24 hour operations, automated gates.

The terminal operators' point of view will be addressed by analysing a business case (investigating whether the terminal operators will gain financial benefit from the investment in new terminal with, for example, higher level of automated trans-shipment) so that additional traffic can be attracted to rail based transport and will benefit the terminal operator.

The users/customers (of the terminals) such as rail freight operators, trucking companies, maritime shipping will benefit from the investment in the terminal by a shorter turn-around time and higher asset utilization, among other aspects. The higher automation in the terminal may mean a loss of employment (negative impact) reflected in the analysis; therefore, the analysis must include socio-economic aspects into the cost benefit analysis. Ultimately, the analysis will have to explore and determine whether the increased capability through investments in the project will improve the attractiveness of the terminals and rail freight or not. In order to verify the feasibility of the project, a key issue is the quantification of the present volume of goods traffic, and forecasts for the future pattern of traffic flows.

5.3 Methodological framework

Every time an investment decision occurs, one form or another of weighting costs against benefits is involved, and some form of calculation over time needs to compare the former with the latter when they accrue in different years.

This section aims to define the methodological framework adopted for the financial (business case) and economic (public point of view) analysis of operations of the future (by 2030 and/or 2050) new terminals under the Capacity4Rail project. The methodology is mainly derived from the *Guide to cost-benefit analysis of investment projects* of the European Commission (European Commission, 2008). Here we will conduct analysis from two aspects: examining business case i.e. Financial Analysis (FA) and Cost Benefit Analysis (CBA). The FA represents a commercial point of view, while the CBA goes beyond it, as an essential tool for estimating the socio economic benefits of projects including all impacts: financial, economic, social, environmental, etc.

The objective of CBA is to identify and monetise (i.e. attach a monetary value to) all possible impacts in order to determine the project (in the current study the future terminals) costs and benefits; then the results are aggregated (total costs minus total benefits = net benefits) and conclusions are drawn as to whether the project is desirable and worth implementing. The calculation of costs and benefits is on an incremental basis, by considering the difference between the project scenario and an alternative scenario without the project (sensitivity analysis). The level of analysis used in CBA refers to the society in which the project has a relevant impact.

FA and CBA differ because the first one uses the *private* or *business* point of view of the subjects who runs the project/operations (and/or make it commercially feasible); whereas the CBA takes the *public* point of view, in that it compares only differential costs and benefits borne or taken by the community. Costs and benefits may be borne and accrue at different geographical levels, so a decision has to be made on which costs and benefits should be considered. This typically depends on the size and scope of the project: municipal, regional, national and even EU level impacts (geographical scope).

Financial analysis (FA)

The main purpose of the FA is to compute the project's financial performance. This is from the viewpoint of owners' of the infrastructure or operator of the service (in the current study it is terminal operation and service). The methodology is Discounted Cash Flow (DCF) analysis.

This implies the following calculation pillars.

- The consideration of cash flows only, i.e. the actual amount of cash paid out or received by the project. Thus, for instance, non-cash accounting items like depreciation and contingency reserves must not be included in the DCF analysis. Cash flows are in the year in which they occur and over a given reference period with an additional residual value when the actual economically useful life of the project exceeds the reference period considered.
- When aggregating cash flows occurring in different years, the time value of money justifies the discount back to the present of future cash flows using a time-declining discount factor.
- Checking the financial sustainability of the project is an important deciding factor for the investor. The financial sustainability of the project should be assessed by checking that the cumulated (undiscounted) net cash flows are positive over the entire reference period considered. The net cash flows should take into account investment costs, all financial resources and net revenues, without residual value, unless the liquidation of the asset is in the last year of analysis considered.

In mathematical terms, the Financial Net Present Value (FNPV) is:

$$FNPV = \sum_t B_t (1+i_t)^{-t} - \sum_t C_t (1+i_t)^{-t} - K$$

Where is:

- B_t = Benefits (inflows) in year t;
- C_t = Costs (outflows) in year t;
- i = Discount rate
- K = Initial investment

The Financial Rate of Return (FRR) on investment is the discount rate that zeros out the Financial Net Present Value (FNPV). A comparative benchmark allows evaluating the project performance.

In other words, if the FRR of the investment is the discount rate, the FNPV equals to zero:

$$FNPV = \sum_t B_t (1+FRR)^{-t} - \sum_t C_t (1+FRR)^{-t} - K = 0$$

As discussed in previous paragraphs, the first elements for the analysis are:

- Time horizon;
- Discount rate;
- Geographical scope;
- Benefits/Revenues.

Time horizon

We need to define the maximum number of years for which forecasts are reliable. The forecasts regarding the future of the project refers to a period appropriate to its economically useful life of the main assets and long enough to encompass its likely mid-to-long term impact. The *Guide to cost-benefit analysis of investment projects* of the European Commission suggests typical time horizon of 15-25 years for short-life equipment/asset. For the analysis of terminal handling assets, the current analysis has assumed up to 30 years (including 5 years for investment) of time horizon, with the exception of 60 years for basic infrastructure in Hallsberg Marshalling yard.

Discount rate

The Financial Rate of Return (FRR) is the rate to discount at present future values in the financial analysis to reflect the opportunity cost of capital (European Commission, 2008). On the other hand, the Social Discount Rate (SDR) is the rate to discount at present future values in the economic analysis. It reflects the social view on how net future benefits should be valued against present ones (European Commission, 2008). The *Guidance on the methodology for carrying out cost-benefit analysis* suggests to discount costs and benefits with a real SDR and the SDR benchmark values:

- 5.5% for Cohesion and IPA countries and for convergence regions elsewhere with high growth outlook;
- 3.5% for Competitive regions.

Considering the investment nature in this project the reference values are:

- 3.5% for SDR in CBA, with exploration of rate values between 2% and 5%;
- 5% for FRR in FA, to assume a higher minimum remuneration rate for the investor.

Geographical scope

Since the Capacity4Rail project is in the framework of the EC transport policy and the costs and benefits of the project refer to the EU collectively, the geographical scope is therefore the European territory; in other words, the following specific types of terminals at the EU level:

- Rail - Road intermodal service operation 1: Germany;
- Rail - Sea intermodal service operation 2: Spain.
- Rail - Rail unimodal service operation 3: Sweden;

Benefits/ Revenues

The project will generate their own revenues from the sale of terminal services. This revenue depends upon the forecasts of the quantities (number of containers, wagons and trains handled or loaded/unloaded) of services provided and by their (competitive) prices for different types of cargo as well as services. Transfer, subsidies, VAT or other indirect taxes are not included in the calculation of future revenues. Revenues depend upon unit market tariff for services in each terminal.

5.4 Traffic estimation

The general performance of the European freight market has shown: a sustained growth for many years: the total demand of freight transport in Europe (EU27) increased by 2.8% per year between 1995 and 2007), a decrease in the years 2008-2011, due to economic crisis, and again a recovery in recent years.

In addition, the market share has followed the same trend: the total market share for rail in EU27 has decreased from 21% in 1995 to 17% in 2009 and then increased to 18%. Finally, EU policies tried to support a model of sustainable development and in particular to promote a transport system oriented towards those more efficient ways and respectful to the environment. Within this framework the EU white paper sets the goal for a large modal shift from road to the other modes, among which rail plays a very important role.

In this context, three different scenarios of freight traffic increase, concerns the three terminal typologies (Rail - Road, Rail - Rail and Rail - Sea) studied.

In particular:

- A Business as usual (BAU) scenario with approximately constant market share for rail;
- A high modal shift scenario (High), according to increasing market share for rail targeted by the EU white paper;
- A low modal shift scenario (Low), intermediate between the previous two.

Increase factors refer to the two periods 2015-2030 and 2030-2050 according to the 2030 and 2050 steps of the EU White Paper. Table 20 shows the increase factor and the percentage of increase per year for the three growth scenarios.

Table 20: Increase factor and percentage of increase per year

	Increase factor			Increase % per year		
	2015-2030	2030-2050	*2015-2050*	2015-2030	2030-2050	*2015-2050*
Business as Usual	1.16	1.17	***1.37***	1.0%	0.8%	***0.95***
Modal shift Low scenario	1.34	1.38	***1.87***	2.0%	1.6%	***1.8%***
Modal shift High scenario	1.65	1.84	***3.06***	3.4%	3.1%	***3.2%***

Figures 33÷35 show the number of ITUs transshipped in a year in the Munich Riem Rail - Road terminal, for BAU, Low and High growth path, respectively for Consolidated Scenario, Scenarios 1 and 2 and for the period 2015-2050.

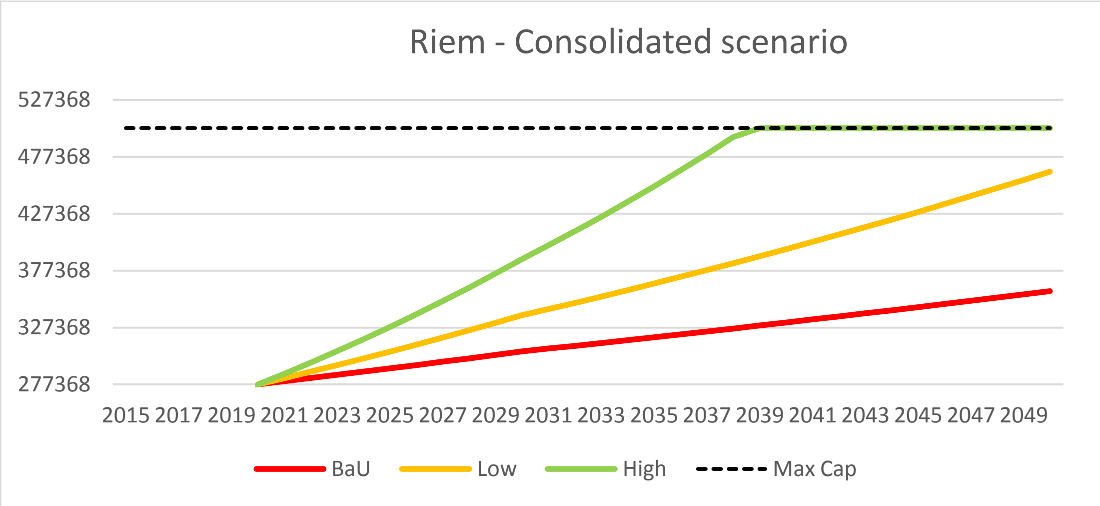

Figure 33: Rail - Road terminal of Munich Riem - increase of transhipped ITUs for the consolidated scenario

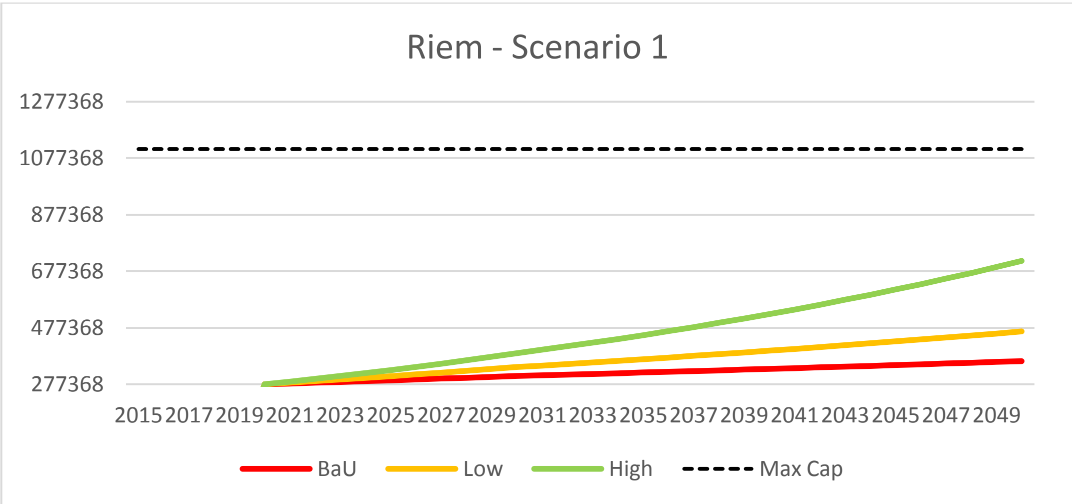

Figure 34: Rail - Road terminal of Munich Riem - increase of transhipped ITUs for scenario1

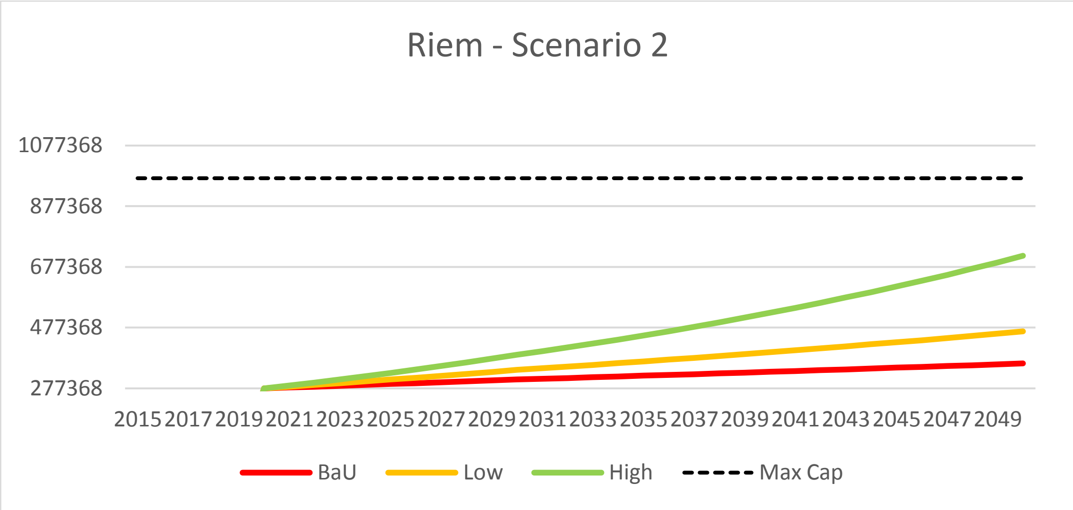

Figure 35: Rail - Road terminal of Munich Riem - increase of transhipped ITUs for scenario2

In the figures the maximum capacity as calculated from simulations are also indicated. In both Scenarios 1 and 2, traffic growth is greatly under the maximum capacity, while with High growth Consolidated Scenario reaches capacity.

Figure 36 shows number of transshipped ITUs according to growth path for the small-scale linear terminal.

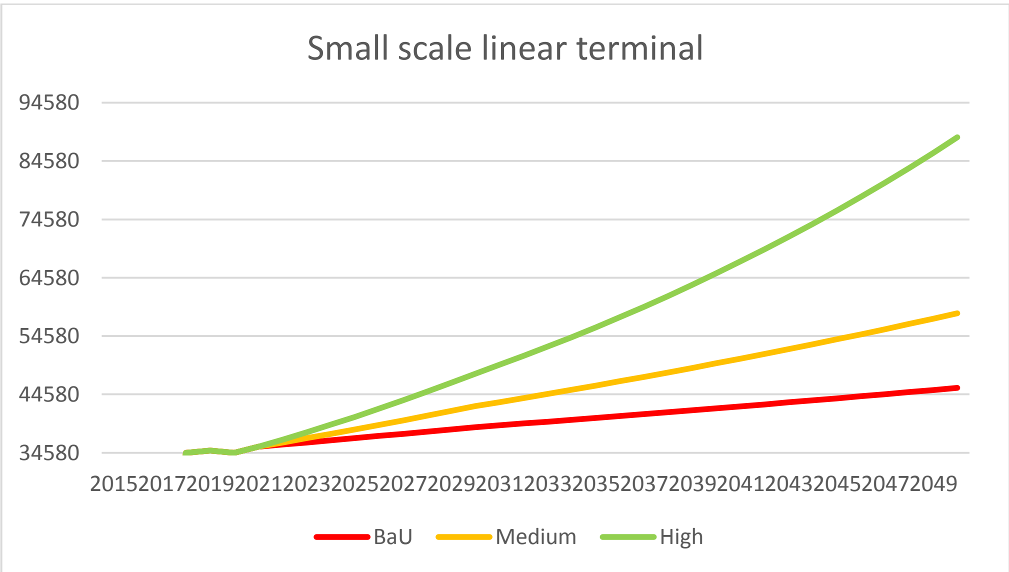

Figure 36: Linear terminal - increase of transhipped ITUs

Regarding Rail - Sea terminal, figures 37-39 show the number of ITUs transshipped in a year in the Valencia terminal for BAU, Low and High growth path, respectively for Consolidated Scenario, Scenarios 1 and 2, for the period 2015-2050.

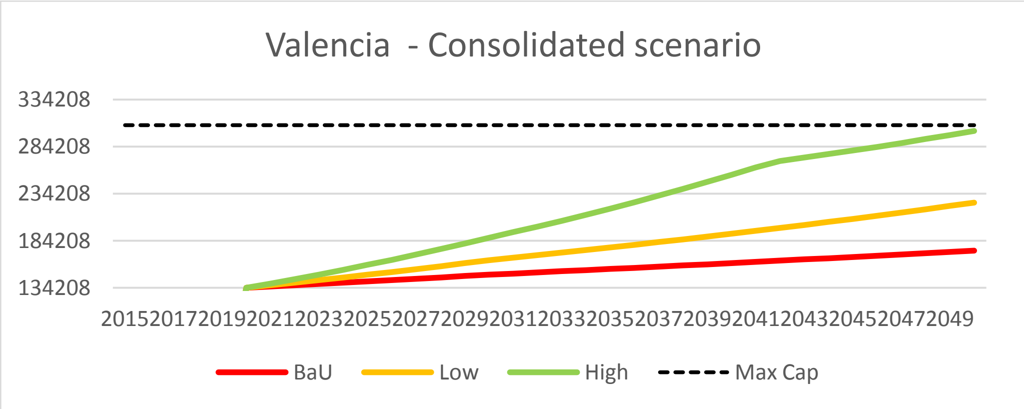

FIGURE 37: RAIL - SEA TERMINAL OF VALENCIA - INCREASE OF TRANSHIPPED ITUS FOR THE CONSOLIDATED SCENARIO

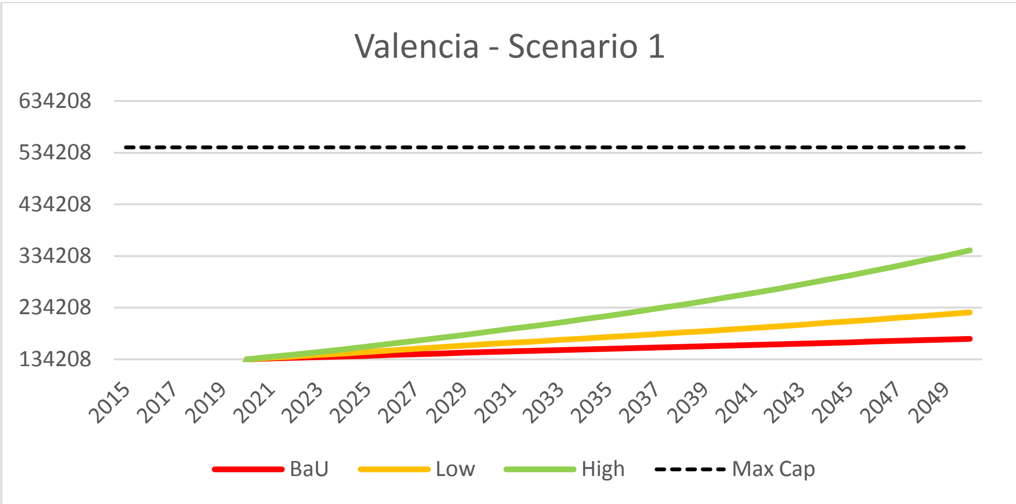

FIGURE 38: RAIL- SEA TERMINAL OF VALENCIA - INCREASE OF TRANSHIPPED ITUS FOR SCENARIO1

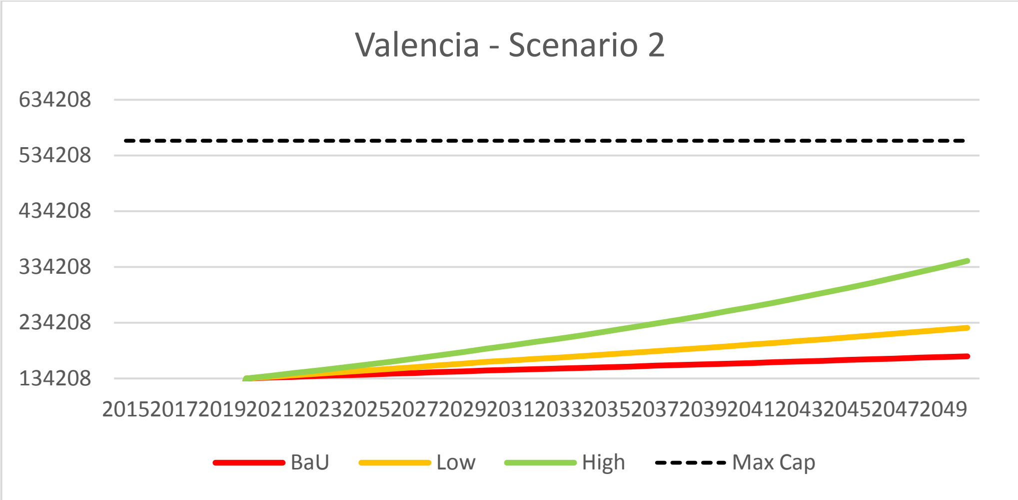

FIGURE 39: RAIL-SEA TERMINAL OF VALENCIA - INCREASE OF TRANSHIPPED ITUS FOR SCENARIO2

The maximum capacity, as calculated by simulations, is in both Scenarios 1 and 2 greatly under the maximum capacity, while in Consolidated Scenario High growth reaches capacity at the end of the period.

Concerning Rail - Rail terminal, figures 40-42 show number of wagons shunted in a year in Hallsberg marshalling yard for BAU, Low and High growth path, respectively for Consolidated Scenario and Scenarios 1 and 2 for the period 2015-2050.

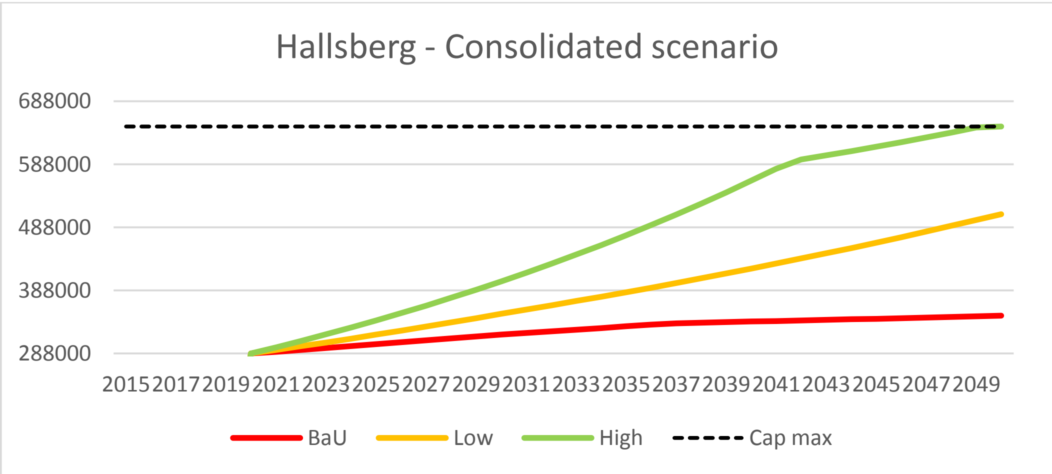

FIGURE 40: RAIL - RAIL MARSHALLING YARD OF HALLSBERG - INCREASE OF SHUNTED WAGONS FOR THE CONSOLIDATED SCENARIO

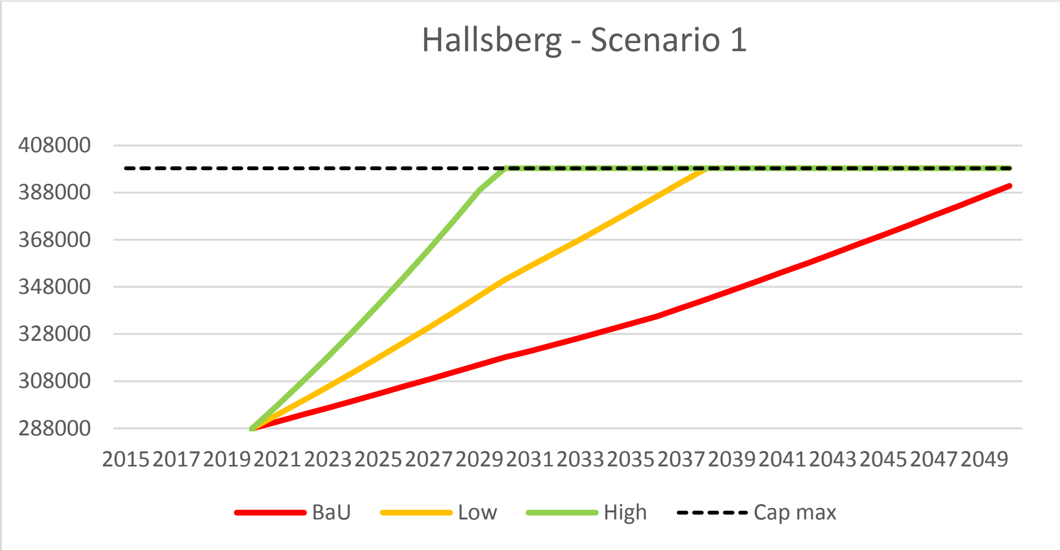

FIGURE 41: RAIL-RAIL MARSHALLING YARD OF HALLSBERG - INCREASE OF SHUNTED WAGONS FOR SCENARIO 1

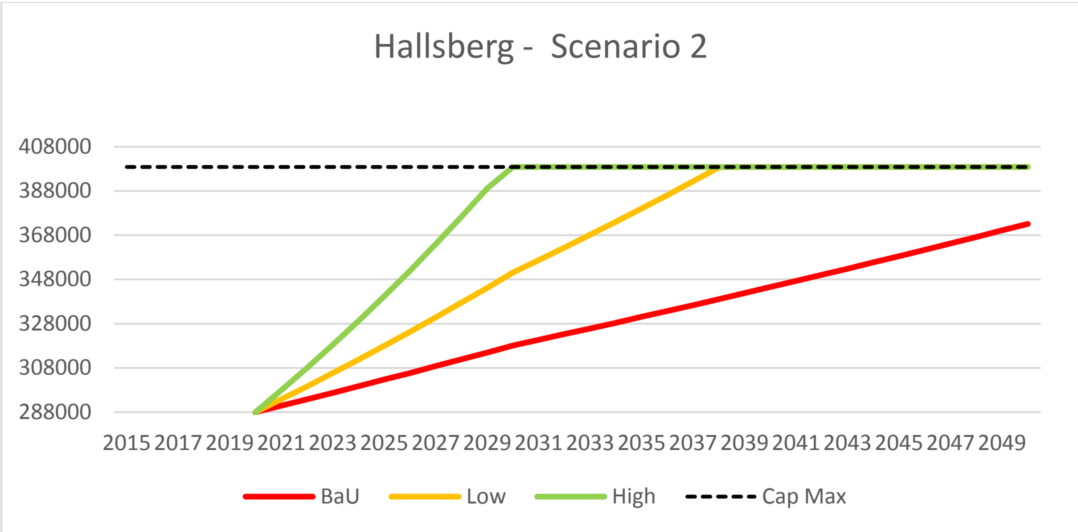

FIGURE 42: RAIL-RAIL MARSHALLING YARD OF HALLSBERG - INCREASE OF SHUNTED WAGONS FOR SCENARIO 2

In the figures the maximum capacity as calculated from simulations has also been indicated.

In this case, the maximum capacity of Consolidated Scenario is higher than the maximum capacity of Scenarios 1 and 2, because in the Consolidated Scenario the yard is considered as the sum of two independent yards (both of them with a hump) one for the normal length train and the other for the long train. In both Scenarios 1 and 2, the High and Low traffic growth reach the maximum capacity, while in Consolidated Scenario only High growth reaches the capacity.

5.5 Costs analysis

The first logical step in the FA and CBA is the estimation of how large the total investment cost will be. The cost of a transportation project in economic terms is the value of the resources consumed to bring the project about. The two categories are investment and operational costs.

Investment costs

Investment cost includes the procurement of terminal automated equipment (such as ship to shore Gantry cranes or RTG Transtainer), installment of automatic gates, driverless shunting locomotives, self-propelled wagons, construction works including civil works for terminal development and rail track (extended part or completely new) and for the case of RTG the installment of railway tracks.

Operational costs

The operational costs comprise of all data on disbursements foreseen for the purchase of goods and services, which are not of an investment nature, consumed within each accounting period. They include 24 hours operations that will include highly skilled crane operators, loco drivers, office costs etc. In the previous section we identified the geographic area of the project i.e. three types of terminals situated in three geographical locations representing European case. The collection of data on investment and operational costs from the concerned case studies terminals is using a previously developed data collection protocol supplemented and validated by discussions in meetings participated by representative from the terminals and other C4R project partners.

5.6 Business case by financial feasibility analysis

Total costs and costs per loading unit

The total costs refer to a year as the capital costs and the operational costs. In the first step, it relates to the actual capacity utilization per year from 2014, nevertheless the capacity of the terminal can be higher than the actual utilization. The investment costs. Calculated below, take into account yearly capital costs by depreciation and an interest rate. For basic investment in rail and terminal infrastructures, the depreciation rate is normally 30 years. Also for Gantry cranes, the depreciation rate period is 30 years, while for reach stackers the adopted depreciation period is 5 years but with a residual value of 30%. The interest rate is 5% in all basic calculations.

Detailed description of calculation of the operational costs is below. To have a better understanding of the costs the cost for operation excluding basic terminal investments is included. This is often the cost calculated by the terminal owners. The basic investments have in most cases been done long time ago by the state and are not always allocated to the actual terminal. However, it is interesting to calculate anyway the total cost for the cases where a new built terminal is necessary. Example of calculation of total yearly costs and cost/TEU is in table 21 for Munich-Riem.

Table 21: Example of calculation of total costs per year and TEU from Munich-Riem.

Total costs			
		Cost €/year	Cost €/TEU
Capacity for calculation TEU/year	300 000		
Operational cost			
Cost for shunting engine		433 153	1,4
Other operating costs		7 949 000	26,5
Sum		8 382 153	27,9
Capital cost			
Annuity technical equipment		1 395 268	4,7
Annuity basic terminal investment		5 033 966	16,8
Sum		6 429 234	21,4
Total cost		14 811 386	49,4
Total cost excluding basic terminal investment		9 777 420	32,6

Investment costs

The investment costs are in most cases not known by the terminal owner, because they have been spent a long time ago and normally in various successive steps. Therefore, the calculation of investment costs is a result of applications of models developed at KTH for a newly built terminal. The parts of the terminal considered are those, where costs are per unit (e.g. the terminal area, the number of tracks and the track lengths, the handling equipment etc. Cost per unit (i.e. cost/meter track, cost per gantry crane etc.) has been gathered from infrastructure managers, rail industries and manufacturers. The target is to take into account all costs, even if they are not paid directly by the terminal owner, i.e. like shunting engines.

Operational costs

Operational costs were provided by the terminal owners, sometime completed or adjusted to make them comparable each other. Costs for shunting engines are often not included in the terminal costs and their calculation was separate and then submitted for approval to the terminal owners themselves.

Future demand

The future demand has been calculated in 3 situations for 2030 and 2050:

- A basic forecast with constant market share for rail;
- Two *shift to rail* forecasts with increasing market share for rail according to the EU Transport White paper 2011.

The total cost includes operating costs and the capital costs for the technical equipment and terminal not including the basic infrastructure investment. An example for Munich-Riem is in table 24.

TABLE 22: EXAMPLE OF CALCULATION OF INVESTMENTS COSTS FOR MUNICH RIEM TERMINAL

Investment costs	Unit	Number	Cost € / unit	Cost Thousands €	Share %
Terminal Investment					
Land acquisition (m2)	m2	280 338	25	7 108	6,9%
Connection Track 200 m (5 tracks) - Track foundation	m	1 000	317	317	0,3%
Connection Track 200 m (5 tracks) - Track structure	m	1 000	634	634	0,6%
Points (switches) (excluding heaters)	m	45	169 035	7 607	7,3%
Handling tracks - Track foundation	m	9 800	317	3 106	3,0%
Handling track - Track structure	m	9 800	634	6 212	6,0%
Shunting tracks - Track foundation	m	8 000	317	2 536	2,4%
Shunting tracks - Track structure	m	8 000	634	5 071	4,9%
Buffer stop	No.	5	4 226	21	0,0%
Catenary to the handling tracks (200m)	m	600	1 056	634	0,6%
Catenary to other tracks	m	8 000	1 056	8 452	8,2%
Road link to the main network	m	2 800	53	148	0,1%
Fences, gates, barriers	m	2 880	37	106	0,1%
Security equipment (cameras / alarms)	m	2 880	53	152	0,1%
Handling and space requirements - dim. 110-tonne axle load	m2	138 171	116	16 057	15,5%
Administrative building & maintenance depot (m2)	m2	800	528	423	0,4%
Fuel tanks	No.	2	4 226	8	0,0%
Lighting	m / track-m	301	1 056	318	0,3%
Drainage	m	9 800	106	1 035	1,0%
Noise barrier	No.	3	2 112 939	6 339	6,1%
Crane runway	No.	3	4 014 584	12 044	11,6%
Rainwater retention	No.	1	1 584 704	1 585	1,5%
Forch water	No.	1	316 941	317	0,3%
Spill through	No.	1	105 647	106	0,1%
Land examination	m2	0	-	-	0,0%
IT system	No.	3	306 376	919	0,9%
Sum		700	-	81 254	78,5%
Technical eqiupment					
New reachstacker	No.	1	475 411	475	0,5%
Used reach stackers	No.	1	158 470	158	0,2%
RMG cranes	No.	6	3 486 350	20 918	20,2%
Locomotive	No.	1	739 529	740	0,7%
Sum				22 292	21,5%
Total Investment Costs				103 545	100,0%

TABLE 23: EXAMPLE OF OPERATION COSTS FOR MUNICH RIEM

DUSS Munich-Reim terminal Annual terminal operational cost components/items	Share %	Cost € Thousands	Source
Annual transhipment equipment running/hire (excluding procurement) cost	5,8%	487	DB
Annual transhipment equipment maintenance cost including procurement of spare parts but excluding major procurement /investment	12,6%	1 053	DB
Annual Personnel cost (split into salaries + social/health/pension insurance)	43,1%	3 585	DB
Annual insurance cost (equipment + operation)	1,7%	142	DB
Annual energy cost	4,1%	338	DB
Annual Terminal hire/rent/mortgage/bank interest cost	3,9%	323	DB
Annual infrastructure maintenance cost	9,8%	813	DB
Other terminal costs (fuel tanks, truck depots security and others)	9,6%	802	DB
Rent	4,2%	350	DB
Annual cost for shunting engine	5,2%	433	KTH model
Cost in thousand Euros - Total (Average for the period 2011-2014, Excluding VAT)	100%	**8 326**	

TABLE 24: EXAMPLE OF FORECAST AND CALCULATION OF OPERATIONAL COSTS PER YEAR AND TEU FOR MUNICH-RIEM

Forecast								
	Forecast			Costs				
	2014	2030	2050	2014	2030		2050	
Increase factors				**Operational cost (B€/year)**				
Business as usual	1,00	1,16	1,37	8,4	9,7		11,5	
Mode shift low scer	1,00	1,34	1,87	8,4	11,2		15,7	*
Mode shift high sce	1,00	1,65	3,06	8,4	13,8	*	25,6	*
Number of TEU/year				**Cost/ TEU (€/ TEU)**				
Business as usual	300 000	348 000	411 000	27,9	27,9		27,9	
Mode shift low scer	300 000	402 000	561 000	27,9	27,9		27,9	*
Mode shift high sce	300 000	495 000	918 000	27,9	27,9	*	27,9	*
				*) Capacity investments is needed				

Financial feasibility analysis

Example of a financial feasibility analysis for Munich Riem is in table 25. To analyse the financial feasibility, we assume that the default handled volume is 300,000 TEU/year based on historical data. The income is based on charging in average 30 Euro/handling, including auxiliary services. With these assumptions, the terminal is profitable in all scenarios.

TABLE 25: EXAMPLE OF FINANCIAL FEASIBILITY ANALYSIS WITH FORECAST OF INCOMES AND LOSS/PROFIT PER YEAR FOR MUNICH-RIEM

Financial analysis								
		Income			Cost for	Loss/profit		
Business economic calculation		2014	2030	2050	300 000	2014	2030	2050
	€ / TEU	B€	B€	B€	TEU B€	B€	B€	B€
Business as usual	30,00	9,0	10,4	12,3	8,4	0,6	0,7	0,8
Mode shift low scenario	30,00	9,0	12,1	16,8	8,4	0,6	0,8	1,2
Mode shift high scenario	30,00	9,0	14,9	27,5	8,4	0,6	1,0	1,9

Sensibility analysis for different interest rates

The sensibility analysis aims to take into account different interest rates for the capital costs Table 26). Beside 5% interest rate, calculated as normal rate in business economic calculations, also 3% and 2% rates take into account that in 2016 the normal rate was very low and that the state can approve profitability of intermodal terminals by setting a lower rate for these types of assets.

TABLE 26: EXAMPLE OF SENSIBILITY ANALYSIS FOR DIFFERENT INTEREST RATES FROM MUNICH RIEM

		Interest rate: 5%		Interest rate: 3%		Interset rate: 2%	
		Cost €/year	Cost €/TEU	Cost €/year	Cost €/TEU	Cost €/year	Cost €/TEU
Capacity for calculation TEU/year	300 000						
Operational cost							
Cost for shunting engine		433 153	1,4	433 153	1,4	433 153	1,4
Other operating costs		7 949 000	26,5	7 949 000	26,5	7 949 000	26,5
Sum		8 382 153	27,9	8 382 153	27,9	8 382 153	27,9
Capital cost							
Annuity technical equipment		1 395 268	4,7	1 081 758	3,6	929 850	3,1
Annuity basic terminal investment		5 033 966	16,8	4 024 757	13,4	3 556 831	11,9
Sum		6 429 234	21,4	5 106 515	17,0	4 486 681	15,0
Total cost		14 811 386	49,4	13 488 667	45,0	12 868 834	42,9
Total cost excluding basic terminal investment		9 777 420	32,6	9 463 910	31,5	9 312 003	31,0

5.7 RESULTS OF FINANCIAL FEASIBILITY

The terminal typologies analysed in this report are.

- Intermodal terminals:
  - Rail - Road: Munich Riem
  - Rail - Sea: Valencia Principe Felipe
  - Rail - Road: small-scale typical automatic liner terminal
- Internal rail production terminal:
  - Rail - Rail: Hallsberg marshalling yard

The extensive description of these terminals is in Deliverable 2.3.1, while an overview of their key features is in Table 4 (section 3.3).

Total cost per year and unit

The total costs per year, divided into operational and capital costs, are in table 27. The total costs for intermodal terminals is bigger for Munich, with 14.8 M€ per year, related to highest capacity and utilization rate. Valencia's total cost is calculated to 3.0 M€ per year with a utilization of 100,000 units per year. The small-scale automatic liner terminal is the cheapest one, with 223 k€ per year, in this case with the low utilization of 16,500 TEU per year only, though its handling capacity is up to 100 000 units for a small additional cost. This cost estimation is less reliable, because it is a prospect solution not yet in service. If we add the cost for the rail siding (not already existing for other purposes), beside which the terminal is localised at, the total cost will be 304 thousand €/year. However, a marshalling yard like Hallsberg is very expensive (total cost is 24 M€ per year), but has another function and is not directly comparable with an intermodal terminal.

The cost distribution by operating costs and capital costs is in figure 43. The operating costs, which the terminal operator themselves should be able to control, is 40-60% of the total cost, which grows to 60-85% of the total costs by adding the capital costs for technical equipment. The capital cost for basic terminal investment, not always directly paid by the terminal operator stands for 15-40% of the total cost. The cost per unit is in table 28. This is more interesting than the total cost because it relates to the actual utilization.

TABLE 27: TOTAL COSTS PER YEAR FOR THE TERMINALS IN THE REFERENCE SITUATION

	Cost €/year			
	Inter modal terminals			Marshalling yard
	Munich	Valencia	Liner AMCCT	Hallsberg
Terminal typology	Rail-road	Rail-sea	Rail-road	Rail-Rail
Capacity for calculation TEU/year	300 000	100 000	16 500	250 000
Operational cost				
Cost for shunting engines/marshalling	433 153	274 682	0	3 835 779
Other operating and maintenance costs	7 949 000	1 195 030	92 483	9 263 376
Sum	8 382 153	1 469 712	92 483	13 099 155
Capital cost				
Annuity technical equipment	1 395 268	315 239	98 026	4 048 456
Annuity basic terminal investment	5 033 966	1 226 382	32 544	6 918 640
Sum	6 429 234	1 541 622	130 570	10 967 096
Total costs				
Including basic terminal investment	14 811 386	3 011 334	223 053	24 066 251
Excluding basic terminal investment	9 777 420	1 784 951	190 509	17 147 611

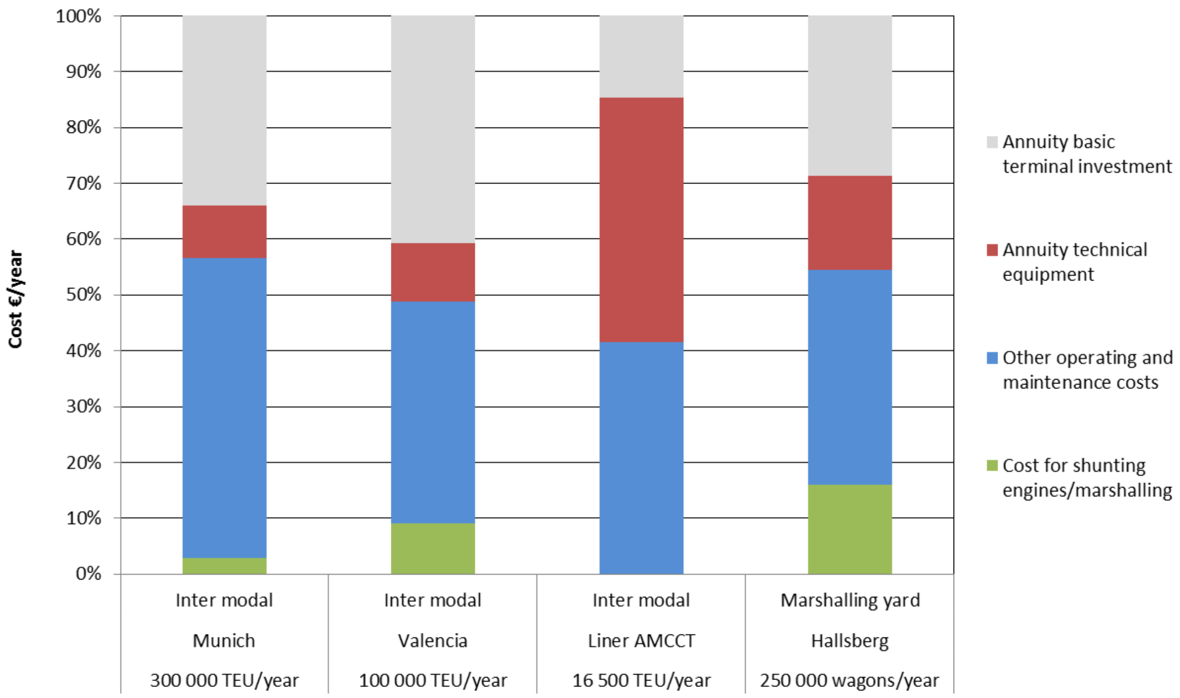

FIGURE 43: DISTRIBUTION OF TOTAL COSTS PER YEAR FOR THE ACTUAL TERMINALS

Table 28: Total costs per unit for the actual terminals

	Cost €/TEU			€/wagon
	Munich	Valencia	Liner AMCCT	Hallsberg
Terminal typology	Rail-road	Rail-sea	Rail-road	Rail-Rail
Capacity for calculation TEU/year	300 000	100 000	16 500	250 000
Operational cost				
Cost for shunting engines/marshalling	1,4	2,7	0,0	15,3
Other operating and maintenance costs	26,5	12,0	5,6	37,1
Sum	27,9	14,7	5,6	52,4
Capital cost				
Annuity technical equipment	4,7	3,2	5,9	16,2
Annuity basic terminal investment	16,8	12,3	2,0	27,7
Sum	21,4	15,4	7,9	43,9
Total costs				
Including basic terminal investment	49,4	30,1	13,5	96,3
Excluding basic terminal investment	32,6	17,8	11,5	68,6

In a first step, we have calculated the operating costs per TEU: 28€ for Munich, 15 € for Valencia and 6 € for the automatic liner terminal, thanks to the low cost for the liner terminal because there is no shunting engine and no personnel.

In a second step, we have calculated the operational costs and the capital costs for the technical equipment. This is normally a medium term cost: the resulting values are 33 €/TEU for Munich, 18 €/TEU for Valencia and 12 €/TEU for the automatic liner terminal.

This is close to the market price for handling units and wagons: for example, the average income in Munich terminal is 30 €/TEU.

In the third step, a total cost includes also the basic investments for building new terminals (figure 44).

The results are 49 €/TEU for Munich, 30 €/TEU for Valencia and 14 €/TEU per TEU for the automatic liner terminal. This cost can be helpful, mostly whenever the rebuilding of the yard is necessary. However, the cost for handling wagons on a marshalling yard is quite different, the operating cost is 15 € per wagon and in Sweden the operator has to pay a fee of 7 € per train or 0.3 € per wagon which make a total of approximately 16 € per wagon. This is the socio-economic marginal cost. By adding the yearly maintenance and operational cost for the infrastructure manager it will be 52 € per wagon. Calculating the total cost, it will be very expensive: in this case 96 € per wagon.

For the basic rail infrastructure of a marshalling yard the depreciation period is 60 years (the track foundation are normally older), as well as for technical equipment, it is estimated 30 years.

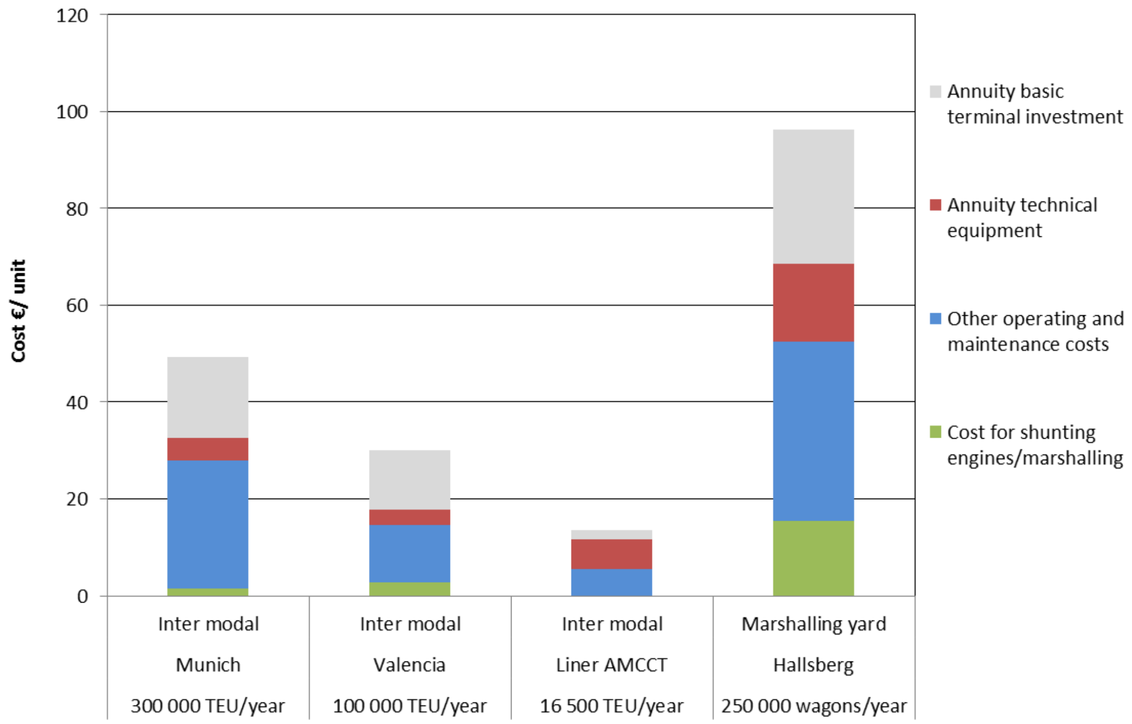

FIGURE 44: COST PER UNIT WITH DISTRIBUTION OF COST TYPES FOR THE ACTUAL TERMINALS

However, it may be necessary to change rails and crossties after a number of years so in average 60 years and 5% rent overall investment cost will be an accurate average cost for renewal. The most probable reinvestment are longer tracks and new technical equipment for example retarders.

Financial feasibility analysis

The financial feasibility analysis compares costs with potential revenues. This approximates the profitability because there is no perfect market for terminal handling, which is an activity in the transport chain not always priced separately and not even for the full cost considering all capital costs.

For calculations, the demand levels are:

- Actual demand at 2014: starting point with factor 1.00;
- Modal shift low scenario 2030: next level with increase factor of 1.34;
- Modal shift high scenario 2050: highest level with increase factor of 3.06.

Modal shift low scenario 2030 is approximately the same as business as usual scenario 2050, which have a growth factor of 1.37.

Therefore, the situations analysed are today´s level, a normal increase and a maximum level. The cost per unit is assumed to be constant in Munich at 30 €/unit and in Valencia at 17 €/unit but in the automatic linear terminal it will decrease from 14 to 3 €/unit (table 29).

TABLE 29: COST PER UNIT WITH DISTRIBUTION OF COST TYPES FOR THE ACTUAL TERMINALS.

	Cost €/year			
	Inter modal terminals			Marshalling yard
	Munich	Valencia	Liner AMCCT	Hallsberg
Terminal typology	Rail-road	Rail-sea	Rail-road	Rail-Rail
Demand				
Business as usual 2014	300 000	100 000	16 500	250 000
Mode shift low scenario 2030	402 000	134 000	22 846	334 423
Mode shift high scenario 2050	918 000	306 000	92 830	765 318
Cost per year				
Business as usual 2014	8 382 153	1 701 260	223 053	13 099 155
Mode shift low scenario 2030	11 232 084	2 200 962	223 554	14 500 000
Mode shift high scenario 2050	25 649 387	4 728 867	311 448	18 125 000
Cost/unit				
Business as usual 2014	28	17	14	52
Mode shift low scenario 2030	28	16	10	43
Mode shift high scenario 2050	28	15	3	24
Income				
Revenue € /unit	30	30	14	52
Income/year				
Business as usual 2014	9 000 000	3 000 000	223 053	13 099 155
Mode shift low scenario 2030	12 060 000	4 020 000	308 843	17 522 632
Mode shift high scenario 2050	27 540 000	9 180 000	1 254 916	40 100 085
Loss or profit per year				
Business as usual 2014	617 847	1 298 740	0	0
Mode shift low scenario 2030	827 916	1 819 038	85 289	3 022 632
Mode shift high scenario 2050	1 890 613	4 451 133	943 468	21 975 085
Loss or profit per unit				
Business as usual 2014	2	13	0	0
Mode shift low scenario 2030	2	14	4	9
Mode shift high scenario 2050	2	15	10	29

In conventional terminals, the handling cost will increase because they need more human resources, reach-stackers, gantry cranes and finally investments in larger handling area with higher volumes. For the automatic terminal, it is different with rather low and constant costs up to 30,000 TEU and then investment in 1 more transfer unit up to 100,000 TEU but no need for more staff (figure 45). In addition, the marshalling yard has a rather fixed cost but on a very high level and can handle up to 500,000 wagons with today´s infrastructure and operating principles. The cost per wagon will decrease by volume (figure 46). The income is estimated and has been calculated as in Munich and Valencia at 30 €/unit and in the automatic linear terminal at 14 €/unit. In the marshalling yard it has been calculated as 52 €/wagon, which is today's operating and maintenance cost, i.e. what operators and infrastructure managers are paying for it.

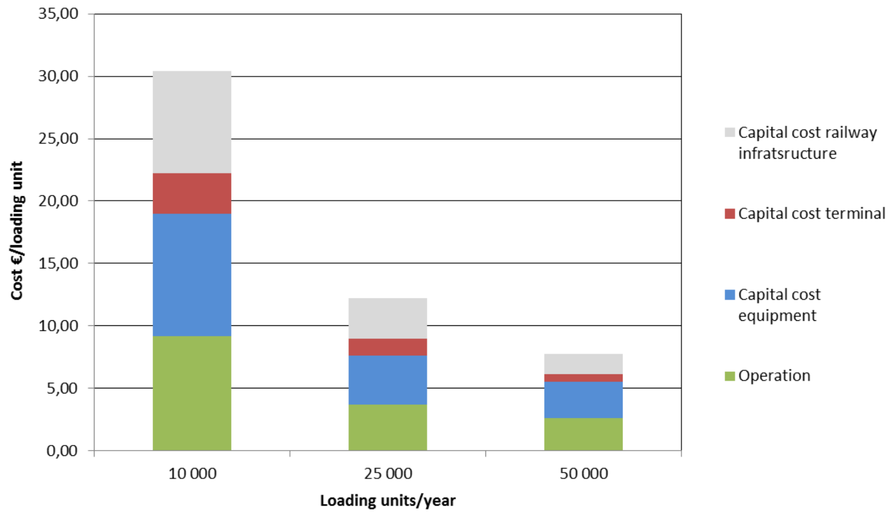

FIGURE 45: SMALL-SCALE AUTOMATIC TERMINAL WITH AUTOMATIC TRANSFER UNIT. CALCULATED COST PER LOADING UNIT (CONTAINER OR SWAP-BODY)

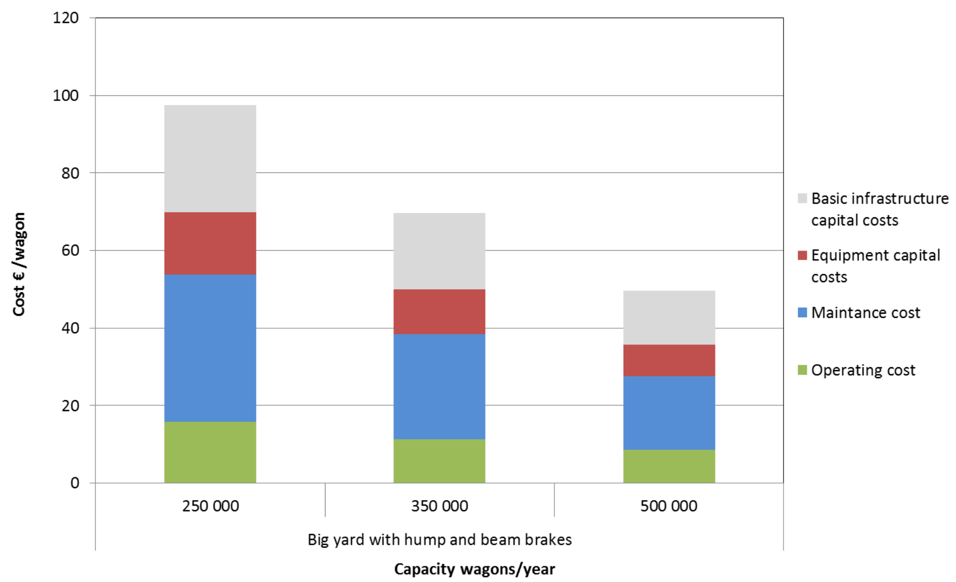

FIGURE 46: COST PER WAGON FOR MARSHALLING AT HALLSBERG MARSHALLING YARD DEPENDING ON DEMAND AND COST COMPONENTS

The loss or profit is the difference between costs and revenues. The result is that the intermodal terminals are profitable from the start and the profit will increase with higher volumes.

The profit results 2 €/unit in Munich and in Valencia at 14 €/unit in the automatic liner terminal and it will increase from break-even at the lowest level to 10 €/unit at the highest level. Nevertheless the price for the liner terminal is also lower, with 14 €/unit compared with 30 €/unit for Munich and Valencia. Also for the marshalling yard, there is a theoretical profit increasing with higher volume. However, the yard is not as a stand-alone business unit, but a pre-requisite for the rationalization of wagonload's transport system within the service production chain.

5.8 Economic assessment by cost-benefit analysis

The Cost Benefit Analysis relates to the three typologies of terminals over a 30 year period, the most suitable time horizon for the considered infrastructural investments. The investment costs were concentrated in the first five years, particularly those related to area acquisition and construction, have been broken down starting from year 1 to year 5 included, while the investment costs related to the gate, to the automatic crane or to the horizontal translators split between year 4 and 5. Benefits start from year 6 to year 30. For the small-scale linear terminal only, the investment costs has been divided in the first 3 years and, consequently, benefits covers the period from year 4 to year 30, taking into account that the construction works take a shorter time period compared to the other terminals.

Considering the investment costs, of Rail - Road and Rail - Sea terminals, due to the lack of specific data regarding the cost of procurement of the areas and construction, a parametric value for surface unit derived from the cost of construction of other terminals, provided by experts within C4R research consortium was employed. In the same way, the estimate of automatic crane and gate cost came from consortium experts, while for horizontal transfer a value founded in the 1999 literature, has been employed, appropriately revalued at the average rate of Eurozone inflation.

Regarding operational costs, data provided by the operators of the three considered case studies has been used, appropriately modified to take into account technological and operational changes foreseen by the considered scenarios. Personnel-related and energy costs are calculated net of tax. All operating costs increased annually with the average inflation rate in the Eurozone over the years 1999 - 2015.

Concerning Hallsberg marshalling yard, the investment costs (e.g. land acquisition and construction) were calculated using a parametric value for surface unit, based on the same data used in the financial analysis, taking into account land acquisition, track substructure and structure, switches, catenary, drainage, lighting and fences. While investment costs; concerning rolling stock (e.g. self-braking and self-propelling devices or automatic couplers), are not charged to the marshalling yard. For operating costs, data was provided by the operators of the considered case study, appropriately modified to take into account of technological and operational changes foreseen by the considered scenarios. In particular, personnel cost has been reduced due automatic coupling/uncoupling of the wagons. Personnel-related and energy costs are calculated net of tax. All operating costs increased with the average inflation rate in the Eurozone over the years 1999 – 2015.

For all three terminal types benefits are identified in transit timesaving, decrease of external costs and, finally, from the extra traffic revenues. In order to evaluate timesaving and external cost benefits, the payload is 10 tonnes for the ITUs and 22 tonnes for the wagons shunted in marshalling yard.

The first class of benefits, takes into account the difference in transit time between the present situation (2015) and the correspondent value of the considered Scenario, coming from simulations. The amount of saved transit time multiplies by the correspondent transhipped tonnes and for the Value of Time (VOT). Literature reports VOT for a general goods type between 1.0 and 1.7 €/t; for the calculation it has been assumed the lower value (1.0 €/t). For instance, for the Rail - Road terminal (table 30), the total transit time of an ITU in coming by truck and out-coming by train is presently 22 h. In the consolidated scenario it became 12.67 h with a time saving of 9.33 h, therefore the benefit due to time saving is 9.33 € for each tonne of payload, while benefit for the scenarios 1 and 2 are respectively 18.48 € and 17.13 € for each tonne of payload. Tables 30 to 33 show the saved transit time for Rail - Road, Linear terminals, Rail – Sea and Rail – Rail, estimated by the simulation model. Concerning the second class of benefit, this has been considered only for the part of traffic that exceeds the present amount (2015) assuming that new traffic is entirely captured from the road market. In this way, traffic increase has been multiplied for the external cost reduction coming from literature from 42.2 to 30.8 €/1,000 tkm. In addition, the lowest value (30.8 €/1,000 tkm) has been used in this case.

TABLE 30: RAIL - ROAD TERMINAL OF MUNICH RIEM - TOTAL AND SAVED TRANSIT TIME

	2015	Consolidated Scenario	Scenario 1	Scenario 2
Total Transit Time (ITU)	ITU - TTR $_{Truck-Train}$ = 22 [h] ITU - TTR $_{Train-Truck}$ = 10.48 [h]	ITU - TTR $_{Truck-Train}$ = 12.67 [h] ITU - TTR $_{Train-Truck}$ = 8.78 [h]	ITU - TTR $_{Truck-Train}$ = 3.52 [h] ITU - TTR $_{Train-Truck}$ = 2.45 [h]	ITU - TTR $_{Truck-Train}$ = 4.87 [h] ITU - TTR $_{Train-Truck}$ = 0.53 [h]
Saved Transit Time (ITU)	-	ITU TS $_{Truck-Train}$ = 9.33 [h] ITU TS $_{Truck-Train}$ = 1.70 [h]	ITU ST $_{Truck-Train}$ = 18.48 [h] ITU ST $_{Truck-Train}$ = 8.03 [h]	ITU TS $_{Truck-Train}$ = 17.13 [h] ITU TS $_{Truck-Train}$ = 9.95 [h]

TABLE 31: SMALL-SCALE LINEAR TERMINAL - TOTAL AND SAVED TRANSIT TIME

	Terminal Riem (2005)	Linear terminal
Total Transit Time (ITU)	$TTT_{\text{average Truck-Train and Train-Truck}}$ = 16.24 [h]	TTT = 3.34 [h]
Saved transit time (ITU)	-	ST = 12.90 [h]

TABLE 32: RAIL - SEA TERMINAL OF VALENCIA - TOTAL AND SAVED TRANSIT TIME

	2015	Consolidated Scenario	Scenario 1	Scenario 2
Total Transit Time (ITU)	ITU - $TTR_{\text{Train-Ship}}$ = 6.77 [h] ITU - $TTR_{\text{Ship-Train}}$ = 39.33 [h]	ITU - $TTR_{\text{Train-Ship}}$ = 5.05 [h] ITU - $TTR_{\text{Ship-Train}}$ = 15.06 [h]	ITU -$TTR_{\text{Train-Ship}}$ = 5.42 [h] ITU -$TTR_{\text{Ship-Train}}$ = 7.45 [h]	ITU - $TTR_{\text{Train-Ship}}$ = 5.62 [h] ITU - $TTR_{\text{Ship-Train}}$ = 7.37 [h]
Saved Transit Time (ITU)	-	ITU $ST_{\text{Train-Ship}}$ = 1.72 [h] ITU $ST_{\text{Ship-Train}}$ = 24.27 [h]	ITU $ST_{\text{Train-Ship}}$ = 1.35 [h] ITU $ST_{\text{Ship-Train}}$ = 31.88 [h]	ITU $ST_{\text{Train-Ship}}$ = 1.15 [h] ITU $ST_{\text{Ship-Train}}$ = 31.96 [h]

TABLE 33: RAIL - RAIL MARSHALLING YARD OF HALLSBERG – TOTAL AND SAVED TRANSIT TIME

	2015	Consolidated Scenario	Scenario 1	Scenario 2
Total Transit Time (wagon)	TTT= 4.57 [h]	TTT = 1.73 [h] TTT_{long} = 4.46 [h]	TTT = 4.50 [h]	TTT = 4.44 [h]
Saved transit time (wagon)	-	ST = 2.84 [h] ST_{long} = 0.11 [h]	ST = 0.07 [h]	ST = 0.13 [h]

Finally, for the extra traffic revenues of Rail - Road and Rail - Sea terminals, the income is from the increase of transhipping activities due to the increased movement of ITUs in the various scenarios considered, assuming direct transhipment of all ITUs and a revenue of each handled ITU of 30 €.

For Rail - Rail terminal incomes are coming from the increase of shunting activities due to the increase of shunted wagons in the various scenarios, considering the amount of 0.3 € / wagon.

For small-scale linear terminal, the benefits come from transit time saving taking into account the difference in transit time between a standard large scale terminal (in our case Munich Riem) and the correspondent value of the small-scale linear terminal, identified through simulations. Benefits from a decrease of external costs have been considered for all traffic handled by linear terminal assuming that all traffic captured is from road and extra traffic revenues have been considered coming from the whole traffic, considering the amount of 13.5 €/transhipped ITU.

5.9 Results of cost-benefit analysis

The Cost Benefit Analysis covers a 30-year period. CBA Net Present Value (NPV) has been calculated using three different values of the rate of return: 5% (near to 5.5% fixed as maximum value by the EU Guide to Cost Benefit Analysis for Investment Project) and a couple of lower values (3% and 2%), to investigate the variability of the NPV to change in the discount rate. As a general remark, higher rate of return gives a lower NPV for all three infrastructural scenarios considered. For each scenario, lower growth gives lower NPV, as expected for projects involving a cash flow with big investments at the beginning of the period and benefits delayed to the end of the evaluation period.

For Riem Rail - Road terminal, there is an increase in the NPV between 37% and 47%, switching the rate of return from 5% to 3% and between 61% and 78% for a 2% rate of return, depending upon the scenarios considered.

The linear terminal shows the same trend where the decrease of rate of return from 5% to 3% increases the NPV between 32% and 39% and the decrease of the rate of return from 5% to 2% increase NPV between 54% and 65%.

For the Rail - Sea terminal of Valencia, the decrease of rate of return to 3% increases the NPV between 36% and 40%, while a rate of 2% increase the NPV between 61% and 67%.

Finally in Rail - Rail marshalling yard in Hallsberg, the highest rate of return provides the best values since NPV is always negative, while a rate of return of 3% leads to a deterioration in the NPV between 26% and 31% and a rate of return of 2% between 43% and 51%.

Rail - Road terminal of Munich Riem

Table 34 shows the values of the Net Present Value calculated for Riem terminal for concerned scenarios and values of the rate of return.

Scenario 2 shows the best values of NPV thanks to a lower investment for the area and higher volume of handled traffic. While Scenario 1 has lower values due to lower traffic, consolidated scenario shows a set of lower NPV compared to the correspondent growth of Scenarios 1 and 2, taking into account that it is an intermediate scenario between present situation and the future infrastructural situation.

TABLE 34: RAIL - ROAD TERMINAL OF MUNICH RIEM - NET PRESENT VALUES FOR DIFFERENT SCENARIOS

Net Present Value									
	Consolidated Scenario *[Billion €]*			**Scenario 1** *[Billion €]*			**Scenario 2** *[Billion €]*		
Rate of Return	**BAU**	**Low**	**High**	**BAU**	**Low**	**High**	**BAU**	**Low**	**High**
2%	139	189	267	348	429	578	418	501	652
3%	117	158	222	288	354	475	354	422	545
5 %	85	113	156	198	242	324	259	305	387

Small-scale linear terminal

Table 35 shows the values of the Net Present Value for three values of the rate of return.

TABLE 35: SMALL-SCALE LINEAR TERMINAL - NET PRESENT VALUES

Net Present Value *[Billion €]*			
Rate of Return	**BAU**	**Low**	**High**
2%	86	93	102
3%	74	80	86
5%	56	59	62

For the linear terminal, NPV values show the same trend as the other cases. Of course, the NPV values are lower, compared to a traditional Rail - Road terminal, since it is smaller, for both the investment scale and the traffic volume. It is interesting to compare the linear terminal with the traditional large Rail - Road terminal in terms of the ratio between sum of discounted benefits and costs, which do not consider the terminal scale difference (Tables 36 and 37). The linear terminal presents values of the ratio systematically higher than the traditional terminal.

Rail - Sea terminal of Valencia Principe Felipe

Table 38 shows the values of the Net Present Values calculated for Valencia Principe Felipe terminal for concerned scenarios and values of the rate of return.

TABLE 36: MUNICH RIEM RAIL - ROAD TERMINAL (SCENARIO 1) – BENEFIT/COST RATIO

Terminal Riem – Scenario1 Benefit/Cost			
Rate of Return	**BAU**	**Low**	**High**
2%	2.82	2.75	3.36
3%	2.37	2.62	3.18
5%	2.12	2.37	2.82

TABLE 37: SMALL-SCALE LINEAR TERMINAL – BENEFIT/COST RATIO

Linear Terminal Benefit/Cost			
Rate of return	**BAU**	**Low**	**High**
2%	16.64	18.94	20.66
3%	15.37	17.47	18.76
5%	13.02	14.89	15.44

TABLE 38: RAIL-SEA TERMINAL OF VALENCIA PRINCIPE FELIPE - NET PRESENT VALUES FOR DIFFERENT SCENARIOS

Net Present Value *[Billion €]*									
	Consolidated Scenario			**Scenario 1**			**Scenario 2**		
Rate of Return	**BAU**	**Low**	**High**	**BAU**	**Low**	**High**	**BAU**	**Low**	**High**
2%	360	410	501	464	527	642	467	529	644
3%	305	346	420	394	445	538	396	447	540
5 %	224	251	301	288	322	384	290	326	387

Scenarios 1 and 2 are very similar, with little prevalence of the second as it has slightly higher traffic, while Consolidated Scenario shows a set of lower NPV compared to the correspondent growths.

Rail-Rail marshalling yard of Hallsberg

Table 39 shows the values of the Net Present Value calculated for the marshaling yard of Hallsberg for concerned scenarios and values of the rate of return.

TABLE 39: RAIL - RAIL MARSHALLING YARD OF HALLSBERG - NET PRESENT VALUES FOR DIFFERENT SCENARIOS

Net Present Value *[Billion €]*									
	Consolidated Scenario			**Scenario 1**			**Scenario 2**		
Rate of Return	**BAU**	**Low**	**High**	**BAU**	**Low**	**High**	**BAU**	**Low**	**High**
2%	-133	-117	-104	-204	-203	-202	-176	-174	-173
3%	-115	-102	-91	-179	-178	-177	-155	-154	-152
5 %	-88	-79	-71	-141	-140	-140	-123	-122	-121

All scenarios show negative NPV values due to the high investment and maintenance costs, on the other hand, time savings and volumes are not enough to pay back costs. However, it is reductive to isolate the marshalling as a single element, while it is an essential part of a system and of the wider wagonload business. Moreover, this is only a case study, which does not exclude the fact that the application of such innovations to other marshalling yards may lead to results that are more favorable. Finally, in this case, the Consolidated Scenario is the best one, due to the highest number of handled wagons compared to the other scenarios.

6. Conclusions and inputs for other WPs and SPs

The activities carried out in relation to the design of the rail freight terminal of the future, demonstrated that the following objectives set at the beginning of this deliverable are achievable:

a) Definition of terminals typologies capable to cover the large majority of rail freight traffic;
b) Identification of a set of Key Performance Indicators by terminal typology capable to represent the operational modes of the terminal and to be sensitive to the effects of the innovations;
c) Focused and enlarged case studies to comply with the above typologies;
d) Identification of innovations suitable to be included in a consolidated scenario for each terminal typology and case study;
e) Identification of innovations suitable to increase the global efficiency of logistic chains;
f) Assessment of future terminal performances including the effects of innovative technologies and operational measures;
g) Calculation of operational and investment costs of newly designed terminals business case and cost-benefit analyses;
h) Consolidation of a suitable methodology for future traffic estimation, financial and cost-benefit analysis.

The research specifically targeted the contributions of terminals to the rail freight systems in 2030 and 2050.

The activities completed in WP2.3 achieved a large set of results concerning typical terminal operation in the present situation and in selected future scenarios and provide interesting and original results, particularly concerning:

1) Achievable operational standards of intermodal and wagonload terminals;
2) Financial results concerning the business case of the same terminals;
3) Economic results from the societal viewpoint useful to select the future European actions in the freight transport and rail systems fields.

Within Capacity4Rail this research will provide key inputs for various other activities namely:

- WP2.4, preparing a catalogue of specifications for future rail freight terminals;
- SP3, developing operation strategies increasingly using automation to optimised performance and enhance capacity at network level;
- SP5, cross cutting the technical work streams of various SP to ensure a whole-system approach to draw the common vision of future affordable, adaptable, automated, resilient and high-capacity railway system.

For conventional terminals, with reach-stackers and gantry cranes, the cost per loading unit is in the range 20-30 €/TEU, which is also a common market price for terminal handling. This is the operating cost and the capital cost for the technical equipment, which normally the terminal operator is responsible for. The cost models include also the basic investments, which is the long-term cost for building new terminals. The total cost is in the range of 30-50 €/TEU. This is normally not included in the market price, because some of the investments have been done long time ago by the state and are not allocated to each terminal.

Scenario analysis was undertaken, implementing KPIs for different improvements of operation and technique in the different terminal typologies.

Technical measures including; fast transtainers, horizontal and parallel handling, automated gates, automatic couplings on locos and operative measures like long trains, H24 working time and automatic ITU and vehicles control and data exchange indicate a better terminal performance.

While these measures have also shown that they are profitable following an assessment by cost benefit-analysis. The main benefits were identified from transit timesaving, decrease of external costs and, finally, from the extra traffic revenues.

Analysis of linear traffic showed that it is possible to have more terminals to cover a larger market, in combination with considered new techniques. As horizontal transfer makes it possible to have terminals on an electrified siding so the train can make short stops on intermediate stations. This means that there will be no need for shunting with diesel and parking of wagons, as well as full automation of transfer of loading units will be possible. The cost for a small-scale automatic linear terminal has been calculated to 12 €/TEU for operation and capital costs for technical equipment; including the rail infrastructure the total cost will be 14 €/TEU. The low cost for the liner terminal is due to the absence of shunting engines and dedicated personnel. It ensures a very high benefit/cost ratio.

Alternatively, handling wagons on a marshalling yard is quite different: the operating cost in Sweden is 15 € per wagon. By adding the yearly maintenance and operational cost for the infrastructure manager it will be 52 € per wagon. Calculating the whole cost, it will be very expensive: in this case 96 € per wagon, which reflects the cost to build a new marshalling yard. For marshalling yards, automatic couplers, automatic brakes on wagons, automatic wagon identification, duo locos and driverless locos improved KPI. In this case, the cost-benefit analysis gives a negative result because of the huge investments.

However, the yard is not as a stand-alone business unit, but a pre-requisite for the rationalization of wagonload's transport system within the service production chain. A fully automated marshalling yard is technically possible and potentially strongly effective: the automatic coupler is an ultimate solution for WL, especially if it can be radio-controlled, making longer trains easier to operate and, even if it is a big investment, it can lower long-term costs.

Automation of terminals and terminal functions seems to be the most efficient way to reduce costs and increase benefits in future terminals. There are many ideas but not so many systems ready for the market today, which means that strong effort must be carried out (e.g. in Shift2Rail program) to implement automated systems in real operation.

Finally, introduction of IT-systems to get total control of the consignee from origin to destination, including terminal handling, is a prerequisite for any future rail development.

7. References

[1] Baldassarra A. Impastato S. Ricci S. (2010). "Intermodal terminal simulation for operations management". European Transport n. 46: 86-99.

[2] Baldassarra A. Margiotta A. Marinacci C. Ricci S. (2012). Containers Management Simulation in Short Sea Shipping. International Research Conference on Short Sea Shipping 2012. Estoril.

[3] Ballis A. and Abacoumkin C. (2001): "An Expert System Approach to Intermodal Terminal Design". Transportation Research.

[4] Bektas T. Crainic T.G. (2007). An overview of Intermodal Transport. Université de Montreal. Publication CRT 07-03. Centre de Recherche sur les Transport. Montreal. Canada

[5] Bontekoning Kreutzberger (1999). "Concepts of new-generation terminals and terminal-nodes" The Netherlands TRAIL Research School Delft University of Technology / Erasmus University Rotterdam.

[6] CE Delft. INFRAS. Fraunhofer ISI (2011). "External Costs of Transport in Europe". Delft, September 2011

[7] Cefic-ECTA (2011). "Guidelines for measuring and managing CO2 emissions from transport". Coop Logistik AB operations. Brussels. Belgium.

[8] Davidsson P. Persson J.A. Woxenius J. (2007). "Measures for increasing the loading space utilization of intermodal line train systems". Proceedings of the 11th WCTR. Berkeley.

[9] De Jong. G.C. (2008). "Value of freight travel-time savings". Revised and extended chapter for Handbooks in Transport. Volume 1: Handbook of Transport Modelling (Eds. Hensher D.A. and Button K.J.). Elsevier.

[10] European Union (2008) "Guide to cost-benefit analysis of investment projects". Structural Funds. Cohesion Fund and Instrument for Pre-Accession, 7.

[11] Feo-Valero M. Garcia-Menendez L. Garrido-Hidalgo R. (2011). "Valuing freight transport time using transport demand modelling: a bibliographical review". Transport Reviews. 201. 1-27.

[12] Halse A.H. Killi M. (2012). "Verdsetting av tid og pålitelighet for godstransport på jernbane" (Values of transport time and reliability for railway freight). TØI report 1189/2012. TØI. Oslo.

[13] Hamilton S. (2003). "Maximizing Your ERP. A practical guide for managers". McGraw-Hill. New York. USA.

[14] Kordnejad B. (2014). "Intermodal Transport Cost Model and Intermodal Distribution in urban Freight". Procedia Social and Behavioural Sciences. 125. 358-372.

[15] Mangone A. Ricci S (2014) "Modeling of port - freight village systems and loading units' tracking functions". IF - Ingegneria Ferroviaria. 1.

[16] Nelldal B.L. (2012). "VEL-Wagon cost calculations". Seventh Framework Programme European Commission. Stockholm. Sweden.

[17] Ortuzar J. D.. Willumsen L. G. (2011). “Modelling Transport. Fourth edition. John Wiley and Sons Ltd. West Sussex. UK: 466-468.

[18] Quattrini A. (2009). Intermodal freight terminal: a synthetic model for the evaluation of operational performance. PhD Thesis. Sapienza Università di Roma.

[19] Ricci S. (2014). “Systematic approach to functional requirements for future freight terminals”. Transport Research Arena. Paris.

[20] Taniguchi E. Van der Heijden R. (2000). “An evaluation methodology for city logistics”. Transport Reviews 20 (1): 65-90.

[21] VU University Amsterdam (2012). “Values of time and reliability in passenger and freight transport in The Netherlands – Significance”. John Bates services.

[22] Woxenius J. (1998). “Evaluation of small-scale intermodal transhipment technologies”. In Bask A. H. Vepsalainen P.J. (Eds.). Opening Markets for Logistics. Proceedings of the 10th NOFOMA Conference. Helsingfors: 404-417.

[23] Woxenius J. (2007). “Alternative transport network designs and their implications for intermodal transhipment technologies”. European Transport 35: 27-45.