Final Report

IMPULSE – Interoperable Modular Pilot plants Underlying the Logistic Systems in Europe

Project
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1 EXECUTIVE SUMMARY

The Project Co-ordinator is Krupp Fördertechnik GmbH, Germany (logistics, Fast Handling Systems). Contractors are ERRI, The Netherlands {railway issues, with railways as subcontractors: DB AG (D), FS (I), SNCB (B), SNCF (F)}; Framatome and Technicatome {subcontractor Coherence (B)}, France (handling systems, sensor equipment, system analysis); Costamasnaga (rolling stock) and Euretitalia, Italy (analysing the potential volume, future terminal concepts); DUSS, Germany (terminal planning and operation) and the Universities ETH Zurich IVT and NTUA, Athens and Research Centre SGKV, Frankfurt.

1.1 OBJECTIVES

The IMPULSE project has been conceived to meet the challenges set by the Integrated Transport Chain theme of the Fourth Framework Transport Programme to increase the competitiveness of intermodal transport against ever rising trends in road freight traffic and offering an initial step towards the goal of sustainable mobility.

IMPULSE aims to reach its key objective through 4 complementary subtasks designed to:

?? analyse requirements for integrated terminals and rolling stock in terms of prime elements (market forces, Trans European Network effects, transport modes, intermodal transport units and trunk haul production forms), measured against pertinent criteria including cost effectiveness, interoperability, modularity, availability and reliability;

?? modify and harmonise existing advanced intermodal terminal technology in use at pilot installations to fit the results of the initial analysis and meet the requirements of the key objective;

?? test the installations and demonstrate their impact on socio-economic parameters including network operation, intermodal break-even distance, value added services, human behaviour, regional transport flows and environmental conditions;

?? provide additional recommendations for future policy on intermodal transport.

1.2 TECHNICAL DESCRIPTION

The IMPULSE Project is following the integrated transport chain approach, which composes of pre- and on-carriage for collection and delivery, terminal operation and main haulage including the management of the whole chain. Technical aspects takes into consideration the innovations developed by the Partners. This regards transhipment systems and advanced handling, terminal management and identification, location & positioning techniques, rolling stock design and finally aspects of labour protection.

1.2.1 Framework Conditions

The requirements for integrated terminals and rolling stock in terms of key factors have been analysed. Gauge, electrification and signalling systems are still diverging between different railway networks. Therefore borders of railways are still source of additional delay. Despite from some „Freightway“ corridors, this fringe conditions will form the basic offer in the near future. For the micro-locations of terminals in the network the accessibility for all modes of transport is very important. The travel time can be dramatically increased if the reception and departure sidings are insufficient and the transfer to the transhipment tracks takes time.

Analysis of European freight transport shows an increasing share of road traffic (73,2% in 1997) and an annual growth rate of 3.8% in the 1990th, whereas rail has a market share of 14,4% and a general decreasing trend. Compared to this, combined transport has had considerable growth rates in the past 30 years (9% p.a. domestic and 7% p.a. international freight in 1997) but recent developments show that the “natural” growth is not self-evident.

Based on a pragmatic approach, IMPULSE has therefore analysed the potential market, which can be attracted from current road flows. Using containerisation factors and further quantitative and qualitative criteria the potential volume of intermodal transport has been elaborated. The results show a large potential in short and medium distances (200 – 300 km).

1.2.2 Technologies, Improvement and Testing

Transhipment System, Terminal Operation and Management

A couple of new transhipment systems have appeared in the past years. As a starting point they have been categorised and a first description and evaluation has been performed. A transhipment plant comprises the rail transfer area; the materials handling equipment, the intermediate buffer area and the loading and travel lanes.

A transhipment plant is used not only as the interface between the physical modes of transport but also as the clearing point for information running on ahead of, and accompanying, the transported material. The demand on terminal operation is increasing by scheduled trains, train-to-train transhipments, increasing number of clients (private railways, intermodal operators) and complexity of data in the freight notes (customs, hazardous goods).

In this framework, terminal management systems (TMS) with an open architecture have been proposed to facilitate the operation. The Consequences of improved TMS are:

- Less errors by multiple manual data input due to electronic interchange support
- Optimal Utilisation of personal resources
- Less area need/optimal utilisation of terminal space
- Better disposition and utilisation of rolling stock and equipment
- Invoicing for basic and additional services possible
- Transparent chain door-to-door by tracing of special cargo.

GPS and Radio Transmitter System for Identification and Location

Global Position Systems (GPS) and Radio Transmitter Systems originally developed for tracking and tracing have been applied for the improvement of identification and location inside of intermodal terminals. Other functions (as detection of shocks and detection of opening/tampering of the door of an ITU and tracing and tracking for a wagon or ITU) can be considered. Another variant of the system can use cellular technology (GSM) instead of radiowave transmission. In this case, a client can locate and identify his goods just by giving a phone call to its ITU.

Judging the accuracy, a couple of tests have been made resulting in accuracy of around 30 metres for a stand-alone GPS, 10 metres using a more precise DGPS algorithm and 1 to 5 metres using a multipaths rejection algorithm.

In conclusion, it appears that, in a very hard environment like a terminal, where the infrastructure and the stacking of containers are creating multipaths and shadowing effects, software with a high degree of complexity is imperative to achieve a one-metre accuracy. Under this condition, the behaviour of the GPS/Radio system is conclusive up to now, regarding the radio range, energy consumption, «real-time» degree (2 or 3 min) and accuracy.

Location and Positioning by Laser Sensor applied to Gantry Crane

In conjunction with automation it is prerequisite that an up-to-date knowledge of the actual “cartography” of the terminal (wagon and ITU) is kept in the terminal management system and in addition more accurate information on the precise location and positioning of different ITU on top of intermodal wagon, storage places and lorries as well as empty places is obtained. In order to overcome this problem a „Configuration Setting Module“ checks the type and status of wagon, the type of ITU including height control, the type, status and orientation of lorries and the status of the storage area.

The chosen principle involves acquiring a 2-dimensional image of ITU and platforms by a sensor suitably mounted on the crane frame. The image is generated from the sensor scan: as the crane moves along the crane track, the sensor can execute a total scan of the area below the crane. Information on size and position of targets is extracted from this image by means of geometric operators (pattern recognition).

During the tests in the operational terminal of Noisy-Le-Sec (Paris) it could be shown that all targeted objects (wagon, lorry, ITU) could be measured with considerable accuracy.

Fast Transhipment at the moving train

Being part of the Krupp Fast Handling System Terminal Concept, the Demonstration Site in Duisburg-Rheinhausen composes of the following structural elements: Light Barrier Curtain and Camera System for identification and location of gripping points of ITU and empty spigots of intermodal wagon in relation to a defined reference point, rail track with measuring system which follows the reference point through the transhipment zone with high accuracy, acquisition device, traction unit, automated dynamic handling device with craneway (semi gantry crane), cross conveyor with pallets and transfer table, storage/ buffer area and system control & monitoring.

By means of a series of tests carried out on the site under different environmental and weather conditions it has been demonstrated, that

- fast and smooth transhipment from and to a moving train is possible;
- different types of ITU incl. swap bodies and semi-trailers can be handled automatically;
- no adjustments have to be made to the wagon, but also „Innovative Goods Wagon“, (DB AG) and modified wagon are possible to be processed (compatibility);
- conventional locomotives like a “KÖV” are able to convey the wagon group through the plant with sufficient accuracy (transferability);
- the installed measuring systems and the handling device can follow the train speed;
- storage places can be served automatically directly from the moving train;
- adjusting of the loading scheme is possible while the train is moving through at distinct working places (5-10 m long) taking into consideration criteria of safety at work.

The Krupp System can be seen as fully developed and applicable to different terminal requirements from small to medium (Single Area Variant) and high performances.

Modified Intermodal Wagon

The analysis of the best combination price - performance come to the result of an intermodal wagon with bogies and conventional charge plane with a loading length suitable to charge two swap bodies. Modified intermodal wagon with variable carrying capabilities and adjustment to different loading scheme (interface wagon - ITU) designed and manufactured by Costamasnaga have been tested in the terminal of Padova in conjunction with conventional handling equipment (Fork Lift Truck) and in the Krupp Fast Handling Plant to experience the interrelation with advanced technology. The tests have shown the general feasibility in conjunction with both handling principles. The solutions for fixing different ITU on the wagon should be based on vertical UIC pins with twist lock function.

1.2.3 Demonstration of Impact

After completion of technical work it has been the task to demonstrate the impact of the proposed measures on the integrated transport chain by modelling the chain and terminal operations taking into consideration the test results and conclusions. The goods transport database of IMPULSE concentrates on specific cases or corridors for the application of new train operation forms.

A further activity is the definition of cost places relevant for intermodal transport along the integrated transport chain including pre- and on-carriage. IMPULSE applies a transparent, analytic cost accounting with investment, depreciation, interests, maintenance, energy and personnel or - if not available - market prices or rental charges for specific issues.

The IMPULSE modelling procedure is based on a macro-model and a micro-model. An interface between the macro and the micro model has been established through "cost versus volume" curves for different rail forms and technologies. The pre- and post-haulage subsystem has been split in fixed and variable costs for alternative vehicle and ITU types, collection/ distribution schemes and transport ranges/distances combinations. The cost in the main haulage has been split in infrastructure cost (train-kilometres, ton-kilometres) and rolling stock cost (marshalling operations, running train).

The **micro-model** consists of an expert system and a terminal simulation module. The scope of the expert system is to produce alternative terminal designs with the parameters: Cargo volume, percentage of stackable ITUs, percentage of semi-trailers, length of loading tracks, cost of terminal land and maximum land available, mean stacking height, rail operational form, as well as handling equipment/systems.

The role of the simulation model is to check, optimise and provide information about truck dwell time, equipment utilisation, queues at the gates for every design proposed by the Expert system. The simulation model "includes" transhipment, siding and departure tracks as well as in and out gate, truck waiting and serving areas and ITU storage areas. The output results are statistically processed and the resulting values are compared with pre-defined “quality of service” criteria.

The **macro-model** has been developed in order to analyse the attractiveness of multi-modal transport chain from a multi-regional up to a European scale. It allows the User to define networks, operational forms, costs and delays calculations rules and a range of transhipment terminals.

1.2.4 Recommendations

Advanced Intermodal Terminals and Innovative Rolling Stock

Efficient terminals are a key aspect for the competitiveness of the whole integrated transport chain. Innovation in automation technologies makes sense in terminals with a high peak-hour factor or in terminals with high daily throughput. Dependent on the demands in IMPULSE optimum technologies are found out. The type of railway access is an important element related to operation forms on network that influences terminal design. Operation forms with short terminal stopping time require a direct access to terminal with main locomotive and the fast processing of such trains in order to support rational utilisation of rolling stock.

The intermodal wagon is component of the intermodal transport chain. Its characteristics are resulting from system analysis and needs following lines of development:

Structural parameters such as length, platform height and tare weight to allow more, larger and heavier ITU to be transported even on networks with gauge limitations; Redesign of bogies and application of electronic (disk) brakes to allow for higher commercial speeds and low noise; Articulation of wagon rakes and/or automated coupling to reduce staying time in train formation yards and increase utilisation;

Communication systems with sensors to ease status control as well maintenance and increase wagon circulation.

In particular the interfacing with advanced intermodal handling leads to automatic configuration of loading schemes and to fix ITU for save transport.

Train Operation Forms Open up Additional Potential in Short / Medium Distances

The share of the long-distance market already being considerable by the railways, the medium and short-distance markets are now coming into view. This is a market with large freight volume. The case studies of IMPULSE have shown the potentiality of a special train operation form: The Shuttle²-train seems to be a very economic method of transport. It is defined as a fixed composition of wagon which is running twice a night between two terminals replacing one complete set of wagon. With this characteristic the Shuttle²-train can be less expensive than pure road transport. Besides the origin-destination volume of the terminal regions such trains benefits from an enlarged catchment area and transfer from other destinations (regional hub). Advanced handling optimally supports such logistics, which is fully automated and able to serve these trains in the night nearly without employees.

1.3 RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Faster handling and automated operations provide the potential to key up additional volume for intermodal freight transport. This résumé has been drawn up at the IMPULSE Final Conference, Brussels on June 16-17, 1999. The IMPULSE Project aims to investigate, develop and test technical–organisational measures to improve intermodal transport and to demonstrate their traffic impact.

“The European Commission sees a strong relation between sustainable mobility and intermodality” states J.A. Vinois, Head of Unit in DG VII. The largest potential market of such improved services is on medium and short distances in additional to the classical far distance runways. In order to compete with pure road transport, price and quality of service has to be matched. On concrete routes throughout Europe shuttle trains which drive two times a night are able to reduce the railway costs significantly.

Around 100 attendees from the European Commission, the railways and intermodal operators as well as industry and research centres have listened to the presentations of the conference with great interest and participated in lively discussion.

At the end of the Conference, Project Co-ordinator Klaus-Uwe Sondermann, expressed the need for a reference application project as a joint challenge for both industry and operator. This is necessary to bridge “from innovation to application”.

This project needs verification on concrete operation thus intermodal operators and railways, should apply the results and install innovative shuttle²-trains. Regarding the intermodal wagon the findings of the tests and conclusions for improvement should be applied on an small series of this wagon to allow gaining operational experiences. With respect to the terminals, innovative technologies have proven their technical feasibility and need to be applied in large-scale demonstration project.

2 OBJECTIVES OF THE PROJECT

2.1 OBJECTIVES

The IMPULSE project has been conceived to meet the challenges set by the Integrated Transport Chain theme of the Fourth Framework Transport Workprogramme to increase the competitiveness of intermodal transport[1] against ever rising trends in road freight traffic, providing added benefits of greater environmental and social protection and offering an initial step towards the goal of sustainable mobility.

IMPULSE aims to reach its key objective of:

Determining, introducing and recommending focused technical and logistics developments which will result in the increased economic-, management- and technical efficiency of intermodal transport to deliver trans European freight at lower cost, within a quality framework, while meeting the customers' needs.

IMPULSE achieves this through a series of 4 complementary subtasks designed to:

?? analyse requirements for integrated terminals and rolling stock in terms of prime elements (market forces, Trans European Network effects, transport modes, intermodal transport units and trunk haul production forms), measured against pertinent criteria including cost effectiveness, interoperability, modularity, availability and reliability.

?? modify and harmonise existing advanced intermodal terminal technology in use at pilot installations to fit the results of the initial analysis and meet the requirements of the key objective.

?? test the installations and demonstrate their impact on socio-economic parameters including network operation, intermodal break-even distance, value added services, human behaviour, regional transport flows and environmental conditions.

?? provide additional recommendations for future implementation policy on intermodal terminals and methods to improve market penetration to all the actors (whether political or operational) involved in intermodal transport.

2.2 APPROACH AND LINK OF WORKPACKAGES

In order to carry out the worksteps mentioned above, the project has been broken down into four subtasks and 19 workpackages. These are covering the subject of the „Integrated Transport Chain" in both directions: Horizontally, all modes of transport (gravity on rail transport), pre- and on-carriage, terminal operation and chain

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[1] Intermodal Transport is defined as "The movement of goods in one and the same loading unit or vehicle which uses successively several modes of transport without handling of the goods themselves in changing modes". Combined Transport or Combined Transport Rail Road are more popular in use for more or less the same definition. The IMPULSE Project does not want to join into an academic discussion on weather or not to distinguish between both terms and proposes to use them as synonyms.

management are considered, whereas, vertically, technical and organisational aspects are analysed in depth for subsystems and components.

The following diagram shows the interrelation of Workpackages (see numbers 1.1 to 4.5) and the flow of information from initial to final activities through agreed Data Formats.

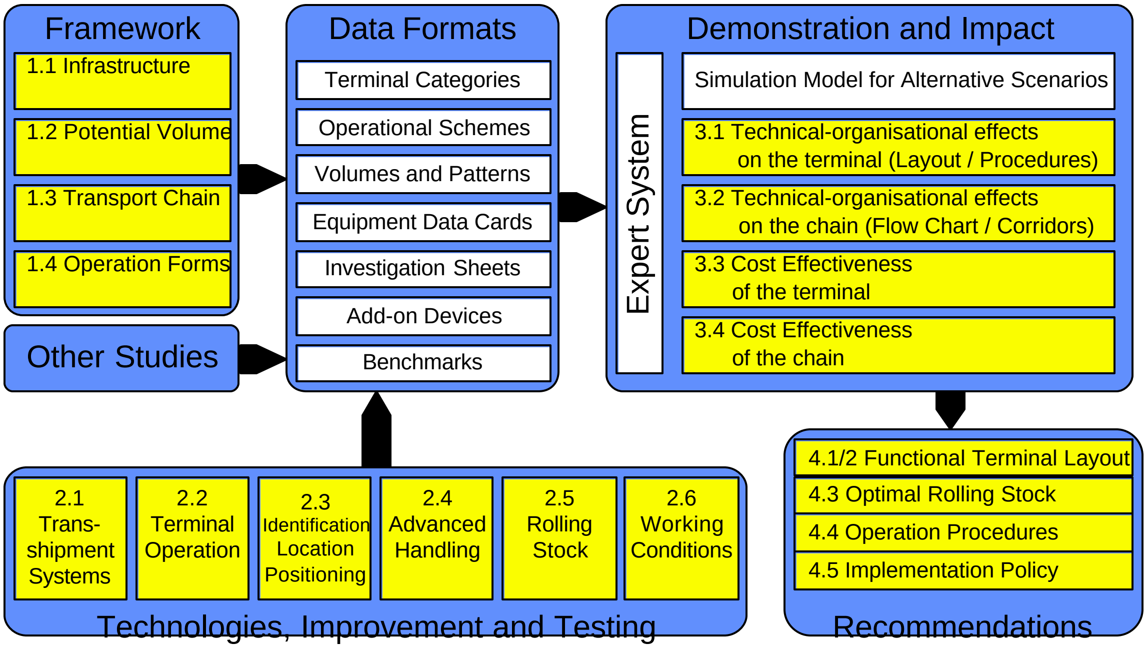


Fig. 2.2: Structure of the Project

Each of the Workpackages ends with a Final „Deliverable“, which composes of the basic approach and results and is meant to inform the scientific community and the public. Each Deliverable corresponds to the output of a Workpackage so that their position could be seen from the diagram as well.

In the framework of the 1st Subtask marginal conditions of intermodal transport are analysed with respect to their input on the terminal and rolling stock design. Workpackage (WP) 1.1 is dealing with the infrastructural framework conditions. Its results are presented in Deliverable 1 (D1). WP 1.2 provides the statistical background of combined transport in Europe and derives the potential volume of intermodal transport (D2). WP 1.3 analyses fringe conditions of the integrated transport chain (D3.2) and provides a „Glossary“ of terms (D3.1) relevant in the field as a joint basis of understanding. The operation forms of the network modes maritime, inland waterways, rail and road are described and routing schemes to link intermodal terminals of different size and function are proposed in the framework of WP 1.4 (D4).

Subtask 2 contains technical analysis, improvement and testing. Based on the requirements formulated in Subtask 1, new transhipments systems are analysed and evaluated (WP 2.1 = D5). Exemplary technologies which have become operational in pilot installations are harmonised and technically proofed. This regards technologies for identification, location and positioning (WP 2.3 = D7), advanced handling (WP 2.4

= D8) and rolling stock (WP 2.5 = D9). Special attention is laid on the interfacing and system consistency. Possibilities of the improvement of Terminal Operation is subject of WP 2.2 = D6. Aspects of labour protection and safety at work in conjunction with the man-machine interface and new working places in innovative handling systems are dealt with in WP 2.6 = D10.

Activities performed in the Subtask 3 could be seen as the demonstration of the impact of new technologies and corresponding operation schemes. For this purpose the output of previous Workpackages is collected by means of suitable Data Formats. An expert systems is used to gather the information and select relevant cases for modelling. Alternative scenarios are used for comparison of different sets of framework conditions. Technical-organisational effects on terminals (WP 3.1 = D11) and the whole transport chain (WP 3.2 = D12) are demonstrated as well as cost impacts on terminals (WP 3.3 = D13) and chain (WP 3.4 = D14).

Finally, recommendations are formulated with respect to different categories of terminals (WP 4.1 and 4.2 = D 15 and D16), optimal interfacing between rolling stock and the handling equipment (WP 4.3 = D17), operation procedures of intermodal transport chains and terminals (WP 4.4 = D18). The last workpackage 4.5 gives recommendations for the implementation policy (D19).

2.3 TIME SCHEDULE

The project is designed to last 3 ½ years and has started in February 1996. The Subtasks are carried out subsequently whereas Workpackages within Subtasks take place simultaneously to facilitate cross fertilisation.

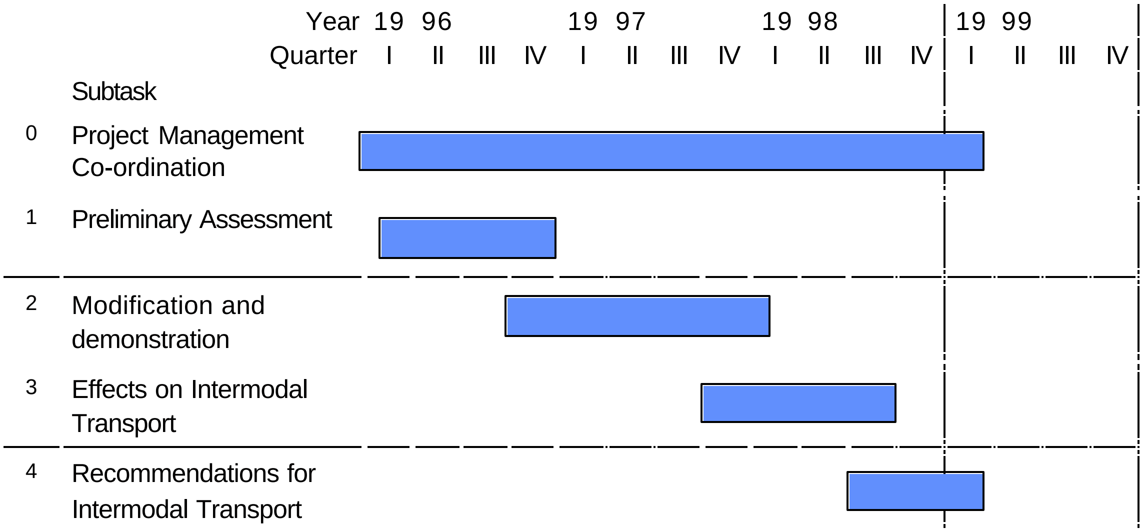


Fig. 2.3: Initial Schedule of the Project

The works have lasted a little longer than expected due to the involvement of many Partners in order to encourage a mutual European understanding, the selection of demonstration cases and the availability of test sites, the dependency of the test on previous works as well the relation of the results to following demonstration activities. Model building took also a longer time, since inconveniences and missing points of expected input needed to be worked out in parallel.

3 MEANS USED TO ACHIEVE THE OBJECTIVES

As one can see from the Objectives of the Project and the respective Work Breakdown Structure the activities performed in the framework of IMPULSE are rather diverse. They are touching classical research study issues as well as industrial RTD objectives as well as academic features like modelling of impacts. Therefore a couple of methods and means have been applied during the Project well appropriate to the respective subject and objective.

In the initial phase in which the framework conditions have been described and analysed, literature study and exploitation of existing research results as well as best practice have been done. With respect to the database a couple of international, national and company databases have been consulted and finally tried to be merged by appropriate statistical tools. Regarding the operation forms it has been the decisive step forward to confront first finding with practical experience during a Workshop Meeting between respective IMPULSE Partners and experts from the transport market. The workshop has led to consideration of some thesis. The Glossary of course, could be drafted only in conjunction with good knowledge on standardisation, definitions and codes of practice (e.g. UIC leaflets). In result the Glossary itself is a tool to achieve mutual understanding and facilitate exchange of information.

In order to reach Subtask 2 results again literature study was supplemented by investigation inside the institutions and companies involved. For the overview a series of leaflets has been analysed and confronted with a set of performance and cost criteria.

As many of the Subtask 2 activities were dealing with “Terminal” a series of Terminal visits were executed mainly by the railways. During these visits information regarding practical terminal operation could be collected and a good picture of the differences and common features could be drawn up. The visits were also used to experience bottlenecks of existing situation and desires for future optimum operation. However it could not replace industrial research to achieve a real step forward and therefore the involvement of test sites was one of the mayor methods in the practical phase of the Project. Practical test were executed in the workshop of Costamasnaga, the intermodal terminals in Padova (Italy) and Noisy-Le-Sec (France) and the Krupp Fast Handling System in Duisburg-Rheinhausen (Germany). The experience gained from these tests can not be replaced by any theoretical consideration and need to be evaluated with high grade. These test were related to the identification, location and positioning technologies, the advanced handling and the intermodal wagon.

Furthermore some measures on security and safety at work could be demonstrated. They were resulting from discussions with respective authorities responsible for safety, accident prevention and insurance. In order to achieve their agreement manuals on safety measures had to be drafted to be agreed on.

Regarding the modified wagon all worksteps of projecting from analysis of requirements, evaluation of existing and drafting of new solutions, detailed engineering, prototype building and testing were done.

The tests in conjunction with Fast Handling System have been demonstrated during on-site presentations to the whole Consortium and interested persons from the railways and the European Commission.

After the test phase an Impact Analysis incorporates a series of model building and model evaluation activities. Both, intermodal transport chain and intermodal terminal in particular have been broken down into modules such as the terminal, the main haulage, their interface and other.

Transport Impact of the proposed technical-organisational measures is demonstrated by means of computer models. The IMPULSE modelling procedure is based on a macro-model and a micro-model combination that produce the necessary information for the cost calculation scheme. The micro-model consists of an expert system and a terminal simulation module. The interface between the macro and the micro model has been established through "cost versus volume" curves for different rail forms and technologies. The cost calculation scheme has been particularly developed with the aim of comparing the cost-effectiveness of different alternatives.

The scope of the expert system is to produce alternative "technically sound" terminal designs. The input fields enables the User to define the terminal design parameters (cargo volume, percentage of stackable ITUs, percentage of semi-trailers, length of loading tracks, cost of terminal land and maximum land available, mean stacking height, rail operational form), as well as handling equipment/systems (reach stackers, gantry cranes, transport devices, the Krupp’s “moving train” technology, Technicatome's terminal configurations, etc). Furthermore, the Expert system enables the implementation of a number of advanced add-on technological devices that include advanced rail access systems, identification, location and positioning devices, semi-automatic control, information systems for terminal preplanning and rolling-stock related technological bricks.

The role of the simulation model is to check, optimise and provide information about truck dwell time, equipment utilisation, queues at the gates for every design proposed by the Expert system. The simulation model "includes" transhipment, siding and departure tracks as well as in and out gate, truck waiting and serving areas and ITU storage areas. The simulated equipment serves both rail and road sides according to a predefined service strategy. A “train arrival scenario“ includes train schedules and number of ITUs to be unloaded/ loaded is used to “activate” the simulation. For each train served, the model generates a number of associated truck arrival patterns. The output results are statistically processed and the resulting values are compared with pre-defined “quality of service” criteria.

The macro-model has been developed in order to analyse the attractiveness of multi-modal transport chain from a multi-regional up to a European scale. It allows the User to define networks, operational forms, costs and delays calculations rules and a range of transhipment terminals. A freight demand is defined between regions and the model computes the flows carried by each operational form simulated in the model.

A “solver procedure” tries to find the optimal flows allocation on the operational forms and the optimal choice of terminal at the transhipment nodes in order to minimise the global operation cost taking into account the model constraints. As the costs depend on flows and that the distribution of flows depends on the costs, the model is formulated as an equilibrium problem.

In order to obtain the respective input for the modelling all technical workpackages have been exploited but in addition Expert Interviews in Terminals and Ports and with Intermodal Operators have been executed and a DELPHI inside the Consortium and associated railways has been performed. The Delphi has dealt with the technical parcels and efficient combinations as well as the calculation of handling productivity.

Regarding cost items an inquiry has been carried out to obtain a couple of cost places relevant for intermodal transport as well as values dependent on technology and country.

Besides conventional drafting and checking of reports, tables and figures Working Meetings have been a further tool to come to a mutual agreement on certain topics. These were organised as office meetings or on-site visits.

Regarding the objective of ongoing Dissemination and Publication, seven public Newsletters, a couple of Presentations to a wider audience and finally the IMPULSE Final Conference have been executed.

In view of the Project Management the conventional set of Tools has been established. It covers work breakdown and technical responsibilities, reporting of physical and technical progress and finally checking, drafting and approving of Final Report and Deliverables (Quality Control).

A Management committee composing of all Project Partners has been installed for Project Co-ordination.

4 SCIENTIFIC AND TECHNICAL DESCRIPTION OF THE PROJECT

This section comprises different technical chapters covering the work performed under the Project and highlights the main results achieved. Tables, figures or charts have be used to underline the argumentation. The chapters are following the work breakdown structure of the Project on a Workpackage by Workpackage basis.

4.1 INFRASTRUCTURE FRAMEWORK CONDITIONS (WP 1.1)

The works which are summarised in the following, have technically been co-ordinated by ERRI/SNCF (Workpackage Leader). Costamasnaga, Euretitalia and ETH IVT have contributed.

The work-package (Infrastructure Framework Conditions) collects together the available information and experiences of different studies on intermodal transport to give a database view of all the overall goals of the project.

The main goal was to analyse the actual problems of the existing Intermodal Network, in order to suggest a solution for the increasing effectiveness of a future Intermodal System.

The sources used to establish this report were the following:

?? documents on the terminals ,on rail and waterway network
?? interviews with competent specialists and representatives of different organisations
?? information on lines, terminals obtained from European railway companies and combined transport operators.

The study consists of the following:

?? Description of the current situation with respect to lines and terminals, structure of existing intermodal network, description of terminals, examination of various railway lines.
?? Description of development plans, identifying operating techniques, examination of transport scenarios
?? Analysis of links and terminals, to use nodes, delivery/collection points along the route, different types of terminals, to cover the economic and capacity problems of terminals
?? Conclusions and recommendation for the new terminal and rolling stock concepts

Three types of terminals are analysed and especially the constraints of the terminals from the infrastructure point of view.

The **sea port terminals** have had a “historical importance” since they are the origin of major flows of containers which have to be carried out to the final destination. The study characterise the “ Northern range” from Hamburg to Le Havre (Hamburg , Bremen, Rotterdam, Antwerp and Zeebrugge, Le Havre), the Mediterranean and

Adriatic ports (Valencia, Barcelona, Algericas, Fos/Marseilles, Genoa, Livorno, La Spezia, Ravenna, Trieste..), the atlantic ports (Bilbao, Santurce),the Scandinavian and Baltic ports (Goteborg, Stockholm,Turku, Uusikaupunki, Hanko).

The most importance information from the **inland port terminals** are collected however this information not complete and not always dating from a recent year. The information on European Container ports was provided on Rhine/Main ports (including traffic data), the France (Seine, Rhône) ports and those of Belgium, The Netherlands, Pas-de-Calais (Meuse/Maas, Scheldt/Schelde).

The main information on European railway lines on more than 250 European **rail/road terminals** highlights different aspects of their infrastructure:

- Location and access
- Capacity
- The specific infrastructure of the intermodal terminals and freight centres

This part of study highlights the various problems faced by the network distinguishing and characterising the static and the dynamic capacity of terminals.

As intermodal terminal it was found a very significant application what was developed in Italy. The " interporto" are decided as a "concentrations of logistic structures in the vicinity of a railway yard for the formation of traditional and intermodal blocked trains".

The centre of interest in an "interporto" is the intermodal terminal, which must be able to organise complete intermodal trains and should be in an area of a relevant combined transport market.

This part of report provides a comparison on rail/road terminals investigating the relation between the area of the terminals and the number of units handled. A detailed information on the productivity of the equipment is provided.

Collecting the interviews with intermodal transport experts the study gives information on possible projects of European importance taking into account a horizon about 5-6 years.

The report provides detailed information on the **constraints of the rail network** which has been obtained from the different railway companies and also using information of AGTC (European Agreement on important international combined transport lines and related installations - United Nations) agreement as database on European combined transport lines.

The purpose of this section on the constrains of the rail network was to analyse this database and information highlighting the aspects of:

- structure gauges
- electrification (see Figure 4.1/1)
- signalling (see Figure 4.1/2)
- length of passing tracks (see Figure 4.1/3)
- problems found at border points
- saturation
- problems linked operations

?? hubs

?? new lines projected and their implications

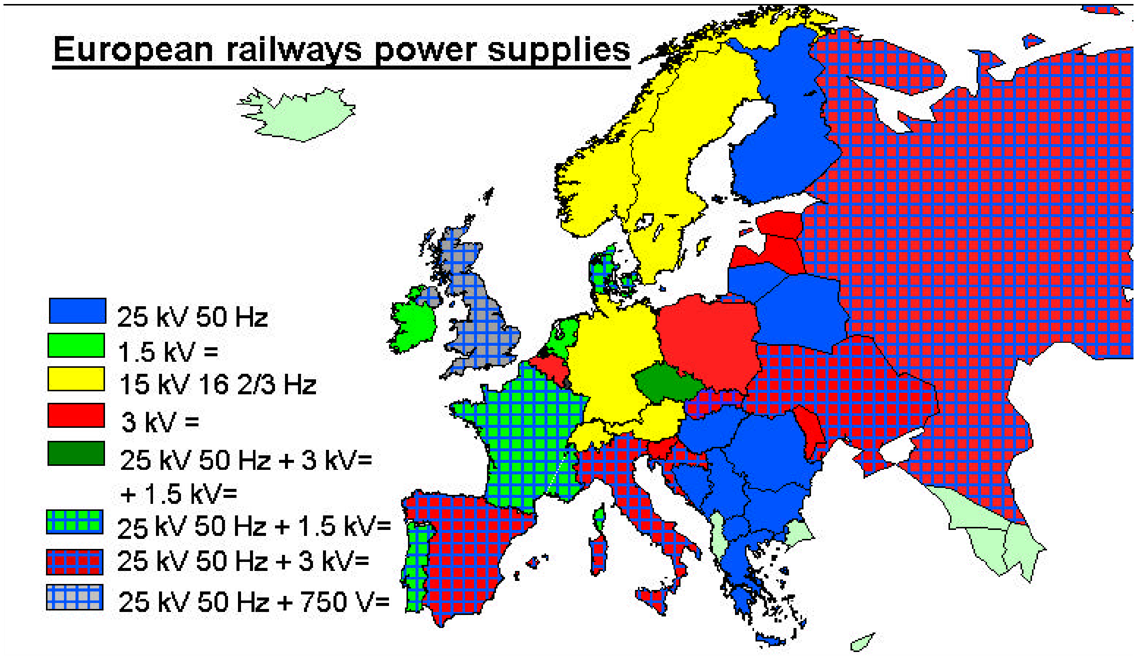


Fig. 4.1/1: Railway Power Supply in Europe

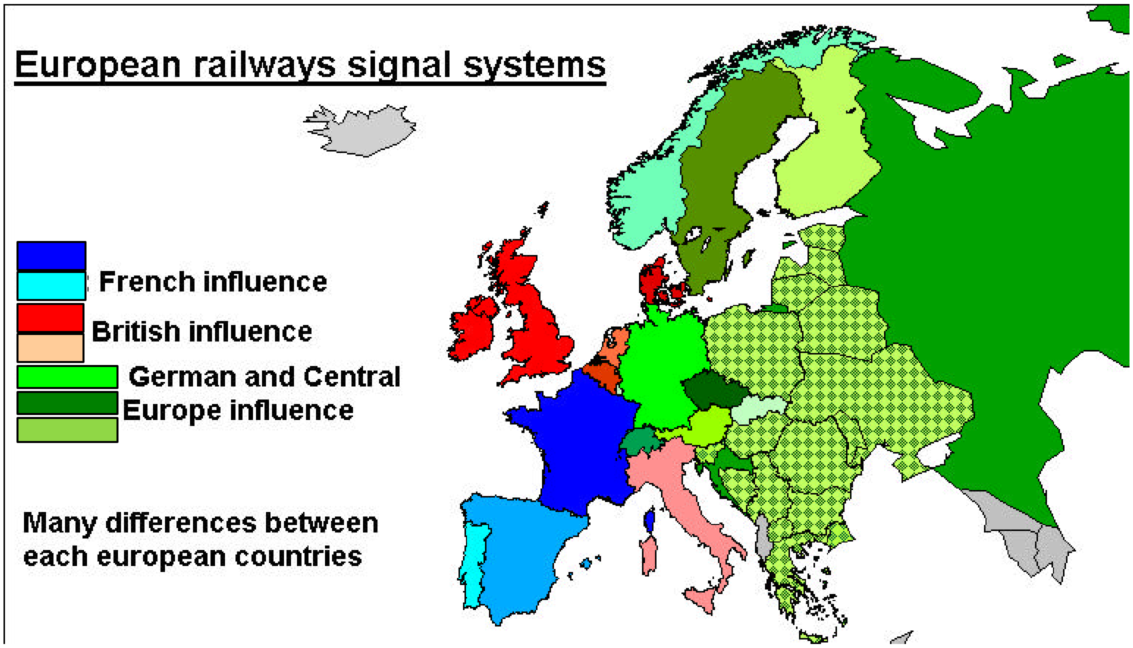


Fig. 4.1/2: Signalling System in Europe

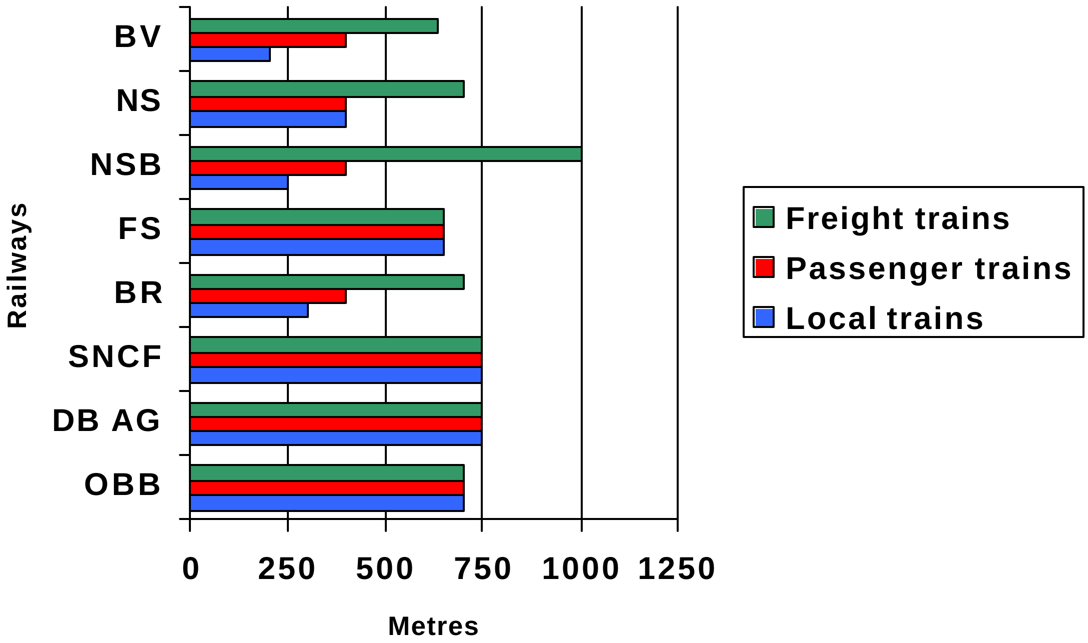


Fig. 4.1/3: Length of Passing Trains in Europe

The following part of report was dealing with the constraints of the inland waterway network characterising the existing waterway structure, the capacities, bottlenecks and the future projects of the European system.

The report gives a classification of European Waterways based on " Document Trans/ SC.3/131 United Nations ECE " which is not complete but has very important information on journey times between the terminals.

As conclusion and recommendations the study pointed out that the existing infrastructure must be considered as a condition that can be slightly modified but that needs to be taken into account for any new solution.

The report investigated what the implications are on the existing infrastructure and on the future design of the terminals and the rolling stock and what solutions can be put forward regarding terminals and rolling stock considering the given infrastructure.

In the base year (1993 for these figures) 50 % of the continental intermodal traffic was shared between only 15 % of the terminals.

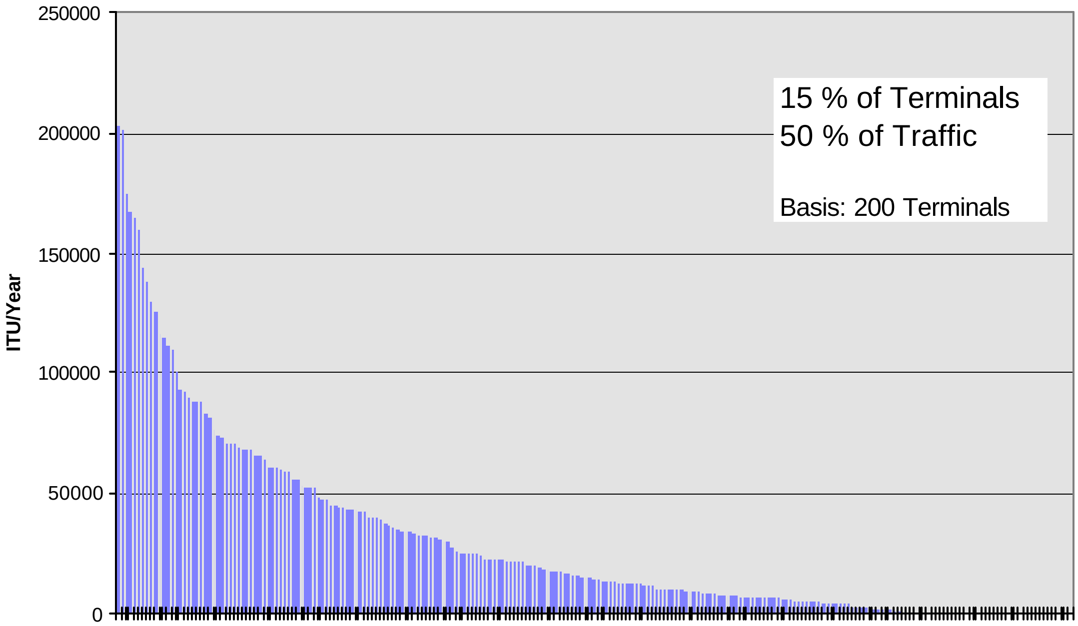


Fig. 4.1/4: Terminal Sizes in Europe

At least the report gives guidelines for the future terminal design (rail-road access, handling, information system and capacity) and the rolling stock design considered the structure gauge, the maximum axle-load and the track gauge.

The main benefit of this report was to describe the existing bottlenecks encountered throughout the European network and to give an applicable database to be used for the increased design and service requirements for future European Network.

The report concludes, on the one hand, successive intermodal transport of the future has to overcome with the actual line and node infrastructure, but on the other hand its requirements have to be considered for the planned infrastructure. Although most of the countries are currently aiming at a "GB" structure gauge on their rail network this will be not reached in short time. Length of passing tracks is limiting train length to 700 (600) m in most countries. The maximum load per axle is 20 tons (for a speed of 120 km/h) and 22.5 tons (for 100 km/h). In addition to the gauge, electrification and signalling systems are still diverging between different railway networks. Although differences in circuit and frequency supply can be solved by multi-system locomotives the signalling and respective training of drivers provides additional difficulties and hampers cross border transport. Therefore borders of railways are still source of additional delay. Despite from some „Freightway" corridors, this fringe conditions will form the basic offer in the near future. In transalpine traffic and some bilateral relations the need of specialised rolling stock allowing to carry high-cube-boxes is still existing in order to avoid expensive infrastructure investment (tunnels and bridges). Integration of inland waterways was not very successive in the past and need to be analysed in depth (see e.g. APRICOT Project).

For the micro-locations of terminals in the network the accessibility for all modes of transport is very important. The travel time can be dramatically increased if the reception and departure sidings are insufficient and the transfer to the transhipment tracks takes time (e.g. change of loco, split/assemble train). When considering new access concepts, the responsibilities for trunk haulage and terminal operation - which may be offered by different companies - have to be defined, allowing a safe and reliable operation.

4.2 MARKET OF INTERMODAL TRANSPORT AND POTENTIAL VOLUME (WP 1.2)

The works which are summarised in the following, have technically been co-ordinated by Euretitalia (Workpackage Leader). ERRI, Framatome, Technicatome, NTUA and DUSS have contributed.

4.2.1 Introduction

The objectives of the WP 1.2 of the IMPULSE project were to collect information about freight flows and to present a first analysis of the global situation of the intermodal transport market in Europe.

The main achievement of the Work Package has been the development of a detailed database of freight flows used in subsequent tasks of the project.

The database comprises information about inland flows among European regions, by mode of transport and by commodity. The work has been carried out on the basis of available European and national statistics, and various Community studies.

In the framework of this WP a pragmatic approach based on the utilisation of containerisation factors was adopted for the estimation of the potential market of intermodal transport. Target markets in terms of applicable commodities have been identified through containerisation factors which have been estimated by means of a Delphi enquiry.

A key factor for the development of intermodal transport in Europe is the improvement of the quality of service. But how to measure quality? Which are the parameters to be taken into account for the estimation of modal split? Research in the past has focused on the development of modal split models based on generalised cost. These fail to explain adequately the prevalence of road freight. Part of the work performed in this WP was thus devoted to the identification of a series of parameter to be taken into account in future modelling tasks. Once the main parameter were identified a Delphi enquiry was carried out among experts to rank the chosen parameter in order to weigh their perceived level of importance in the process of modal choice.

One important remark is to be done: the current status of data availability in Europe is below the minimal level of detail and quality required for in-depth analysis based on modelling exercises.

This fact has already be highlighted by many studies, and in particular by the EC-DGVII-APAS report "*Databases and scenarios for European transport*".

Our recommendation is that a methodology for the estimation of region-to-region freight flows from more aggregate data is first established and made available to all future research projects and policy evaluation processes, in order to avoid delays and the burden of extra-work required for data collection, not directly aimed to pursue the objectives of the projects.

4.2.2 Data Availability for Freight Traffics in Europe

As already pointed out, during our review of available sources of information we have confirmed the findings of other studies that consider the current status of data availability in Europe below the minimal level of detail and quality required for in-depth analysis of the spatial relations among different regions.

During the research the only available database including information of freight flows for all modes of transport at a region-to-region level, by group of commodity was the SIMET one. This was the starting point of all our enquiries. The reference year for the SIMET database is 1987, and thus it is rather out of date. Although it required a great deal of effort and time to complete it, the data contained presents some shortcomings, pointed out by the same authors; it is nevertheless the only attempt made to put together such detailed information at a European level so far.

Origin-Destination (OD in the following) matrices by group of commodities covering all EU Member states are published annually by EUROSTAT for the modes: road, railway and inland waterway (*EUROSTAT, Carriage of goods -Railways, -Road, -Inland Waterways, Statistical Document Theme 7 Series C*). The same information are contained in the domain *TRAINS* of the *NEW CRONOS* database. These statistics are available usually with some years of delay, due to the time needed to verify and harmonise the data collected from Member States' statistical offices, and are sometimes incomplete (especially as regards road traffic) due to unavailability of information from some countries.

The data contained comprises:

?? international Country-to Country (C-C) flows among Member States, by commodity (24 groups), expressed in 1000 t and Mio. tkm (only the first value is of interest in the framework of our study)

?? domestic Region-to-Region (R-R) flows for each Member State, by commodity, as above.

The general trend for quality and availability of data for all modes is turning downwards for various reasons among which:

?? the disappearance of customs statistics after 1992. This source of information was essential for a correct estimation of international trade, and for the verification and correction of sample surveys, especially for road transport. The *INTRASTAT* system, set-up to replace the old statistics has not produced the results expected.

?? the liberalisation of railway services; the new private companies operating in the competitive market tend to consider freight flows data as a strategic resource of the firm, therefore keeping it as confidential, and not available for external usage.

Detailed analyses of freight flows are usually carried out in corridor studies for the development of new infrastructures. The results of these studies are published and available only at a rather aggregate level. The databases used for the analyses are usually compiled ad-hoc and treated as confidential. Besides, they are always based on different methodologies and assumptions and are therefore hardly comparable and updateable.

An analysis of some important published studies on intermodal transport was carried out and presented in Deliverable D2.

So far there isn't any complete European statistics available for intermodal freight transport and the future in this field seems to deserve very little improvement.

EUROSTAT does not have any statistics available and is now trying to develop methodologies and procedures for producing regular annual collection of data.

The main efforts so far were concentrated in the development of a methodology for the integration of data from Member States with origin-destination data from operators. Problems arise in the field because of the differences in the registration and production of data among the operators.

In the past it was possible to have good figures simply collecting data from the two main groups of operators:

?? UIRR for continental combined traffic (with semi-trailers and swap bodies)

?? Intercontainer/Interfrigo and satellite companies for the ISO- and Inland-container traffic.

The share of the market among the two groups was clear and they used to operate almost as monopolists in their respective segment. Traffic flows even at a quite detailed level were usually made available for researches and studies, as there were no problems of competition and this data were not considered a strategic resource of the companies.

The situation is now changed: the two main groups of operators have now opened the competition with one another for the global market of intermodal transport (no mean if road-rail combined traffic or ISO containers). Moreover new independent operators are facing the market, concentrating on the most remunerative flows (for example OD connections to some north-European ports).

In this new context detailed data (freight flows at a terminal-to-terminal or even region-to-region level) is often considered as strategic and confidential data and thus not available for third parties.

Global figures of traffic at a country-to-country are generally available and published in annual reports.

Annual volume of traffic handled at different terminals is also available, as well as classification among different kind of Intermodal Transport Units.

4.2.3 Data Collection and Estimation

For modelling purposes we sought data for all modes of transport consisting of OD patterns of flows by mode of transport and by commodity, from region of origin to region of destination. For regional clustering NUTS2 level of detail was suggested (NUTS: Nomenclature of territorial units statistics).

For intermodal transport even more details were requested, concerning the number and type of loading units transported, and information about the whole chain (i.e. not only about the main trunk line).

Of course not all this data was available from official sources, so some estimation had to be carried out. IMPULSE partners contacted various national statistical sources for the collection of primary data. The level of quality and detail of data vary from country to country. Most of the data has been provided in formats that differ from the requested one, so a lengthy work of coding and manipulating data has been required. In some cases data was provided only on paper, and not on electronic form, thus requiring work of data input. None of the sources of information provided the data in NUTS 2 codes. In general the best information gathered was relative to the road transport. Difficulties were encountered in the collection of rail data. Intermodal transport information are generally not collected by national statistical offices, so the only sources are the operators, or their associations.

For each mode of transport, the process performed for the evaluation of the data collected and the estimation of missing information consisted of the following steps:

1. Selection of one (or more) couple of countries for which we want to estimate the OD matrix at a RR (Region-to-Region) level.
2. Query of the database for the retrieval of the data. For the purpose of data comparison, all the information are aggregated at a CC (Country-to-Country) level (e.g. if data is available at RC (Region-to-Country) level the query will aggregate all the flows from the different regions of the origin country)
   The data is presented in tuples like the following:
   {Year; Origin-Country; Destination-Country; Mode-of -transport; source-of -information; total-flow}
3. Analysis of the results of the previous query: usually for each OD pair of countries more than one record is displayed. The analysis will focus mostly on the data relative to the year for which the estimation is requested. The values provided by different sources usually don't match as they should. Most of the times the differences are small and reasonable; in some cases some of the sources provide incomplete data, and so the differences can be very high. The comparison with data from previous years or from other sources (e.g. cross transit through a third country) usually helps to detect the macroscopic errors and to select the most appropriate and reliable source of information)
4. Selection of the data to be used for the final estimation and of the method/algorithm to adopt. The results of the step 3 are used for selecting the data that can lead to the most reliable estimation of RR flows. Depending on the nature of data selected, the most appropriate estimation method is selected.
5. Execution of the estimation and storage of the results in a new table.
6. Possible final checks of the results against some partial data available.

The key feature of the process outlined above is the analysis and comparison of data coming from different sources. This analysis provide all the information which allow an accurate selection of the most appropriate data and methods/algorithm to be applied for the estimation of the final matrix.

Depending on the kind of data available, several methods were employed for carrying out this final step. If flows at RR level were provided, and if the comparison with other information available confirmed their reliability, they were directly included in the final table.

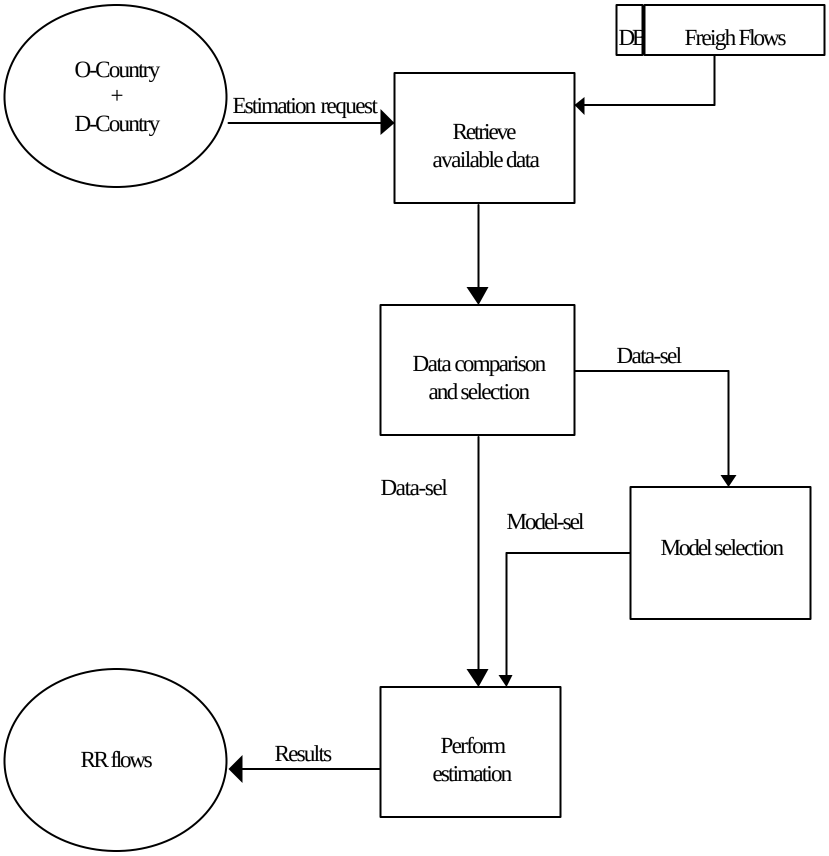


Fig. 4.2.3: The Process of Estimation of Region-to-Region Freight Flows

The final database consists of about: 156.000 records for road transport, 30.000 records for rail transport, 8.000 records for inland waterway transport and 2.500 records for intermodal transport.

The number showed illustrates clearly the different amount of information, and as a consequence, the different level of detail reached for the different modes of transport. We can consider the level of detail of road and inland waterway transport quite satisfactorily, but some problems emerged for railways and intermodal transport. As the main target market for future flows to be attracted by Intermodal Transport is the traffic of goods presently transported by road, we can consider the final results as sufficient for supporting the analysis required in the proceeding of the project.

4.2.4 The Market of Intermodal Transport

Intermodal transport has registered a high rate of growth for many years since the beginning of its services. This growth is partly due to help and subsidies received in various EU Countries. Moreover, part of the market was gained subtracting traffic to conventional rail rather than to road. In the most recent years the growth trends of the past were not confirmed, and clear trends for the future are not self-evident. Globally, UIRR companies have shown an increase of 9% of domestic traffic and 7% on International traffic in 1997. This result appears rather good, but it came after a year of poor performance. Moreover, in 1998 the growth was only 1%, resulting from an increase of international traffic (+2%), and a decrease of domestic traffic (-1%).

The other big intermodal operator, Intercontainer/Interfrigo, registered a period of crisis and re-organisation. In 1997 the results showed a decrease of 4.6% of the global volumes transported, which were at the same level of 1995.

Figures 4.2.4/1 and 4.2.4/2 show the evolution of the international and domestic market for the most important UIRR companies during the last four years. As one can observe, there are no homogeneous trends. Where intermodal transport is more diffused and strong (Germany, Austria) the domestic market is rather stagnant. Even in Italy, where intermodal transport trends have always been positive, was observed a negative trend in 1998.

These figures highlight the importance for intermodal transport to consider new lines of development in order to meet the requirements of a demanding market, which nowadays find in the road transport the only answer to its needs.

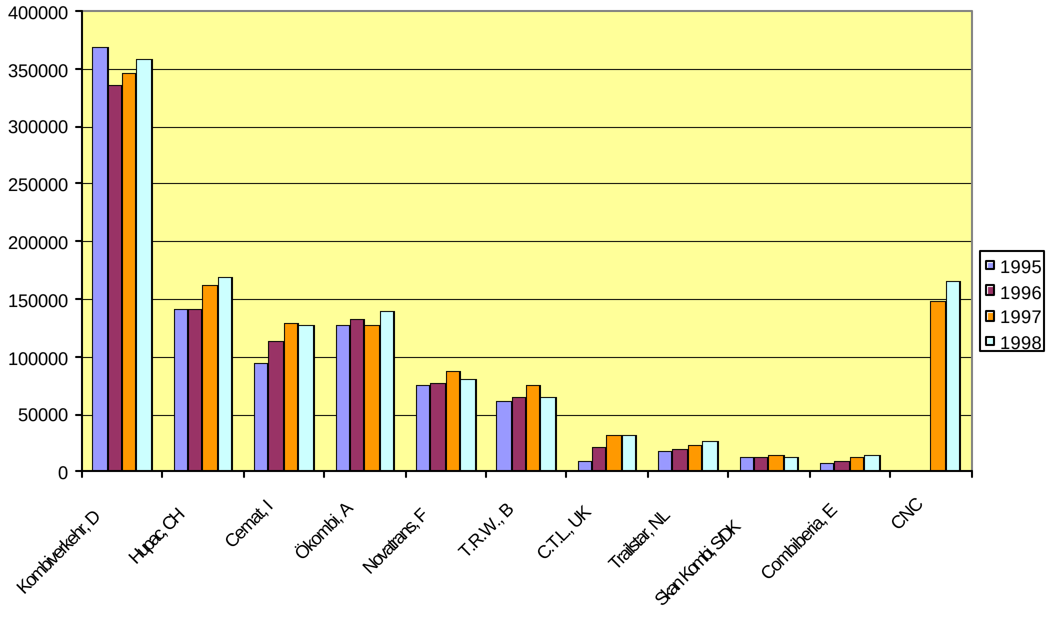


Fig. 4.2.4/1: International Combined Transport Annual Volumes (Consignments/Year) for some UIRR Companies (Source: UIRR)

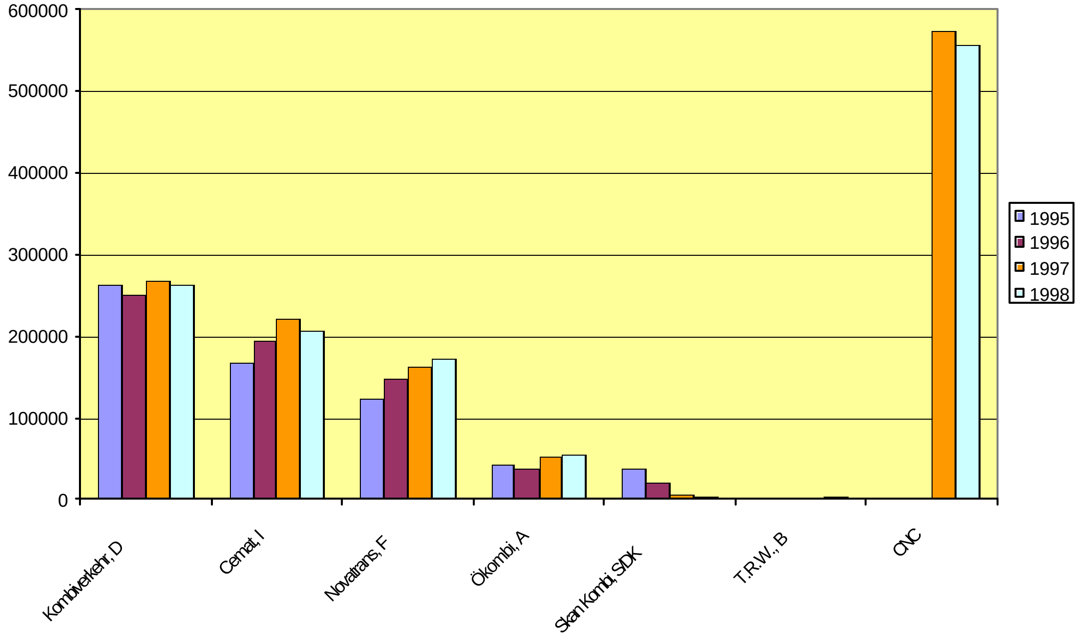


Fig. 4.2.4/2: Domestic Combined Transport Annual Volumes (Consignments/Year) for some UIRR Companies (Source: UIRR)

For the evaluation of the potential demand of transport services different approaches can be followed. The most complex ones require the calibration of econometric models and the availability of detailed information about a multitude of aspects (costs, socio-economic parameters etc.). On the other hand, when setting out to deliver new services, most operators apply simple techniques for the practical estimation of the potential market they can attract. These techniques are based on the selection of the commodities they estimate can be attracted by the service, and the analysis of the present flows between the couple of regions they are going to serve, together with the trends of development.

The analysis of freight flows performed in the first phase of the IMPULSE project was mainly based on this kind of pragmatic approach. We had first evaluated which kind of commodities can be attracted by intermodal transport, and then performed a geographical analysis of the resulting flows. The results of this analysis were mainly oriented to provide indication for the proceeding of the project. More detailed analysis taking into account costs and other parameters was postponed to following workpackages. The approach we have adopted for the evaluation of the commodities to be considered in the analysis is based on the estimation of a series of *containerisation factors.*

We define containerisation as the ability of a good to be transported in intermodal transport units; this in general depends on the characteristic of goods and the distance. The dependency on characteristics of goods mirrors weight, shape, state of aggregation, type and value of goods.

For the evaluation of a set of containerisation factors we first investigated the results of some work already available, to be used as a reference. In order to consider the most recent advances in intermodal transport techniques we have then updated these findings by means of a Delphi inquiry among project's internal and external experts.

The Delphi method is a well-known technique of investigation first developed during the '60 characterised as a method for structuring a group communication process allowing a group of individual to deal with a complex problem. The technique is concerned with the utilisation of experts' opinion in order to achieve some knowledge on uncertain or not well documented subjects. Many applications of the method deals with the collection of current or historical data not accurately known or available.

A group of experts was requested to estimate the most adequate containerisation factor for each of the NST/R groups among a set of three options: 0; 0.5; 1 (NST/R : Standard goods classification for transport statistics / revised). A more detailed segmentation would not be adequate for the problem and would have led to a fictitious accuracy.

0 means that the group of goods is not suitable for intermodal transport units
0.5 means that the group is partially suitable to be transported by mean of intermodal transport units
1 means that the group of goods is largely suitable to be transported by mean of intermodal transport units

During the 1st round of enquiry the experts were submitted the questionnaire and asked to answer it separately one another. In the second round the experts were presented the results of the first round (average of judgements for each commodity), and requested to either confirm their first judgement or change their opinion. If the final judgement differs significantly from the average they were requested to justify their answer. During the second round most of the different judgement expressed in the first round was fixed. Only some minor divergences persisted for a couple of commodities, so we decided not to follow with further investigation and to consider the average values expressed by the experts as the containerisation factors for the different commodities to be used within the IMPULSE project. The final results are shown in the Deliverable D2.

The containerisation factors were then used for a first estimation of the volume of present road transport market which could be attracted by intermodal transport.

Figures 4.2.4/3 and 4.2.4/4 present the results of the calculation of total amount of international road freight traffics potentially attracted by intermodal transport. The calculation has been performed by the application of containerisation factors to the commodity flows at a region to region level. The figures show the dependence with distance of the potential market. Note that for some countries, and in particular for Germany and France, the amount of flows over shorter and medium distances is far above that of the flows over long-distance routes. The values of flows presented are those estimated for the year 1994.

This fact shows how not only should intermodal transport be competitive over long-distance routes, but even over medium-distance ones in order to help solving the problem of a more efficient use of existing infrastructures and utilisation of different modes of transport.

From the comparison of present intermodal transport and containerisable goods flows emerged that if only intermodal transport could attract the 10% of the potential flows over 500 km, it would have a global increase of about 35%; considering also the flows in the range of 300-500 km, this increase would be of more than 40%.

Origin	> 200 km	> 300 km	> 400 km	> 500 km	> 700 km	>1000 km	>1500 km
AT	7.541.367	7.163.137	6.208.102	5.683.212	4.305.808	1.415.354	179.326
BE	29.250.905	13.082.640	9.568.420	7.626.944	5.346.334	2.315.853	908.531
DE	55.766.092	45.091.697	37.191.574	30.640.233	20.727.468	10.382.791	4.809.413
DK	5.047.331	5.047.331	3.550.727	3.193.032	2.301.506	1.457.457	732.693
ES	11.847.203	11.847.203	11.846.402	11.846.349	9.035.612	7.738.889	4.361.250
FI	1.125.867	1.125.867	1.125.867	1.125.867	1.125.867	1.125.867	1.125.867
FR	43.781.379	39.673.148	32.867.661	29.070.160	22.571.102	13.230.797	4.251.596
GR	626.777	626.777	626.777	626.777	626.777	625.663	513.848
IE	248.153	247.697	247.697	244.024	231.355	213.802	142.826
IT	18.068.038	18.067.023	17.383.341	16.767.772	15.112.761	10.158.722	3.573.127
LU	853.088	613.688	427.979	371.110	71.844	22.297	14.442
NL	26.749.826	19.663.431	15.941.829	12.352.433	8.036.157	4.610.342	2.116.818
PT	3.679.082	3.679.082	3.679.082	3.679.082	1.408.900	1.408.900	1.221.945
SE	2.137.247	2.137.247	2.137.247	2.137.247	2.137.247	2.137.247	1.754.255
SW	5.397.040	3.545.529	1.609.374	1.356.284	909.278	391.767	110.999
UK	5.974.032	5.940.079	5.790.355	5.514.704	4.535.756	3.156.253	1.624.142

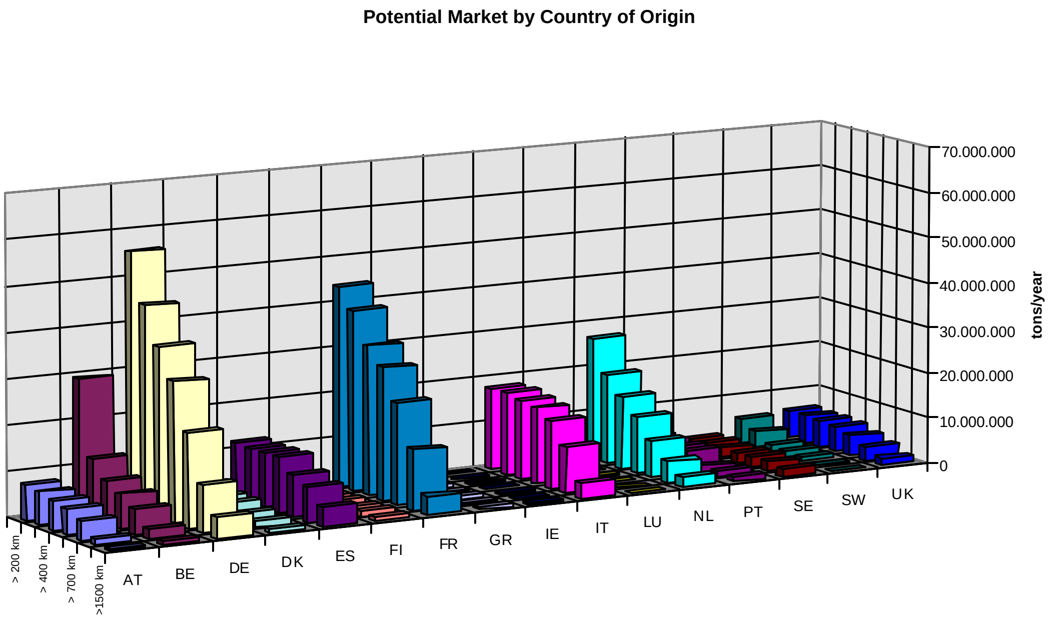


Fig. 4.2.4/3: Total Amount of International Road Freight Traffics that Could be Attracted by Intermodal Transport per Class of Distance and Country of Origin (tons/year, 1994)

Destination	> 200 km	> 300 km	> 400 km	> 500 km	> 700 km	>1000 km	>1500 km
AT	7.801.975	7.344.548	6.270.410	5.454.038	4.047.580	1.386.899	232.830
BE	19.597.662	12.625.071	7.754.392	6.148.265	4.603.060	2.251.051	839.413
DE	62.213.160	52.412.513	42.551.410	34.675.793	22.811.731	11.344.645	4.984.706
DK	5.215.220	5.215.220	4.091.125	3.873.474	3.062.978	1.573.423	602.626
ES	14.545.543	14.545.543	14.461.004	14.459.754	10.862.673	9.105.863	4.481.024
FI	494.917	494.917	494.917	494.917	494.917	494.917	494.917
FR	38.371.697	34.833.270	28.780.894	25.809.402	19.669.980	11.962.805	4.441.527
GR	1.193.235	1.193.235	1.193.235	1.193.235	1.193.235	1.191.075	974.383
IE	440.533	440.533	440.533	440.451	399.495	358.968	149.217
IT	20.662.299	20.661.941	19.891.615	19.187.188	17.421.402	10.582.048	3.724.304
LU	727.961	529.759	398.998	340.411	61.012	11.767	8.086
NL	31.972.356	15.087.800	12.169.220	8.893.490	5.854.022	3.599.977	1.278.502
PT	4.194.412	4.194.412	4.194.412	4.194.412	2.062.674	2.062.674	1.818.822
SE	2.070.383	2.070.383	2.070.383	2.070.383	2.070.383	2.070.383	1.813.219
SW	8.106.901	4.642.778	3.155.208	2.698.348	1.680.591	635.779	216.157
UK	8.856.822	8.743.366	8.371.738	7.783.345	6.017.204	4.060.047	1.920.688

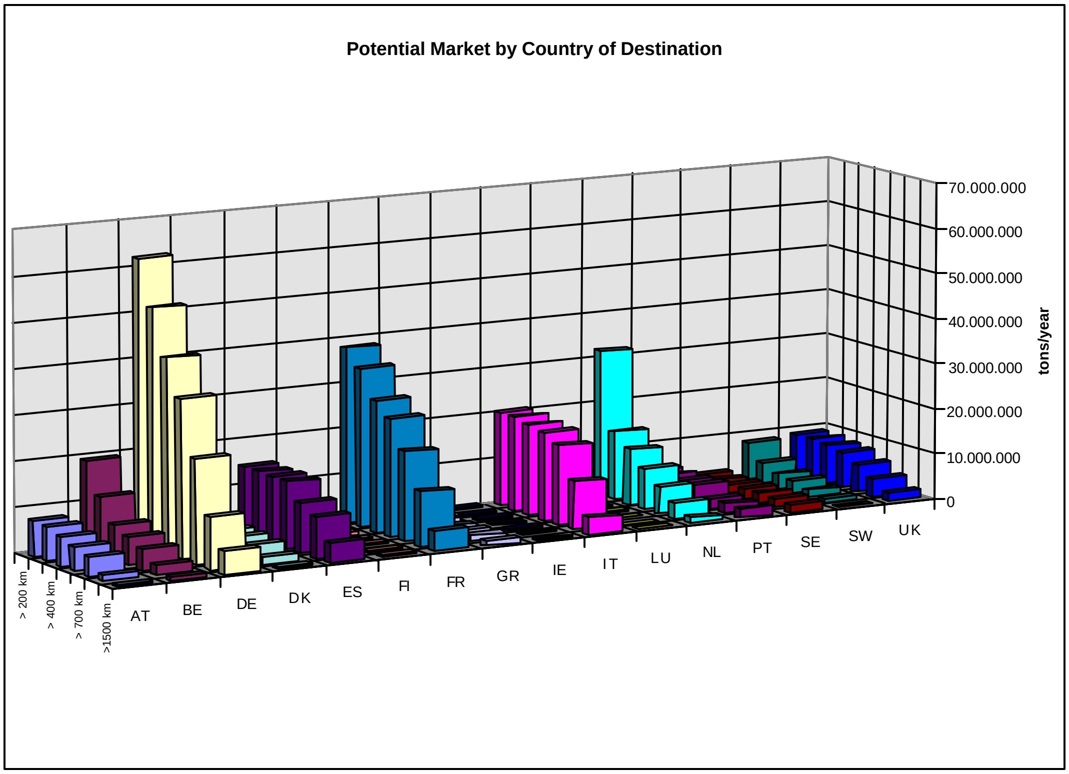


Fig. 4.2.4/4: *Total Amount of International Road Freight Traffics that Could be Attracted by Intermodal Transport per Class of Distance and Country of Destination (tons/year, 1994)*

4.2.5 Quality Factors and Modal Choice

For many reasons, an accurate and reliable method of predicting freight modal split is required. Freight flows are complex due to the variety of shippers and their specific logistics and so it is highly unlikely that a universal mode-choice model can ever be developed. Research in the past has concentrated on the development of modal split models based on generalised cost assuming that business people decisions are more economic driven and not subjective. These fail to explain adequately the prevalence of road freight. The answer is that in most cases the “quality of service” in the road transport sector is higher than in any other. Part of the work undertaken in WP 1.2 was therefore directed to the identification of the factors that mostly influence the choice of the transport mode.

Transport service is a major focus concern to transport decision-maker. Quality of service is not a single variable but rather a set of elements such as reliability of delivery and freedom from anxiety, loss and damage. Generally speaking, speed of freight transport is less important than the prompt despatch of goods at the required time and the guaranteed predictability of transit time. To ensure a good transport service to the customer, the degree of control has been found to be a crucial parameter, especially over delivery. Control over delivery is often the over-riding criterion for choice of a particular mode. Persistently erratic delivery times will prompt the decision-maker to look for alternatives.

Several attempts have been made in order to identify the criteria by which the final decision of mode choice is taken, i.e. the criteria determining external quality. We grouped the transport variables (or indicators, or criteria) entering in this procedure in the following seven groups :

1. Time.
2. Reliability
3. Flexibility
4. Monitoring
5. Security (Avoidance of cargo loss or damage)
6. Accessibility (or Availability) and
7. Qualifications

For each of these groups, a set of more detailed components or aspects have been worked out; for example the time factor was further decomposed into 7 components: Time between moment load unit is ready for transport and the moment terminal procedure starts; Time between the last admitted arrival at terminal entry gate and the real time of departure of train; Time for documentation and handling procedures; Travel time between initial and final terminal; Time for handling and documentation procedures; Time between the arrival of train and the notification to client that the unit is actually arrived and it is ready for delivery and Time between end of procedure at the final terminal and delivery moment. For a further description of other parameters see Deliverable D2.

To evaluate the possible influence in the modal choice decision process of each of the quality parameter identified above, a Delphi method investigation was carried out.

At an initial stage the experts that were going to participate in the Delphi Method were chosen and a questionnaire including explanations was sent to them. The experts’ were chosen among people already participating in IMPULSE project and external intermodal operator or people involved in the particular field. Some are reflecting more operational, other industrial and other overall aspects.

The experts were requested to estimate the importance of each component of each of the modal choice quality criteria. This was achieved by giving a value from 0 to 5, where 0 represents the criterion with the least importance and 5 the criterion with the greatest importance.

At the second round, the opinions gathered during the first round was compiled and distributed to the participants, who might reconsider and perhaps adapt their previous opinion.

At the last round the final outcome was determined. If the experts had the same opinion the particular figure could be seen as agreed, otherwise the average opinion was considered as the final.

From the analysis of the results‘ table it came out the three most important factors to be the following :

- The shippers consider a criterion which has to do with the **security** as the most important. More specifically, they believe that the "probability of load unit and/or cargo loss" is the main parameter which is going to affect their modal choice, as far as the intermodal transport is concerned. From the terminal operators point of view, the **monitoring** is the most important criterion and more specifically the "positioning within chain". From the comments given by the experts during the second round of the Delphi method the above difference may be explained by the fact that although the terminal operators believe that the matter of security is very important, they give less value due to the small percentage of the load units that are getting damaged or lost (1%). On the other hand they are very much interested about the "positioning within chain".
- At the second place of the ranking, both the shippers and the terminal operators consider **reliability** being of great importance. However, each one identifies a different component of reliability as the most important. More specifically, the shippers believe that the "terminal disqualification due to equipment breakdown or personnel discrepancies" is the most important component, while the terminal operators believe that the "intermodal transport chain information system inefficiency" is the most important component.
- Finally, both the shippers and the terminal operators believe that a component of **time** is of great importance by ranking the "travel time between initial and final terminal" at the third place.

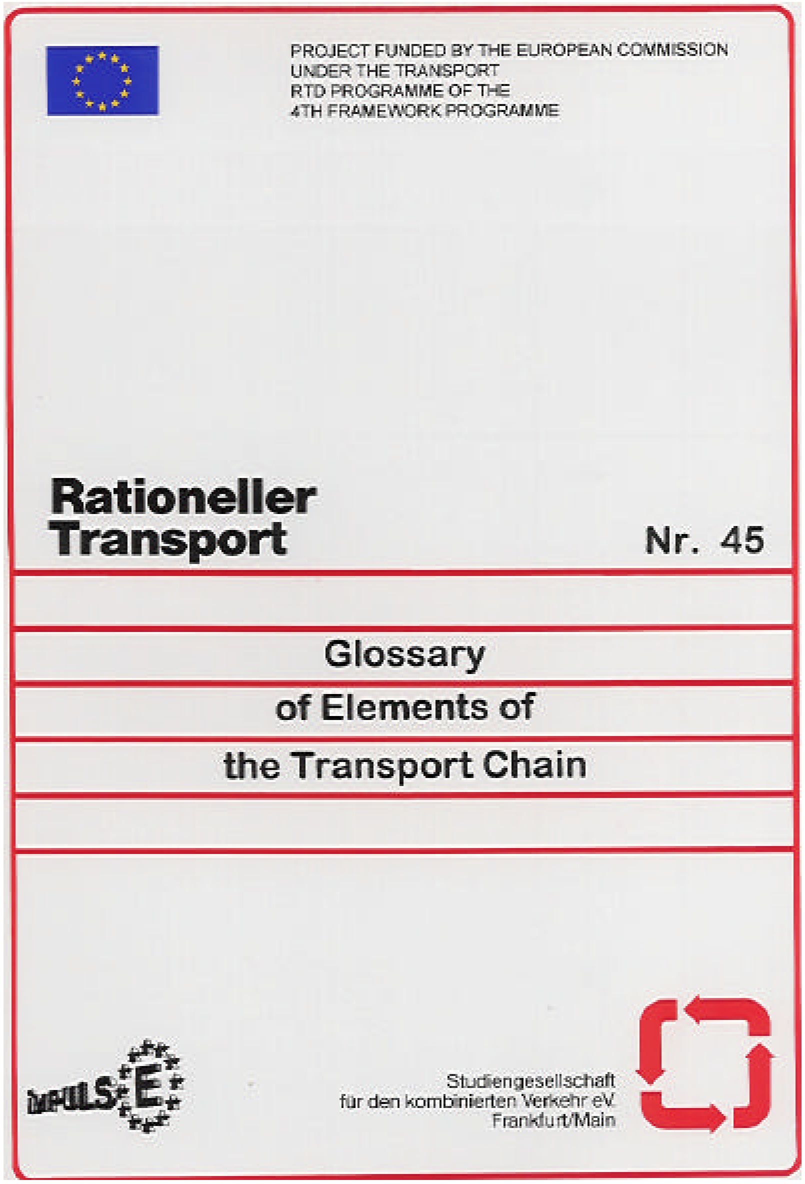
4.3 ELEMENTS OF THE INTEGRATED TRANSPORT CHAIN (WP 1.3)

The works which are summarised in the following, have technically been co-ordinated by SGKV (Workpackage Leader). Krupp, ERRI, Costamasnaga and NTUA have contributed.

The work actually accomplished composes of two Parts:

- Part 1 - Glossary
- Part 2 - Description of bottlenecks, fringe conditions and inconsistencies

The Glossary of Intermodal Expressions is a self-standing document which incorporates the mutual understanding and definition of a couple of idioms used in intermodal transport. It can be ordered at the Studiengesellschaft SGKV in Frankfurt.



PROJECT FUNDED BY THE EUROPEAN COMMISSION
UNDER THE TRANSPORT
RTD PROGRAMME OF THE
4TH FRAMEWORK PROGRAMME

Rationeller Transport

Nr. 45

Glossary
of Elements of
the Transport Chain

Studiengesellschaft
für den kombinierten Verkehr eV.
Frankfurt/Main

Fig. 4.3: Cover Page of Glossary

The activities concerning Part 2 - Description of bottlenecks, fringe conditions and inconsistencies are summarised hereunder.

4.3.1 Introduction

A lot of various activities have to be executed for the production and the transport of goods from the source to the destination of the goods. Starting with the demand of goods, their production, the organisation and realisation of transport chains with their different transport stages to collect, line haul to distribute the goods, i.e. the organisation of a complete intermodal transport chain requires harmonisation and standardisation of all elements of the transport chain.

As an example of consisting and finalised projects, describing these Elements of transport chains and supported by the European Commission are:

- ?? SIMET,
- ?? COST 315,
- ?? SCIPIO,

the databases of which have been compiled dealing with the large variety of their particular importance for the improvement of Intermodal transport and for the development of fast transfer technologies.

Additionally several areas of element definitions exist, which are agreed on the base of recommendations, based on ISO standardisation, which should be the preferred ones. Others exist, based on CEN and International and national transport association bodies recommendations.

All these definitions have been created on a more or less isolated view of these definitions without taken into account the complete transport chain as a whole. The result of this view leads also to functional problems and inconsistencies.

4.3.2 Workpackage Approach

The reduction of these current existing inconsistencies and the replacement of not acceptable existing definitions if possible for the area of element/terms definition level is the aim to give in a first step a basic fundament for the IMPULSE partners for the further workpackages and mutual communication.

The criteria's to check the existing definitions are aligned on the following hierarchical level:

- ?? ISO-recommendation,
- ?? CEN recommendation,
- ?? International association recommendation,
- ?? National recommendation,
- ?? Recommendations of projects within the framework of research projects of the European Commission,
- ?? Partner definition.

Based on these framework conditions a glossary as part 1 and the description of fringe conditions, inconsistencies and bottlenecks as part 2 of the whole workpackage has been developed under the responsibility of SGKV as Workpackage leader, supported by contributions from ERRI, SNCF, DB, KRUPP, NTUA, Costamasnaga, ETH Zürich and SGKV. The glossary consists of the following groups (EXAMPLES):

??	Group 0	General terms (INTERMODAL TRANSPORT, ROLLING ROAD, ...)
??	Group 1	Consignment (CASSETTE, PALLET, ...)
??	Group 2	Equipment/Rolling stock/Intermodal transport unit (ITU) (CORNER FITTING, POCKET WAGON, ...)
??	Group 3	Transhipment area (FREEPORT, HUB, ...)
??	Group 4	Handling equipment (GANTRY CRANE, TUGMASTER, ...)
??	Group 5	Means of transport (BLOCK TRAIN, PANAMAX, ...)
??	Group 6	Identification and related identification procedures (ACTIVE TAG, TRANSMITTER, ...)
??	Group 7	Transport operation activities (BLOCK SYSTEM, LOADING GAUGE, ...)
??	Group 8	Consumer, Transport and Policy actors (FORWARDER, OPERATOR, ...)

For part 2 - description of bottlenecks, fringe conditions and inconsistencies of elements in the transport chain part 1 and the integrated transport chain has been used as a guideline for the whole work within the framework of this project. Definition of expressions and separation of activities of different workpackages will be given along the Integrated Transport Chain. Therefore a systematic characterisation shall be provided from a macro level point of view. In the following the detailed technical investigations can be put in order in relation to this scheme. In this respect the figure provided on the next page has to be seen as a general guideline based on the physical procedures linked to the transport of ITU rather then the logistical, organisational (companies involved) or informational (information to be exchanged) ones.

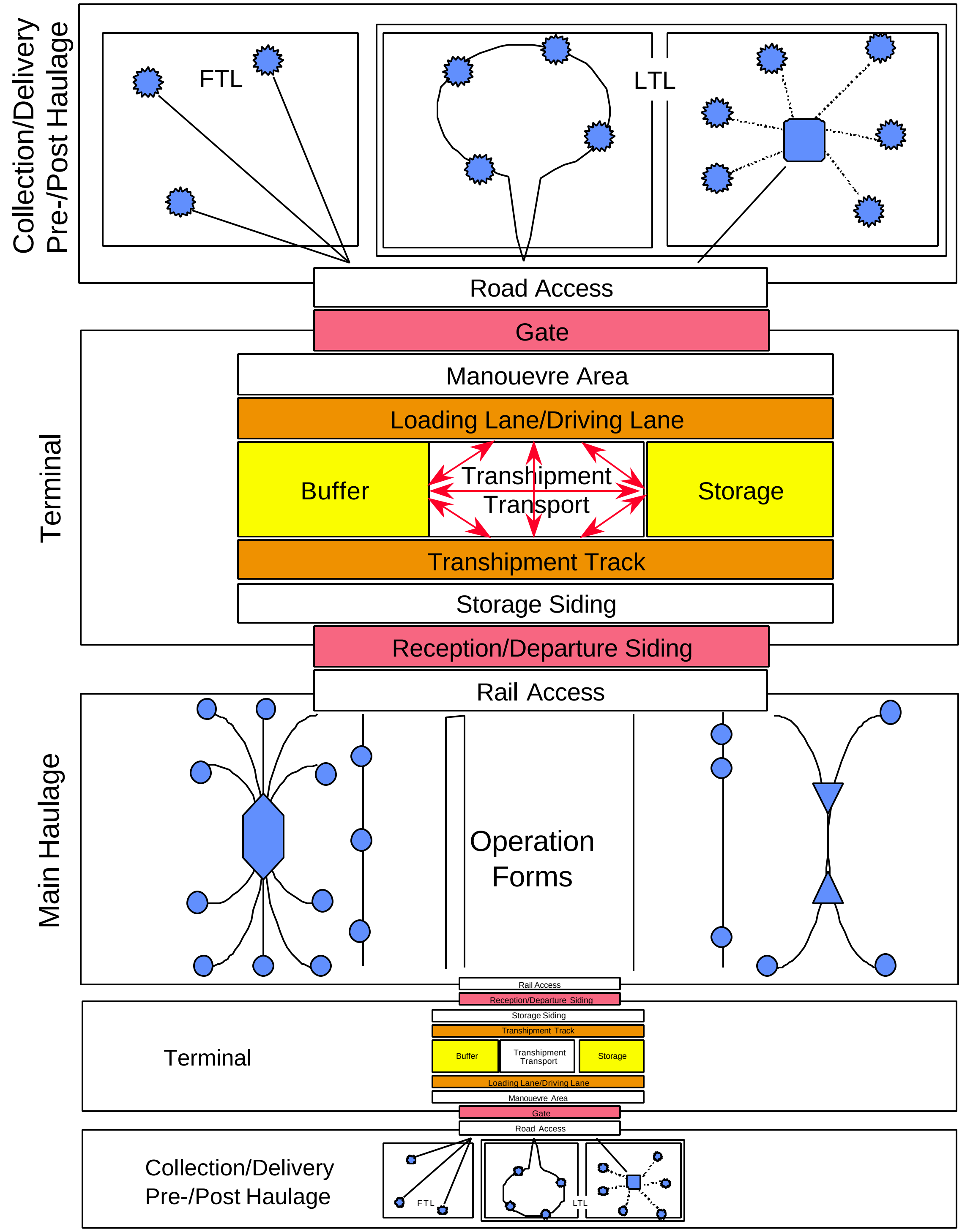


Fig. 4.3.2/1: Integrated Transport Chain (Systematic Scheme)

Logistical functions are e.g. collection and delivery of load, packing/groupage, transhipment near distance - far distance traffic, transhipment between modes of transport, handling of specialised cargoes such as tempered or dangerous goods, storage, haulage service, trucking service, customs service, maintenance and repair of vehicles and means of transport, provision of ITU and equipment, furnishing, ...

The integrated transport chain of Intermodal Transport Units (ITU) can be divided into 5 large sectors:

1. Collection (and Delivery) or Pre- (and Post-haulage) e.g. by Road
2. Terminal
3. Main Haulage e.g. by Rail
4. Terminal
5. (Collection and) Delivery or (Pre- and) Post-haulage

In order not to overload the activities performed in the project, the integrated transport chain will focus on ITU and not consider the stripping and stuffing of these units.

1. So that the pre- and post haulage shall concentrate on Full Truck Load (FTL) when the ITU are directly picked up and/or delivered at/to large shippers or Less then Truck Load (LTL) when the ITUs are directly filled on either a round trip or by picking them up at a forwarders hub. In the forwarders hub transhipment from and to near distance lorries takes place.
2. The terminal operation starts at the roadside gate of the terminal, takes into account logistical and technical-operational procedures in the terminal such as loading /unloading of lorries into a buffer area, storage or depot functions, loading and unloading of trains and the buffering of these trains according to the needs of the main haulage operation forms.
3. For the main haulage different operation forms are in discussion. Hub-and spoke, liner train as intermediate stop train, shuttle train, direct train, liner Train as pick-up and delivery, group train or Train-Coupling and Sharing (TCS), the definitions of which have been provided in part one of this workpackage.
4. The functional layout of the correspondence terminal is similar to the first terminal. although it can physically be shaped completely different. The integration of other modes of transport is in most cases through a buffer or storage area in order to consider the different operational strategies of these modes as well as their operation times.
5. For the delivery of post haulage the same functions are relevant as described in sector 1. Although an ITU which is coming from a large shipper can be delivered through a forwarders hub to various customers.

It must be pointed out that mixtures of operations are possible but can not effectively be integrated in a global scheme.

The basic functions mentioned above are necessary to describe an intermodal transport chain in relation to a defined market environment: These market environment could be a region, a country a number of countries, a continent up to the global environment.

The bigger this environment the bigger is the probability of functional inconsistencies, fringe conditions and bottlenecks of the different elements of an integrated transport chain, which have been identified in part 2 of this workpackage as followed:

- **Consignment**
  - Consignment term
  - Cabotage
- **Equipment / Rolling Stock / Intermodal transport unit (ITU)**
  - Container construction
  - Stackability of containers
  - The use of small size containers
  - Technical aspects of rolling stock for intermodal transport
    - Problem area
    - Future load units
    - Improvement of reliability
    - Transfer between road and rail
    - Train assembly
    - Technical restrictions
      - Load limits
      - Speed in rail transport
      - Train length and mass limits
    - Investments and economy of the wagons
- **Transhipment area**
  - Handling technique
  - Hub
  - Vertical versus horizontal transfer
- **Handling equipment**
- **Means of transport**
  - Container transport in inland waterway mode
  - Ship registration procedure
  - Ship type
- **Identification and related identification procedures**
  - Transport controlling
- **Transport operation activities**
  - Double stack rail transportation
  - Track gauges
- **Consumer, Transport and Policy actors**
  - Policy transport measures

Fig. 4.3.2/2: Elements of the Integrated Transport Chain

4.4 OPERATION FORMS FOR THE NETWORK MODES (WP 1.4)

4.4.1 Introduction and Objectives

As the intermodal terminals depends widely on the trunk haul operation forms and the hinterland transport, this Workpackage establish an intermodal network for Europe including different rail operation forms, terminal types and road distribution. The results are basic inputs for further work steps in developing intermodal handling systems and for modelling purposes.

The work has mainly been carried out by ETH Zurich. Contributions to this Workpackage have been made from the railway partners, Krupp, NTUA and Talbot. An experts workshop has been organised for additional inputs.

The fact that it was not possible to consider the analysis of the intermodal transport market made in Workpackage 1.2 has influenced the results of this Workpackage.

4.4.2 State-of-the-art

The following are the principal operating problems to be tackled on the way to achieving successful intermodal transport development:

- low cost level for road transport in comparison with intermodal transport
- lack of an European-wide network
- insufficient loading gauge and diversity of rolling stock for different railways
- irregular use of terminal capacity (loading peaks)
- missing opportunity to use small terminals with low investment costs and use of private sidings
- high cost level of collection/distribution transport by trucks
- loss of time in the intermodal transport chain
- complex organisation of the transport chain

There are different operation forms at the European railways for haulage transport. Current forms are: direct trains, feeder train systems, liner trains, hub & spoke system and intermodal transport involved in full-load traffic.

Developments of waterborne transport show that for deep-sea transport ever larger ships are being used. Based on this developments, a variety of new problems result:

- enormous peaks at ports, thus resulting in peak demand for hinterland distribution
- concentration of ports, thus resulting with their hinterland connections and feeder services
- coastal shipping lines for distribution from main ports or hub-ports to the existing port regions will become increasingly important
- various transport needs from main ports to other regions with existing smaller ports/terminals can be met by rail.

Inland waterways can only be used for intermodal transport without time restrictions. Large parts of the old waterways cannot be used for intermodal (air draught of bridges).

4.4.3 Objectives for the Intermodal Transport Chain

Making better use of the capacity of the European traffic network together with ecological considerations are given as political objectives for development of intermodal transport. However, current transport reality in Europe is not in line with these political objectives.

In the intermodal transport chain it is important to compare the assumed expense of all elements and not only the cost of a single element. E.g. economical direct shuttle trains for haulage transport use large terminals with high infrastructure costs and often long and expensive distribution transports.

Intermodal transport should cover a large range of traffic flows and distances through a provision of a network solution. All intermodal transport units (ITU) should be included.

Expenses for distribution are a significant element of the total expenses. So small terminals with a small distribution area allow to reduce costs for distribution. Therefore it's possible to accept higher expenses for haulage transport and terminal handling.

4.4.4 New Operation Forms

Existing and new train operation forms are complementary to

?? Increase market penetration of intermodal transport

?? Form a European network

?? Provide cost effective and qualified services also on short and medium distances

One shall consider dedicated Direct Trains from terminal to terminal like Shuttle- or Block Trains, Feeder Systems like Feeder Trains, Train-Coupling-and-Sharing and Pick-up-Trains as well as more sophisticated systems like Liner Trains and even Hub-and-Spoke Operation to be able to satisfy the market requirements regarding development of potential, transport windows and costs effectiveness.

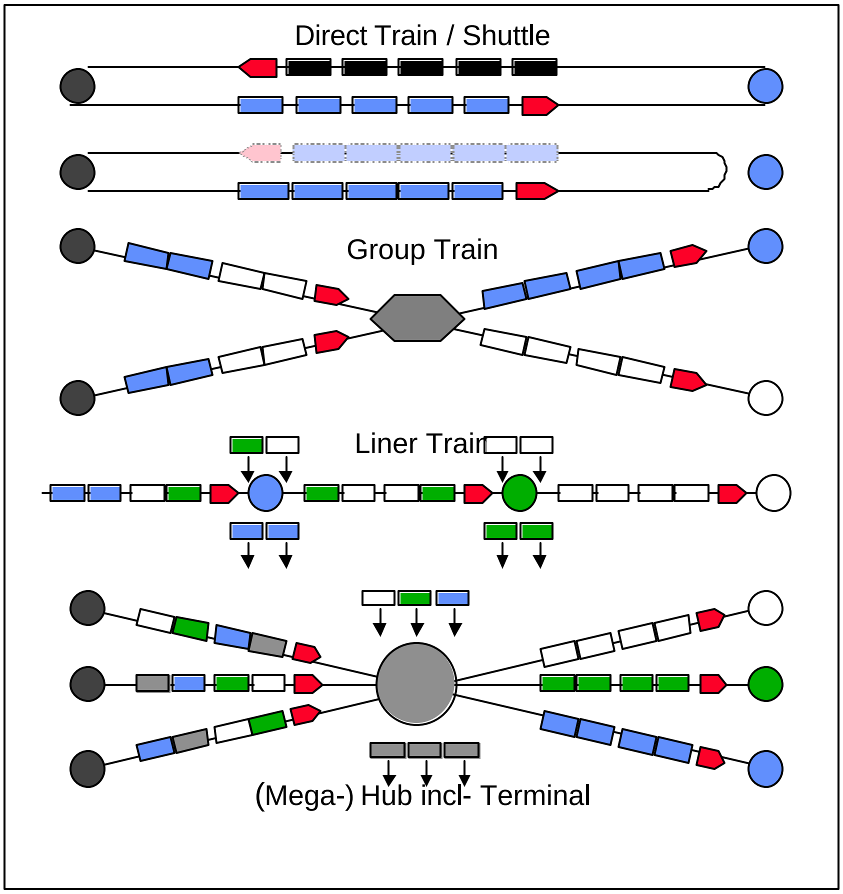


Fig. 4.4.4/1: Rail Operation Forms

All operation forms have their advantages and disadvantages and therefore only a combination of different forms could provide an optimum economic service and a better market share. The combination of different forms on three level seems to be an optimum:

?? **Level 1:** Direct and feeder trains between main terminals, hubs and ports.
This level is a European-wide high-quality service with shortest transport time at lowest costs for haulage transport.

?? **Level 2**: Hub & spoke and liner trains.
This level are services mainly for national transports in an overnight jump. It is also useful for international transports and for distribution of overseas containers in a large region or country.

?? **Level 3:** Full-load traffic
This level is the operation form for all demands that cannot be covered by special intermodal trains.

The levels have to be connected with special terminal layouts, e.g. gateways.

Grafikname:
Erstellt in:
Erstellt am:

Fig. 4.4.4/2: Quality Levels for Operation Network

4.4.5 Recommendations for Future Developments

Rail Operation

It's very important to ensure, that organisational developments of railways (see EC 91/440 directive) do not result in ever more complicated organisational requirements.

For the use of most economical shuttle trains it is necessary to tranship load units in hubs or terminals from wagons to wagons instead of marshalling wagons (e.g. for distribution to small terminals or private sidings).

Rail Infrastructure

It is necessary to commence standardisation of the European network. Another important point is the terminal positioning in the railway network (e.g. access terminal – main-line).

Rolling Stock

Improved use of existing rolling stock is more economical than the acquisition of new rolling stock. Nevertheless, there will be two different developments:

- wagons suitable only for shuttle trains with specifications for special lines (e.g. low floor for alpine lines or UK, high-speed wagons)
- universal wagons for all lines and types of load units

Terminal

Large and medium terminals should be served with different trains during a day for better capacity use.

Hubs with terminal function should be hubs with sorting of ITU and a high degree of automation. A combination hub - terminal is very important for an optimum capacity utilisation.

For the reduction of man power costs and to gain transhipment time, a high degree of automation is required.

It's important to find low-cost equipment for small terminals (less than 40 ITU transhipment per day).

Because more and more trains are electrically powered, it is important to find a means of operating terminals in that way, that trains with electric locomotives can be handled without delay.

Road Distribution

Optimum road transport is a short-distance transport organised by the terminal operator or forwarder.

Interaction with Waterborne Transport

Advances in deep-sea shipping mean that enormous peaks of ITUs arriving at and departing from ports and hubs handling. Optimum co-ordination between waterborne transport and rail transport in Europe is required to reach optimum capacity utilisation of deep-sea ships, barges and trains.

4.5 TRANSHIPMENT SYSTEM DESCRIPTION AND ANALYSIS (WP 2.1)

The works which are summarised in the following, have technically been co-ordinated by Costamasnaga (Workpackage Leader). Krupp, Technicatome, NTUA an ETH IVT, have contributed.

4.5.1 Introduction

The objective of the Workpackage 2.1 of the IMPULSE project is to analyse the existing transhipment systems and solutions, both conventional and innovative, and to evaluate how they meet the requirements of the intermodal network operations.

The results of this analysis will mainly be used as an input for successive tasks of the project were the parameters and performance indexes worked out during the present WP will serve as basis for more in-depth comparison of different terminal solutions and for the calculation of terminal costs and overall performance.

The evaluation proposed in this report is therefore only a first selection and comparison of the different technologies available, based mainly on technical specifications and performance parameters of the equipment.

Two family of automated transhipment systems was taken into account for the analysis:

?? parallel transhipment system, in which several ITU can be transhipped at the same time from rail to road or to the storage;

?? sequential transhipment systems, in which the ITUs are handled sequentially during the operation of train loading/unloading.

An innovative system for maritime terminals was taken into account even though it is still at an early development stage; it therefore could not be tested, and the performance measures are the one provided by the design documents.

The technical specifications of the different equipment were collected and used as input for the evaluation procedure carried out.

As the overall terminal performance does not only depend on the single machine maximum exploitation performance, but generally on all the interconnections of the terminal components (technical, human and environmental), the interfaces between the equipment and the other terminal factors must be taken into account for the evaluation of alternative solutions.

4.5.2 Inventory of Advanced Transhipment Systems for Inland Application

The analysis will be carried out, considering two families of transhipment techniques:

?? parallel transhipment system; in this case loading units are handled with equipment transferring loading units from the train to the storage

?? sequential transhipment system; in this case the train is moved to present loading units to the unloading equipment

For those techniques the advantages and disadvantages will be indicated in order to prepare a list of main points to be improved in the following Workpackages.

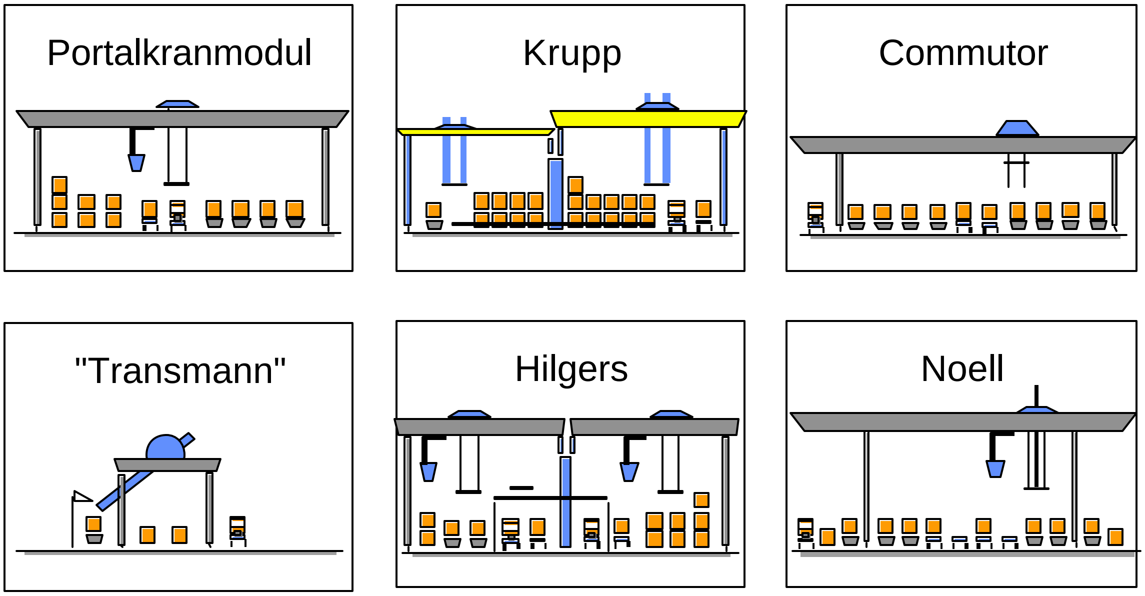
4.5.2.1 Parallel Transhipment Systems

The first family appears particularly suited to the strategy of French Railways (SNCF) to promote intermodal transport through an increased use of rail transport for freight based on the hub-and-spoke concept. To achieve this, it is planned to commission several large automated transhipment yards on the railway network to transfer loading units between several trains. However in order to ensure high productivity at night (overnight delivery) it is necessary to automatically handle loading units and to process several trains at the same time. Different wagons are therefore handled simultaneously with parallel equipment. In the solution developed so far there are many overhead cranes as there are wagons. This is not a problem for high flow yards. However, if this technology is to be used at small rail-road or rail-barge terminals, design adaptations are required: in this case a single handling unit will be used to process several items of or at the rolling stock. Handling techniques and cranes must therefore be adapted to these small terminals. Other problems still to be solved arise: noise, special rolling stock, interfaces, complicated spreader to handle containers and swap-bodies, adaptation to semi-trailers, space optimisation, terminal access.

This basic principle of system have been developed in many projects, with many variants and some pilot plants have been realised.

Our analysis of these transhipment systems has considered the following projects

?? KRUPP FAST HANDLING SYSTEM
?? COMMUTOR
?? COMMUTOR 2
?? HILGERS TRANSHIPMENT SYSTEM
?? MANNESMANN TRANSHIPMENT SYSTEM
?? PREUSSAG NOELL FAST TRANSHIPMENT SYSTEM
?? PREUSSAG NOELL MEGAHUB
?? THYSSEN
?? TUCHSCHMID'S COMPACT TERMINAL



Source: WP 2.1 (Krupp) - FL71109a.ppt

Fig. 4.5.2.1: Transhipment Systems (Overview)

4.5.2.2 Sequential Transhipment Systems

An example of a sequential transhipment system is Krupp's fast handling system which incorporates transfer to and from a moving train. The potential of this type of system in relation to the Intermodal Transport network can be tested on the demonstration plant in Duisburg. The system is capable of being installed in all types of terminal irrespective of volume. The moving train system is only too expensive in the case of the smallest terminals less then 50 loading units per day. Compatibility and interconnectivity is assured with all existing loading units and means of transport commonly in use. Terminals will use a small area and will have good noise protection. Problems could arise from the complex measurement system for the moving train and the investment of a shelf-store in relation in relation to ground purchase and preparation costs.

The only system encountered is the KRUPP FAST HANDLING SYSTEM.

4.5.2.3 Horizontal Transhipment System

A further project is currently being sponsored by the Bavarian State Ministry for Economic Affairs, Transport and Technology. Using the “Faller” system as an example, a feasibility study is to help examine technical feasibility, cost-effectiveness and the potential uses of a horizontal transhipment system. This is a proposal by which standard containers and swap bodies are to be transferred using pallets on roller tracks in a sorting installation and loaded onto container wagons. Because all the ITUs can be unloaded from the train or loaded onto the train simultaneously, the system should enable much shorter standing times for trains to be achieved.

A further new horizontal transhipment system, the „Automatic Loading System - ALS“ has been recently presented in Schwelm (Germany). The system has been developed by Kölker-Thiele, Stelcon and Adtranz and is dedicated to the transhipment of semi-trailers to and from special wagon. ALS composes of a loading ramp, a special low floor railcar which loading platform is situated on the same height as the ramp, and two „transhipment robots“. These crawler units drive automatically from the wagon beneath the semitrailers which have been positioned accurately, lift them and move them onto the railcar or vice versa. ALS allows to unload and reload in each 3 minutes, under the catenary and simultaneously for multiple semitrailers. Each railcar carries two crawler units and one semi-trailer. It is interesting to mention here the FLIHTT project (financed by the EC DG XII) that is entirely dedicated to the study and the conception of an horizontal transhipment system.

4.5.3 Analysis of Advanced Transhipment Technologies

In order to perform an analysis of both conventional and advanced transhipment systems some alternative methodologies were discussed. The approach adopted was to decompose the basic logistical operations (basic transhipment cycle) into components and (simple movements and operation performed within a complex handling movement), working out an estimation of the performance of the equipment to set up an evaluation of the average time and cost of the operation.

4.5.3.1 Definition for the Performance and Cost Evaluation Parameters

The parameters defined take into account a single cycle of transhipment, and are therefore useful for a first comparison of performance of different equipment. This is not however fit for the comparison of entire terminal systems, as they don't take into account the level of service required under operational conditions. For this reason the next section will define some scenarios over which the different terminal configuration can be tested and compared.

Performance Parameters

In order to perform the analysis of the transhipment systems some data describing their characteristics have been collected. These basic data have been elaborated in a such a way to be connected to the major aspects of the systems.

Direct Performance Parameters

The direct parameters are characteristics of the systems directly related to some physical performances of the transhipment cycle. They are related to the maximum capacities of the system, rather than to the average capacities.

1. **Potentiality of transhipment**, in moves per hours: representing the maximum number of the transhipment operations that a single system can carry out
2. **Maximum loading**, expressed in tons: representing the maximum payload with which the system can operate
3. **Type of ITU**: representing the number of ITU that can be transhipped with the system
4. **Maximum power**, expressed in kilowatts: representing the maximum power required by the system for operating conditions
5. **Minimum land area occupied by the system**, expressed in square meters: representing the land necessary for the transhipment system operation (an indication also about the dimensions will be given: i.e. square area rather than rectangular area with great different between the two sides)
6. **Minimum land area occupied by the rail interface of the system**, expressed in square meters: representing the land necessary for rail operation (an indication also about the number of tracks and their length will be given)
7. **Minimum land area occupied by the road interface of the system**, expressed in square meters: representing the land necessary for the road operation (an indication also about the number of lanes, their length and the number of parking places will be given.
8. **Minimum land occupied by the stockage area**, expressed in square meters: representing the land necessary for stocking the ITU. In some case this area is not distinguished by the area of the transhipment system itself.

Indirect Performance Parameters

The indirect parameters are some coefficients that permits to represent important aspects of the transhipment system itself and to be related to some subsystems of the transhipment system. These parameters are in particular useful for the comparison of the transhipment system as they give an immediate evaluation of the performance of the logistic cycle since they present by different point of view the productivity and the effectiveness of the systems.

i1 = **Maximum power/Maximum loading**, expressed in W/N: this ratio represent the behaviour of a transhipment system in relation to the maximum loading that he can operate. If this ratio is low, it means that low power is necessary to a certain loading. This is related to the performance of the system. For example a system with very high power installed can have an high performance or it is not optimised for the loading conditions. This evaluation is made in conjunction with other parameters reported further on.

i2 = **Maximum power/Potentiality of the system**, expressed in W/moves/h: this ratio represent the efficiency of a transhipment system. If this ratio is low, this means that the system is optimised for the transhipment operation (minimum power with a certain number of moves/h). If this ratio is high this means that the system is not very optimised by the transhipment point of view.

i3 = **Potentiality of the system / Minimum land occupied by the system**, expressed in moves/hour/square meter: this ratio represent the efficiency of a transhipment system. If this ratio is low, the use of the land is not very efficient, so the system is not optimised. If this ratio is high, the use of the land is optimised for the application.

i4 = **Minimum land occupied by the rail interface of the system/ Minimum land occupied by the system**, expressed in percent: this ratio represent the area split for the rail operation and the complete operation.

i5 = **Minimum land occupied by the road interface of the system/ Minimum land by the system**, expressed in percent: this ratio represent the area split for the road operation and the complete operation.

i6 = **Minimum land occupied by the stocking/ Minimum land area occupied by the system**, expressed in percent: this ratio represent the area split for the stocking operation and the complete operation.

The use of combination of these parameters permits to have an estimation of the system performance.

Cost Parameters

The transhipment system can also be characterised by a series of cost parameters, that together with the performance measures will be used for the effective comparison of different terminal solutions

These parameters related to costs are on one side some characteristic costs of the system or system parameters directly related to the system effectiveness during operation. They are the following:

1. **Investment Cost**, expressed in ECU giving the cost of purchase of a transhipment system

2. **Maintenance cost**, expressed in ECU per year giving the cost necessary for the maintenance of the transhipment equipment for the operation.
3. **Personnel cost**, expressed in ECU per year giving an indication of managing cost. This datum is necessary for the calculation of the managing cost of the system.
4. **Life of the transhipment equipment**, expressed in years indicating the maximum time for a system to be operated. This datum is very important for the calculation of the investment.
5. **Reliability of the transhipment equipment**, representing the effective percentage of operation of the system compared to the time for which it is required to work (i.e.90%). This datum is a measure of the effective time for which the system can be available.
6. **Power installed**, expressed in kW giving the indication of the power necessary for the operation.
7. **Land occupation**, expressed in square meters giving an indication of the soil use for a transhipment system.

4.5.3.2 Evaluation of the Performance and Cost of the Technologies

The qualitative comparison of all the technologies is made using a series of tables, in which the outstanding factors are examined. In this tables, more typologies of transhipment systems are grouped together (i.e. frontal mobile crane includes the reach stackers, the fork lifts,...) since a lot of characteristics are common. If any characteristic is different it is precised in the table.

	KRUPP FHS Properties	**GANTRY CRANE Properties**
PERFORMANCES	?? higher potential capacity ?? higher buffer capacity	
COSTS	?? higher investment cost ?? higher infrastructure cost ?? higher operation cost	
LAND OCCUPATION	?? lower land occupation compared with a series of gantry cranes with the same potential capacity	
ABILITY TO MANOEUVRE **FLEXIBILITY**	?? no interference with the road vehicles ?? equal	
RELIABILITY	?? higher/equal	
WORKING ENVIRONMENT	?? electricity supply	

Fig. 4.5.3.2/1: Comparison KRUPP FHS / Gantry Crane

	COMMUTOR Properties	**GANTRY CRANE Properties**
PERFORMANCES	?? higher speed (less mass in movement) ?? higher precision in positioning ?? higher load (72 Tons) ?? higher potential capacity	?? limitation of the number of the tracks, of the buffer lines by the span (technical limitation)
COSTS	?? investment cost lower per crane ?? investment cost higher for the terminal equipped ?? higher infrastructure costs ?? lower operational costs (unmanned cranes)	
LAND OCCUPATION	?? about the same if as many tracks and buffer places for both	
ABILITY TO MANOEUVRE	?? faster ?? only one movement in translation	?? trolley and translation movements take place at the same time
FLEXIBILITY	?? operational area limited to the gantry area 20 x 120 m ?? designed to work on identical wagons	?? more flexible: one gantry crane can operate the whole area of the terminal ?? accepts wagons with different designs
RELIABILITY	?? higher per crane ?? equal for the whole terminal	
WORKING ENVIRONMENT	?? electricity supply	?? electricity supply

Fig. 4.5.3.2/2: Comparison COMMUTOR / Gantry Crane

4.5.4 Analysis of Advanced Transhipment Technologies for Application in Inland Terminals

4.5.4.1 Definition of the Operational Hypothesis for the Evaluation

The previous section defined a series of parameters for the measurement of the performance of the different equipment over a single cycle of transhipment. This section will define some basic scenarios over which directly compare the possible solution of terminals adopting different transhipment technologies. Following the results of the task 1 of the present project and some indication coming from the SIMET project, an analysis has been performed to define the application of the technologies in a certain terminal layout. This analysis is aimed to the determination of some reference cases to which the consideration and analysis can be referred.

Basic Parameters for the Scenarios Definition

To define the scenarios we will stick to some basic definitions, that are the following:

?? TERMINAL SIZE:

?? TERMINAL FUNCTION

?? TRAIN CHARACTERISTICS

?? OPERATION FORMS

Definition of the Terminal Scenarios

Basically the scenarios are five:

?? hub&spoke terminal	A
?? large terminal	B
?? medium terminal	C1/ C2
?? small terminal	D

For each terminal, on the base of hypothesis about the form of operation and the daily number of loading units to be transhipped defined in WP 1.4, the peak-hour workload, in terms of number of ITUs/h to be transhipped is defined.

4.5.4.2 Qualitative Comparison for Small Terminals (Scenario D)

Description of interfaces

The interfaces between the different modes of transport are the following:

Road: a certain road access, with a place for the trucks arrival, and an area for the ITU stocking.

Rail: a certain access, with two tracks able to be loaded integrated (“binari a raso”). In this case to optimise the land occupation the best length of track is about 250-300 meters (not the length of a complete train).

Operational modes

Road: Access of the trucks through a gate and going to the parking place. For the internal circulation there is the possibility of interference of the transhipment movements with the truck flow coming out.

Rail: The operational form usually proposed is

- liner train
- eventually feeder train

Feeder system is more cost efficient, but it is related to a certain traffic volume for its efficiency.

Transhipment equipment used

For the small terminals, the transhipment equipment usually used consist of two reach stackers. In this layout there is generally the use of frontal mobile cranes: this means a certain cross section of the terminal. One gantry crane alone is generally not used since it is less flexible and not very efficient over great lengths.

In this case both the COMMUTOR principle and the KRUPP FAST HANDLING SYSTEM have a potentiality that is far higher than what demanded in peak hours. In this case the application of an advanced system seems rather difficult.

Evaluation

About the small terminals we can remark what follows:

- the small terminals, generally present a relevant cross section necessary for the manoeuvring of the frontal mobile cranes. This imply that practically for the conventional equipment used it is very difficult to work along a track 600 or 750 m long: this length is so reduced.
- For these reasons, the marshalling operation of a train play an important role in the economy of the terminal. If a marshalling operation can’t be avoided at all, a reduced number of these operations with an automatic coupler on the wagons can be accepted.

4.5.4.3 Qualitative Comparison for Medium Terminals (Scenarios C1/C2)

Description of interfaces

The interfaces between the different modes of transport are the following:

Road: a certain road access, with a place for the trucks arrival (with several waiting and parking places), and an area for the ITU stocking.

Rail: a certain access, with four tracks able to be loaded integrated in the soil. The length of the track can be of about 450-600 m, depending upon the case.

Operational modes

Road: Access of the trucks through a gate and then to the parking places and/or the loading/ unloading places. In this case, the interference with the internal movements of transhipment and the external truck can be avoided.

For the rail, the operational form usually proposed is

- direct trains
- liner train
- eventually feeder train

Direct trains are not always possible or it is possible a couple of direct trains per day. This operational mode so can't cover all the traffic volume.

Transhipment equipment used

For the medium terminals, the transhipment equipment usually used consist of two reach stackers and one gantry crane.

It is possible to apply the COMMUTOR technology dividing the train in 3-4 parts of 8-10 wagons or less each permanently accoupled each other and with automatic coupling compatible with the traditional coupling (UIC coupling system), parts to be treated as separate each other.

The principle of the COMMUTOR can be applied to only one of these modules of 5-8 wagons, with 4 tracks and 5-8 cranes instead of 33. The automatic coupler can optimise the operation with the feeder train system conceived like this.

So one train is decomposed into parts, one for each track.

Also for the KRUPP system is interesting to think about the application of train modules with the fast handling system.

Evaluation

About the medium terminals we can remark what follows:

- for this applications, a parallel system works on a large cross sectional area for a terminal and with a not so great length (great length means great capacity). So, if there is the possibility of splitting trains into modules to be treated independently and to be easy coupled each other (with an automatic coupled at the extremity of each module), an efficient operation can be made. Unfortunately the problem of different wagons with different lengths still remains. In any case on a length of 5-8 wagons, the cranes can be optimised for operating on wagons of different type.
- For the application of these technologies it is very important to identify and position the wagons and the ITU on the wagons (see WP 2.3).

4.5.4.4 Comparison for Large Terminals (Scenario A/B)

Description of interfaces

The interfaces between the different modes of transport are the following:

Road: a certain road access, with a place for the trucks arrival (with several waiting and parking places), and an area for the ITU stocking.

Rail: a certain access, with eight-ten tracks able to be loaded integrated in the soil. The length of the track can be of about 600 m or more, depending upon the case (1 complete train).

Operational modes

Road: Access of the trucks through two or more gates and then to the parking places and/or the loading/ unloading places. In this case, the interference with the internal movements of transhipment and the external truck can be avoided.

For the rail, the operational form usually proposed is

?? direct trains

?? hub & spoke trains

?? eventually feeder train

Direct trains are the most economic operation possible, but they can be made only on some consolidated traffic connection axes especially if they have an equilibrium between the Origins and the Destinations (i.e. the Italy - Germany connection through the Brenner axis). This operational mode can cover a consistent part of the traffic volume. As explained for the small terminals, the trend actually id to reduce the operation with the liner trains since they are the most costly system of transport after the full load trains.

The feeder system is more cost efficient, but it is related to a certain traffic volume for its efficiency. The use of feeder train composed by nodules of wagons (as for the medium terminals) easy to be uncoupled can permit to optimise the transport.

Transhipment equipment used

For the large terminals, the transhipment equipment usually used consist of four reach stackers and four gantry crane.

It is possible to apply the COMMUTOR technology dividing the train in 3-4 parts of 8-10 wagons or less each permanently accoupled each other and with automatic coupling compatible with the traditional coupling (UIC coupling system), parts to be treated as separate each other.

Due to the volumes proper of a great terminal with a several tracks in parallel, the parallel systems can find their applicability once the problem of having different wagons of different design is solved.

Also for the KRUPP system is interesting to think about the application of train modules with the fast handling system.

Evaluation

About the large terminals we can remark what follows:

?? for this applications, a parallel system works on a large cross sectional area for a terminal and with a length of about 500 m. If there is the possibility of splitting trains into modules to be treated independently and to be easy coupled each other (with an automatic coupled at the extremity of each module), a new train operation can be made. In practise, every module of wagons circulate in the rail network as a single vehicle, implying a change in the management of wagons. For example, the empty wagons management or the wagons maintenance. The introduction of such principle causes a diminishing of the number of vehicles to be treated. Every train will be composed by several modules that can be easily splitted as needed. This idea permits to draw back the attention to the marshalling: the idea of avoiding completely the marshalling led to the conception of transhipment systems capable to operate all the trains in the same time. This caused huge projects. Now, taking advantage of the wagons modules definition, modules to be easily coupled with automatic handling, the automated transhipment technologies can be applied without huge projects.

?? For the application of these technologies it is very important to identify and position the wagons and the ITU on the wagons (see WP 2.3).

4.5.5 Conclusions: Technical Specifications for the Advanced Transhipment Systems

The automated handling systems were conceived to meet the need of improving the performance of the conventional transhipment equipment in an integrated way, optimising the overall terminal performance .

The analysis carried out in this WP starts from the conventional equipment, in order to understand the reasons for the necessity of an advanced system, and in order to fix some points of comparison for the new technologies..

The conventional equipment is manly constituted by the mobile cranes and by the gantry cranes.

This approach developed permits to understand the evolution occurred in the intermodal developments since now and to explore the future possibilities for the application of the advanced technologies.

The first improvement to be done in the transhipment is made by the identification of a transhipment module and of its duplication or multiplication in order to fulfil the demand of transport. The basic module is conceived as an independent subsystem inside a terminal: with its structure, its land occupation its ITU flows form the mode to be transhipped to the final mode. Let’s see an example of module the gantry cranes are the classical example of a transhipment module since they are on the rails and able to be put on behind the other with independent movements; with the stacking located under the portal crane; with parallel ITU flows in and out of the crane. On the other side, the mobile cranes, are not constituting a module since they interfere each other during the operations; their movements can interfere and the ITU flows are not parallel and also that can interfere.

TRANSHIPMENT SYSTEM

conventional ? **multimodules** ? **integrated systems**

So after defining a module, the first step is to duplicate,... multiply. The adoption the modules in parallel indeed bring some advantages, but it is not already an integrated solution, since the interfaces among the modules constitutes the weak point of the terminal. In order to overcome these difficulties, it is necessary to think about a system, an integrated system.

To conceive an integrated system it is not only necessary to design the performance of a single crane, but it is also necessary to design the logistic cycle for the system. This point is very important since the operational forms may affect the design of a terminal (i.e., a terminal with a surface occupation and track lengths optimised for feeder train operation).

From the analysis made, it is clear that the integrated systems can have an acceptable cost only if the traffic volume is elevated.

4.6 OPTIMISATION OF TERMINAL OPERATION PROCEDURES (WP 2.2)

The works which are summarised in the following, have technically been co-ordinated by Krupp (Workpackage Leader). ERRI, Framatome, Euretitalia, NTUA and DUSS have contributed.

4.6.1 Introduction

Competitive intermodal transport requires efficient and customer friendly transhipment facilities.

The development of intermodal transport has rapidly increased the number of intermodal transport units to be transhipped in the terminals. The number of users and links to be served has increased, too. Besides this, additional services (storage, maintenance and repair) are requested. The demand of end-users on timely and reliable information on the status of their intermodal transport units and means of transport has increased, because of the integration of intermodal transport in logistic chains.

At its beginning the flow of intermodal transport units and means of transport of small and medium conventional terminals could be monitored manual by means of appropriate schedules and data sheets. Parallel to the increase of the requirements and the development of information technologies terminal management systems have been developed to fulfil a number of tasks for the internal procedures and the external communication.

Advanced terminals are highly dependent on appropriate terminal management systems to support the logistical flow of goods. Those systems can only be implemented in conjunction with the material flow unit of the terminal control system. Therefore they are sometimes offered as in-build components (“integrated systems”).

Although the efficiency of the terminals certainly depends on having adequate and well-maintained equipment for transfer of intermodal transport units, in practice many of the resultant problems are more related to logistics and organisational procedure.

It is the aim of terminal management systems to tackle these problems and to allow efficient and effective terminal operation thus resulting in optimal utilisation of the installed equipment and the personal resources and a reduction of the overall handling costs.

By optimising the operation procedures the throughput of vehicles, intermodal transport units and the corresponding information per time unit could be increased. Average waiting times shall be reduced to an overall minimum. By means of the terminal management system also the external transport modes can operate with higher efficiency. By this, intermodal transport becomes more attractive to shippers and hauliers.

4.6.2 Terminal Layout

The terminal designed for transferring intermodal transport units between different modes of transport is subdivided into the train operation and transhipment plant and other sectors. Making up the train operation siding are the reception and departure sidings, the erection, removal and transport tracks (loop lines and engine storage tracks) and, depending on the type of organisation involved, the transfer tracks. The transhipment plant comprises the rail transfer area, the materials handling equipment, the intermediate buffer area and the loading and travel lanes. The remaining area includes the HGV approach road and the land made available for any congestion, the reception and departure gate(s), the traffic area (parking spaces and waiting areas, turning area and reversing lane), buildings and technical installations and service areas and depots where applicable.

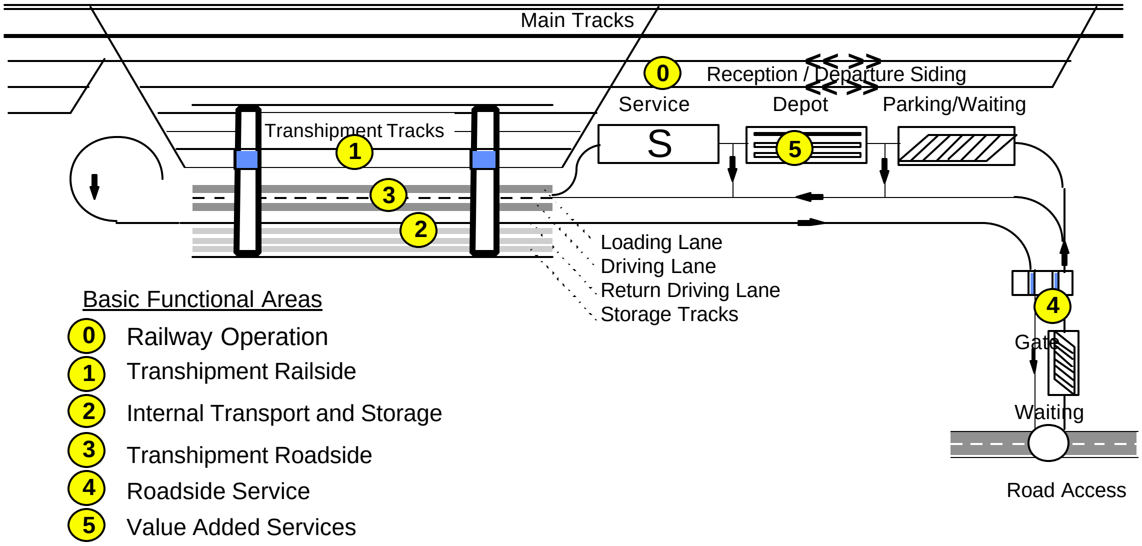


Fig. 4.6.2: Functional Terminal Layout

4.6.3 Terminal Operation

The approach is based on the identification of specific terminal characteristics that are considered as important from the organisational point of view. The terminal characteristics that have been used for the classification are:

?? Shunting operations schemes

?? Truck booking schemes

?? Cut-off time and acceptance of last minute arrivals

?? Percentage of direct and indirect train transhipments

?? Ability for dwell time (more than one day) for the incoming/outgoing loading units

?? Operational scheme for the empty wagons

?? Service/Storage preplanning activities

?? Location (in or outside the terminal) of the truck parking

?? Checks performed by the In and Out terminal gate (including the necessary hardware) for the cargo, the trucks and the associated documents

?? Truck service discipline

?? Handling Equipment Control and Communication Systems

4.6.4 Terminal Analysis

Currently existing terminal organisation and operation procedures in Europe have been analysed in terms of the following aspects

?? public and/or private ownership and organisation of terminals

?? gate-in/gate-out procedures for physical transport

?? gate-in/gate-out procedures for information flow

?? organisational and procedural links (including information exchange, EDI) to mode operators and intermodal operators served in the terminal

Terminals which have been visited are shown on the following Map. They represent a variety of countries, sizes and operators involved.

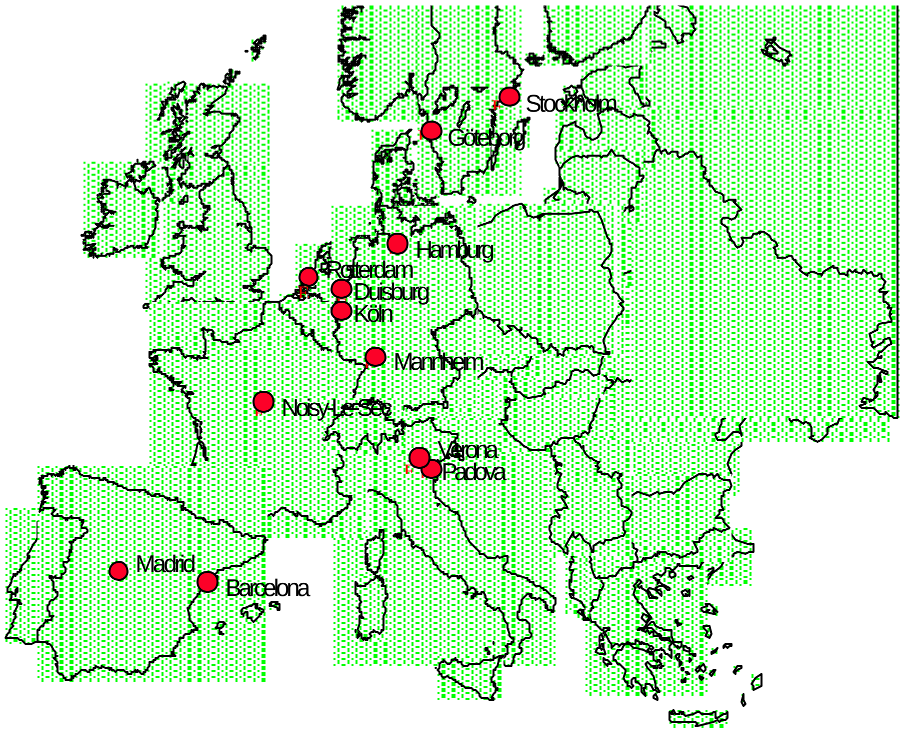


Fig. 4.6.4: Map of Contacted Terminals in Europe

The Conclusion from the field research is that although every terminal in Europe is used for transhipment (and storage sometimes) and the process is based on similar principles there are some slide differences existing. In particular concerning the safety part differences we can observed, which may be explained by:

The computerisation : the use of data processing for the external part is generalised to each intermodal transport operator (exchange of data with other terminal or central office, printing of contracts, ...). Concerning the internal part, most of the TMS (Terminal Management Systems) seen are still under improvement. Managing a terminal with such a tool is really different because it allows to know in real time some data (position of the ITU in particular) and to access easily to those. Although, the main problem is that such system is rather incomplete if it needs some manual operations to check the accuracy of the data.

The traffic: it is an evidence that the operations in rail road terminal with a high traffic (150,000 to 200,000 ITU handled per year) have to differ from those carried out at small terminal (less than 50,000) due to the repetitions of the work.

The number of employees: it is interesting to point out that some little terminal, with a few employees, offer a high ratio men/ITU handled. In this case, the polyvalence must be used, whereas it not always trues for big terminals. The work repartition is as a consequence different.

The facilities: some terminals have some different process when they offer some facilities to their clients, as for example regional haulage or long duration storage. These supplementary options for clients need to be integrated in the process.

The number of intermodal transport operators on the terminal: the management is sometimes shared between some operators. Due to the different activities they can have (only international traffic for example), some procedures of the transport contract treatment, that take place at the entrance, have to be divided.

4.6.5 Quality Aspects

Besides costs and time “quality” has become a further important factor to influence modal choice. The overall quality of intermodal transport is determined by the weakest part of the chain. Therefore all actors involved have to contribute to the same high quality level in order not to loose existing clients and to win new market segments. The intermodal terminal at the interface between modes and even domains of transport plays a vital role in this game, because it is often seen as generator of additional inconvenience compared to unimodal transport.

These “domains” are characterised by still monopolistic railway authorities, intermodal operators, large integrators and forwarders that are controlling large fleets of consignments and small and medium sized enterprises with only few ITU per week. In order to deal with these structures the terminal company shall be organised to ease access to intermodality.

The following basic rules may assist in this exercise:

- the principle of free and public access for both rail and road access
- the neutral position of the terminal operator vis-à-vis the mode and intermodal operators
- non-discriminating tariffs and schedules (e.g. opening hours)
- possibilities of Electronic Data Interchange (EDI) in addition to any other communication means
- guarantee of data security and safety of client related information
- considerable throughput and limited waiting times through visible procedures
- basic service of transhipment and buffer
- additional technical service provided (storage, maintenance, technical inspection of vehicles)

4.6.6 Terminal Management Systems

In the inspected terminals different Terminal Management Systems (TMS) or activity support systems have already been installed or are planned to be implemented in short time. The computer systems are of different age and configuration and fulfil different purposes from rather limited assistance when filling in freight notes, via planning data to more complex operation tasks. However they are historically developed and implemented according to budget restrictions and must not necessarily meet the recent requirement.

A transhipment plant is used not only as the interface between the physical modes of transport but also as the clearing point for information running on ahead of, and accompanying, the transported material. The terminal is thus linked up to the sales companies and the forwarding and trucking companies which handle the pre - and on-carriage and to the rail companies which organise and handle the main journey. Information on the type, quantity and sequence of the wagons and intermodal transport units to be handled made available by telephone, Fax or electronic media is checked and completed by hand where necessary on arrival of the trains or HGVs.

These activities are carried out at either physical or “virtual” Gate of the terminal.

Data, which must be recorded here, includes, among other details, the following information:

?? Reception station

?? Number, length, height, model and tare weight of the intermodal transport unit

?? Loading weight or load unit condition (loaded/empty) and type of material carried

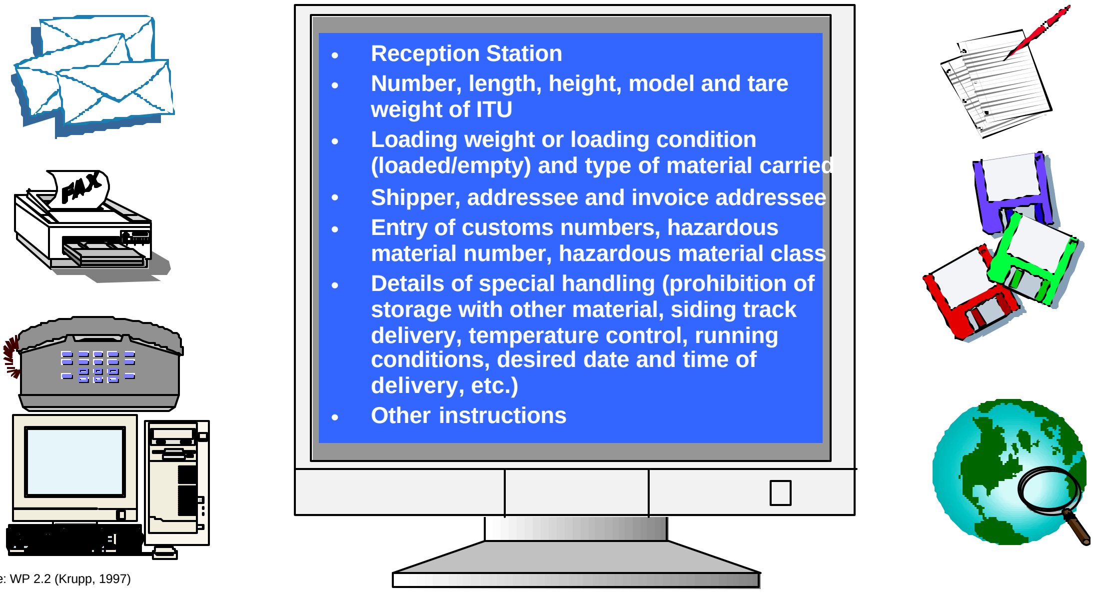
?? Shipper, addressee and invoice addressee

?? Train number, wagon number and position on the wagon if applicable

?? Entry of customs numbers, hazardous material number, hazardous material class

?? Details of special handling (prohibition on storage with other material, siding track delivery, temperature-controlled goods, running conditions, desired date and time of delivery, etc.)

?? Other instructions



- **Reception Station**
- **Number, length, height, model and tare weight of ITU**
- **Loading weight or loading condition (loaded/empty) and type of material carried**
- **Shipper, addressee and invoice addressee**
- **Entry of customs numbers, hazardous material number, hazardous material class**
- **Details of special handling (prohibition of storage with other material, siding track delivery, temperature control, running conditions, desired date and time of delivery, etc.)**
- **Other instructions**

Source: WP 2.2 (Krupp, 1997)

Fig. 4.6.6: Terminal Management System

In order to prevent errors in manipulation, the existing data should always be transferred electronically. The data records completed in the terminal should therefore also be made available to the sales companies, the rail companies and the trucking companies where applicable. Requirements as regards customer confidentiality and data protection must of course be taken into consideration and a specific level of authorisation ensured.

4.6.7 Consequences

Implementation of an improved terminal management system in intermodal terminals can contribute to reduced overall investment costs. This is mainly achieved by reduced area requirements due to less waiting/parking areas in front of the roadside Gate, less gate places and less operational buffer places inside the terminal through accelerated service.

Data input through standardised interfaces reduces the multiple manual operation. An electronic file can be supplemented step-by-step and made available to the customer. At the Gate the service times can be reduced from 10 to 5 minutes, if data set is already in the booking system and needs to be updated, only. This advantage has become obvious in Duisburg: Truckers working for Kombiverkehr are served very quickly at a window while they remain in the cabin whereas all other companies have to fill-in their papers at a counter in the office building.

All terminal equipment (cranes, handling devices, internal transfer machines) can be integrated into the terminal management system. Cranes can either receive their job directly from the TMS or the crane driver can be instructed via a screen. On the other hand the handling device will confirm its manoeuvre to the TMS, so that the status information is update regularly.

The link to mode operators allows for a better disposition and therefore utilisation of the rolling stock and lorries. Timely marshalling of wagon is avoided as well as searching of loading places by lorries. This reduces waiting and handling times in the terminals and thus the quality of service improved.

In addition, the TMS will allow the terminal operators to get to know the exact staying time of rolling stock and ITU in the terminal and will put them in the position to invoice exceptional long staying times. By exploiting statistics, the existing terminal infrastructure is monitored to be used at its optimum, eventual bottlenecks are highlighted and planning of extension possibilities is supported.

Using the information being provided by the TMS the terminal operator can offer further services such as storage, depot or trucking for selected clients who wish so. Besides these pure operational benefits also commercial services (administration, document flow and invoicing) are encouraged.

Monitoring the whole transport chain from door-to-door, which is more and more demanded by shippers and mandatory in case of dangerous goods, is also fulfilled by a terminal management system as status information can be given at any time and the operations are more transparent.

This set of advantages will contribute to more qualitative intermodal transport chains.

4.7 IMPROVEMENT OF IDENTIFICATION, LOCATION AND POSITIONING (WP 2.3)

The works which are summarised in the following, have technically been co-ordinated by Technicatome (Workpackage Leader). Krupp, ERRI, Costamasnaga and SGKV have contributed.

4.7.1 Introduction

One of the aim of the IMPULSE project was to study the facilities and techniques to be implemented for identification, location and positioning purposes.

The study was focused on transhipment activities in intermodal (mostly rail/road) terminals and on their interfaces toward multi-modal transport networks (i.e. rail or road modes).

It takes into account unaccompanied transport chain and large fleets of equipment such as :

- ITUs (containers, swap-bodies and semi-trailers)
- rolling stocks (wagons, locomotives, lorries and barges)
- transhipment and handling equipment but also those ensuring transfers of ITUs inside the terminal (that is mobile equipment as reach-stackers, straddle carriers, fork lift, gantry cranes or AGV, etc...)

Analysing identification, location and positioning functions, the first task of the IMPULSE consortium was to define them precisely.

Identification concerns the acquisition of information on ITU, rolling stocks or handling equipment (and gives information such as type, size, id. number,...).

Location of a movable object consists of knowing its place (or geographical position, i.e. « x, y, z and axis »), within the terminal or on the route.

Positioning means determining the relative position (co-ordinates) and attitude (for example, inclination, door disposition, direction) between a movable object and an handling equipment, with the required accuracy in order to perform or facilitate transhipment operations.

Identification, **location** and **positioning** represent essential information for the organisation of movements on the terminal and along networks and for the quality and performances of handling operations, in order to ensure an optimal efficiency of operations (notably regarding costs and deadlines) and to guarantee the quality of service required by the client.

In the field of transport, identification and location systems have always existed (essentially in the shape of « papers » as consignment note, bill of lading or identification numbers and even identification colours...), assuming a role in the tracking of the freight through the entire transport chain.

Today and taking into account the emerging requirements of industries and of the market (« just-in-time » organisation, competition,...), the transport world has to turn itself toward a high-performing and reliable « production system », where notions such as anticipation, logistics, and respect of delivery time are essential.

Actually, this « just-in-time » organisation imposes a heavy burden on the transport system as regards quality, flexibility and reliability.

For example, if the supply material comes in four hours late, this could easily mean the entire workforce being idle during this time ; further costs will be created by overtime work, failures to meet delivery dates, and so on. A fairly small delay in transport can lead to major financial loss.

The need for utmost reliability in transport and handling, and the existence of contingency plans at the receiving end as a fall-back position create the need for more and more information on the freight and on fleets of equipment.

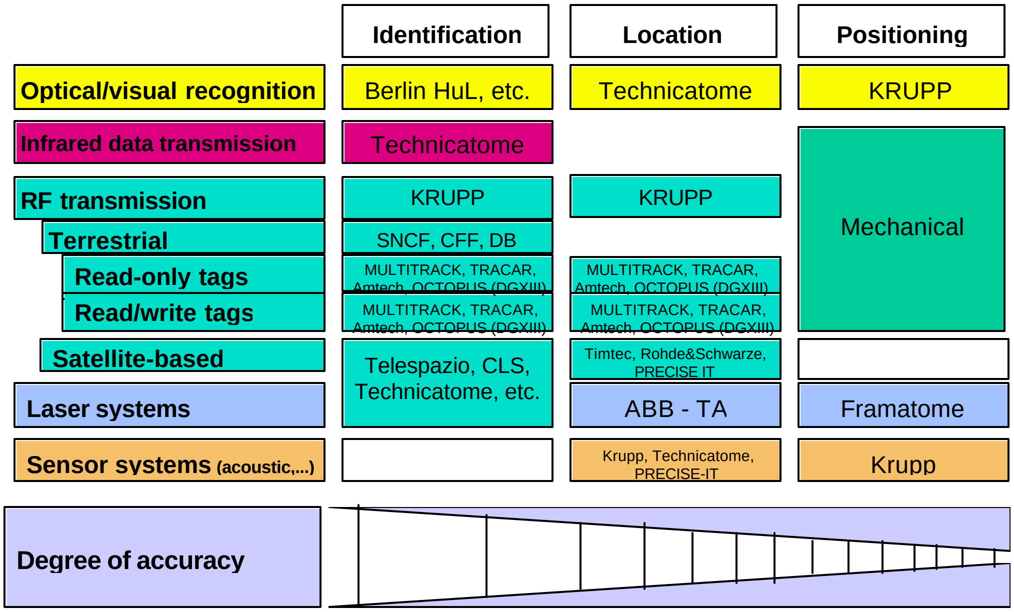
These requirements are positioning ILP systems so as to act as a « red line », as a driver lead, which is a key link to durably ensure competitiveness and high, but homogenous, quality of service.

This main role to be played by ILP systems necessitates to check how technologies are capable to ensure this status.

4.7.2 Technologies Analysis

4.7.2.1 Survey of ILP Systems

Studies led in the scope of the Workpackage 2.3 have consisted of analysing the current and future situation, and identifying means, tools and technologies (still existing or undergoing development) which are susceptible to answer to the expected performances. As it is shown on the following figure, various technologies have been and still can be envisaged to ensure ILP functions.



	Identification	Location	Positioning
Optical/visual recognition	Berlin HuL, etc.	Technicatome	KRUPP
Infrared data transmission	Technicatome		Mechanical
RF transmission	KRUPP	KRUPP	
Terrestrial	SNCF, CFF, DB		
Read-only tags	MULTITRACK, TRACAR, Amtech, OCTOPUS (DGXIII)	MULTITRACK, TRACAR, Amtech, OCTOPUS (DGXIII)	
Read/write tags	MULTITRACK, TRACAR, Amtech, OCTOPUS (DGXIII)	MULTITRACK, TRACAR, Amtech, OCTOPUS (DGXIII)	
Satellite-based	Telespazio, CLS, Technicatome, etc.	Timtec, Rohde&Schwarze, PRECISE IT	
Laser systems		ABB - TA	Framatome
Sensor systems (acoustic,...)		Krupp, Technicatome, PRECISE-IT	Krupp
Degree of accuracy			

Fig. 4.7.2.1: Survey of Identification, Location and Positioning Systems

And, the variety of systems is as wide when looking at technologies used for the transmission of information : GSM or radio frequency technologies, but also infra-red data transmission or world-wide satellite communication systems are well-known.

4.7.2.2 Technologies Evaluation

Given these technologies and their functions, a certain number of them has been chosen to be evaluated by the IMPULSE consortium.

OPERATIONS	***QUALITY***
Cost	***Safety***
Time	***Interoperability***
Operating conditions	***Reliability***
Accuracy	***Security***
Energy supply	***Confidentiality***
Data / frequency	***User qualification***
Integration	***Adaptability***
ISO criteria	***Transition period management***

Fig. 4.7.2.2: Indicators for “Quality of Service”

The first part of the evaluation has been made, taking into account the return of experience of users : these technologies, which have been developed for or adapted to other industrial fields, are currently operating ; they have already been under tests and their features, and notably their limits, are thus completely known.

The second part of the analysis has been made judging these technologies under particular criteria shown in Figure 4.7.2.2 and which can be distributed into two categories, those linked to operations and those more susceptible to represent indicators of quality of service :

At last, these evaluations have been completed through «on-site» tests for particular technologies and applications.

4.7.2.3 Applications Examples

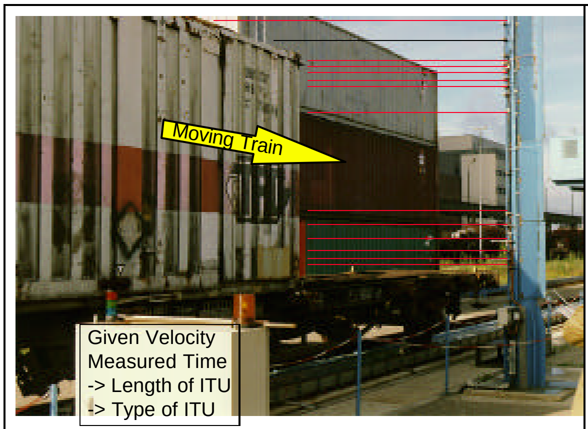


Fig. 4.7.2.3/1: KRUPP FHS «Light Barrier Curtain»

The first example of tested technologies concerns a laser sensors based identification and location system.

The system is composing the *« light barrier curtain »* of the **KRUPP Fast Handling System** and is used to recognise the loading status of the wagon and the position of the ITU.

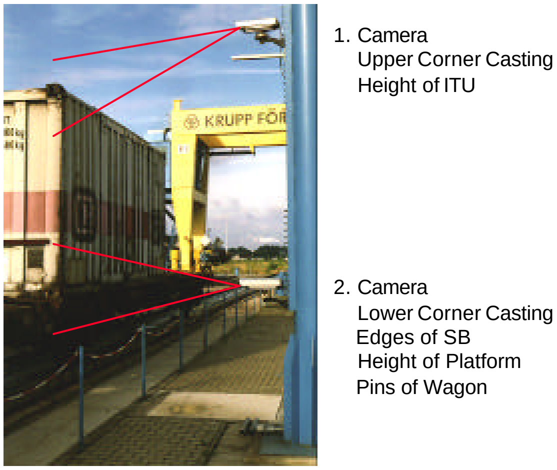


Fig. 4.7.2.3/2: KRUPP FHS «Video Cameras in the Pre-Zone»

Another technological brick of the **KRUPP Fast Handling System** has been carefully evaluated, which consists of a CCD video camera based location system allowing to record the side view of rolling stocks and of ITUs as they pass. The generated data provide reliable information on the position of the gripping points; these information will then be used to create positioning instructions for the handling device.

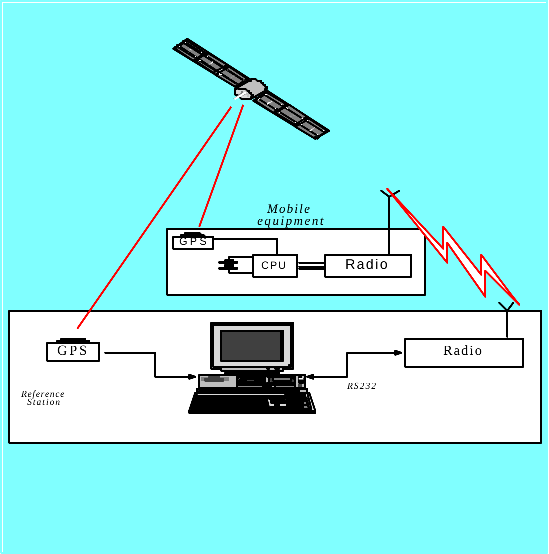


Fig. 4.7.2.3/3: GPS/Radio Based System

The last but not least tested system consists of a GPS and radio based identification and location system, developed by **TECHNICATOME**.

The system consists of a part of autonomously power supplied equipment installed on the mobile object and of a fixed ground station. It is capable of locating and tracking a moving object inside a terminal with a data acquisition time under 2 min. and with a sub-meter accuracy. A tests campaign on the GPS/Radio based prototype system has been set up in the scope of the WP 2.3 in order to evaluate different items such as, **the transmission of information** between the mobile and the ground station, **the GPS technology** and notably, its effective location accuracy and **the energy consumption** of the mobile object

4.7.2.4 Conclusion

The first main result issued from these evaluations can be expressed in this way :

« Technologies allowing cost-effective ILP solutions **are available,**

their performances are known,

and their limits too »

As a consequence, the work to be done is clearly to adapt these technologies to the specific environment and requirements of the user.

And in fact, the first and crucial step to cross over does not concern « technologies' adaptation », but concerns the expression and definition of users' needs.

Defining and expressing needs is not that simple and requires a precise methodology.

Actually, the absence of a global approach is often creating a climate encouraging overstatements and costly, but often useless and not appropriate, technical developments.

In order to fulfil our overall objective which is to obtain an harmonised multi-modal door-to-door transport chain, it is necessary to apply a **« Think global, act local » approach**.

This means enforcing co-ordination and communication between actors and permitting the management of compromises : this will prevent from conflicts and overstatements and will finally allow to harmonise the level of technological integration.

But technically speaking, the work to be done still stays to adapt these technologies.

4.7.3 Technologies Adaptation

Focusing on technologies adaptation and relative tasks, IMPULSE partners have highlighted some considerations and global constraints, directly linked to the intermodal transport environment, and that we have to manage so as to envisage a « smooth » adaptation :

- ***firstly, ILP systems are installed on networks and inside terminals, on moving objects*** ; this implies to take into account notions such as :
    - infrastructure components (satellites, terrestrial facilities)
    - embedded equipment (which implies a strong resistance to harsh environment with stress, vibrations, but also to work under a large range of temperatures, what require a high reliability, availability and safety)
    - energy supply (optimisation of the energy consumption, autonomy and availability)
    - multi-functionality but not necessarily multi-technology
      (this has to be taken into account to ensure a simplification in the required components, which will imply a gain in weight and volumes, and finally lower costs)
    - maintenance's logistic
- ***secondly, ILP systems have to cope with a multi-cultural network, with a myriad of actors from various countries*** ; this implies to ensure :
    - interoperability and possibility for interconnections between systems, norms and national standards
    - management of interface between various local, regional or national norms and standards
    - modular and evolutive systems
    - management of components' and overall systems' life cycles
    - integration of the new system in the existing one, what requires the management of transition periods which can be long.
- ***thirdly, ILP systems are necessarily linked to transmission and communication systems*** ; consequently :
    - data quality has to be ensured (through technological or procedural cross-checking)
      (but a level of reliability and norms relative to that quality have to be fixed)
    - information flows and data stocking have to be managed
    - data treatment has to be elaborated in order to organise them under a defined hierarchy, but also to ensure filtering and ranking process

  - confidentiality (« business interest») and management of access to data have to be guaranteed
  - up-dating, up-grading, maintenance and durability
  - systems cohabitation, notably regarding the interface between manual and automatic (or semi-automatic) systems
- ***and last but not least**, **ILP systems have to present an user interface*** ; this implies to have in mind such notions such as :
  - human factors
  - user friendliness
  - safety
  - working environment (working post and qualification)
  - training
  - maintenance and operation
  - working conditions.

All these limitations or constraints will definitely have an important impact on the specification of the system and on its adaptation.

An obvious conclusion is that there will not be one unique system, but different ones, adapted to specific needs and to a particular environment :

« no unification but interconnections ».

Technologically speaking, these adaptations are possible and difficulties still concern the **expression of the users' needs, which is necessary to elaborate the technical specification**.

4.7.4 Technologies Functions Requirements

(« Needs have to be identified, expressed and even, created... »)

A precise definition of the need is crucial to ensure the service required by the client. During that definition phase, various items have to be managed and the context of integration have to be carefully analysed.

This will begin by a precise evaluation of :

4.7.4.1 User Requirements

(« Who is the user and what does he really want ? »)

Actually, each actor of the transport chain has to precisely define his requirement or expectation. He has to limit his demands to what is really necessary for the smooth running of his process : **the objective is to make it simple, fast and easy** and to allow **« the right people to get the information they need, in the format they want, when they need it ».**

In case the definition of needs is badly realised, it often implies tremendous consequences on the final result, on the final appraisal when regarding costs, milestones and quality of service.

For example, the notion of **real time** is a critical one to cope with ; the user has to define whether the real time degree will be a second, a minute, an hour or a day : different technologies are able to answer to these requirements , but, at varying prices, with different means and on varying time horizons. And this is the same when defining the degree of **accuracy** to be given to a location or positioning system or the **amount of area to be covered**.

Being aware of the user requirements, the point is now to characterise them by some objectives or goals and to quantify these goals.

4.7.4.2 Indicators measuring Interests and Benefits resulting from ILP Systems Implementation

That quantification is not easy to express in a simple way , notably when long terms effects have to be envisaged. Moreover, an ILP system must not be analysed as an isolated technology, but in conjunction with the functions of which it is a part and which it is intended to improve : this makes it really difficult to apprehend resulting global benefits.

But it is clear that ILP solutions will be all the more adapted to the users' needs than their objectives can be quantified.

An other point which has to be taken into consideration when expressing needs deals with culture and history.

4.7.4.3 Culture and History Impact

Needs and the way they are expressed are strongly depending upon the cultural and political environment : what is admitted in a country can be rejected in an other one. And this is the same difference from one profession to another, or from one field to another.

One of the bottleneck to cross over when implementing ILP systems will be to well integrate these notions and to treat them at the interfaces' levels.

One of the most interface to treat is the interface with labour forces, making it necessary to take into account human factors.

4.7.4.4 Human Factors Impact

ILP systems are based on information networks, which are closely implicating human beings. Human factors must be taken into account from the beginning and more particularly during the definition of needs and their expression : the chosen system will actually have to be accepted by the concerned segment of users.

A « smooth » way to render him as acceptable as possible is to define it as a support tool for workers, who will consequently keep their essential role of decision, that is, their « know-how ». The objective must be to enhance the standing of human being, by making people in charge of expert tasks and ILP systems in charge of repetitive or risky ones.

4.7.4.5 Organisation and Procedures Impact

Above all, the implementation of ILP systems is implicating a modification of existing organisation and procedures.

Consequently and in order to fulfil our objective, which is to use ILP systems and the benefits they create in the best way at each level of the transport chain, it is crucial to measure the impact that these modifications will have and to integrate this measurement in the needs expression process : in this way, the required adaptation will be as acceptable as possible.

4.7.4.6 Financial Plan

The financing is often an obstacle making investor not able to have a global view of the problem. The expression of needs has to be compatible with the entire life of the product: actually, the required investment and the exploitation cost are often not suitable with the effective budget of the user. To avoid this, investments and exploitation costs have to be considered on a same level : the notion of a « global exploitation cost» must be envisaged, what implies important reforms as regards of the financial structure (and notably regarding the debate between private and public funds).

4.7.4.7 LCC Approach

A way to implement these financial modifications could be to spread the use of a « Life Cycle Cost » approach to express and define the user’s needs : taking into account the entire life of the product, this approach will allow to harmonise the systems integration, according to an optimised cost.

4.7.4.8 «Create the Need»

The creation of needs which are initially not expressed can be envisaged : that approach, **« create the need »**, can accelerate the decision process and facilitate the centring of objectives. This is particularly true when rules, norms or political decisions have to be applied but also when regarding the potential expansion (the eventual spreading) of the application : actually, the annex or adjacent use of data acquired through ILP systems, and the utilisation of their technical supports, can improve such activities as **maintenance policy and strategy** (e.g. optical system can establish a diagnosis concerning the ITU, i.e. « damaged or not ») or **exploitation** (« ILP acts as a support tool for operators... »), but also **logistics services** and their flexibility (equipment allocations and movements’ anticipation,...).

4.7.5 Technologies Implementation

4.7.5.1 Implementation Approach

Taking into consideration all these recommendations on needs expression, the point is now to integrate these systems : this integration phase is often rather long and whimsical and must be carefully managed in order to avoid over-costs and delays.

One of the most critical consequence of ILP systems integration concerns its impact on organisation and procedures : that integration implies the management of the coexistence of two systems and will often lead to « mix » two types of organisations and procedures, what can be very badly perceived by workers and very difficult to process. To break free from this bottleneck, **synergies between technologies, procedures and organisation have to be ensured** <u>during the specification and implementation phases</u>.

These synergies will allow to obtain different scenarios of ILP systems integration which will be differentiated by their dedicated users and by the varied temporal and financial horizons they imply.

4.7.5.2 Implementation Plans

These implementation plans have been elaborated taking into account terminals and their interfaces with transport networks ; as we reminded it before, these plans are results issued from a <u>global approach, taking into account the overall transport chain</u>.

Here, some implementation plans are presented regarding the situation of the receiver, the chronological issues and the type of technology :

		Market	Short terms	Long terms	Opportunities	Approach
EXISTING SITE	I	Existing Trans European Network (TEN)	?		if possible	Integration of the new technologies STEP by STEP
	L			?	if possible	
	P		?		if possible	Technological bricks
SITE TO BE CREATED	I	New TEN + Pan European Network (PEN)		?	mandatory	Last technology interconnected with the existing surrounding network
	L			?	mandatory	
	P			?	mandatory	Integrated system

Fig. 4.7.5.2: Implementation Plan for Identification (I), Location (L) and Positioning (P) Techniques

The first type of integration will occur **ON EXISTING SITE** . In this case of **« conventional evolution »**, the point will be to proceed slightly, step by step, integrating technological bricks which will not lead to fundamental changes in organisation nor procedures and for which a low investment cost is required (or with a rapid « feed-back »).

The second type of integration can happen **ON SITE TO BE CREATED** : in this case, the opportunity has to be grasped to implement a technological and cultural jump, even if it's clear that the time needed to take the decision and to install the system will be longer . But futuristic ideas must be envisaged : the consequence will be a « **conceptual evolution** », implying huge changes in organisation and procedures but allowing to harmonise the integration strategy.

We can highlight two markets which could be targeted :

?? *Western Europe*, within the framework of trans-European networks re-planning

?? *Eastern Europe and developing countries*, so as to anticipate an « eventual » joining toward western networks.

4.7.6 Conclusion

We can obviously say that technologies are available and adaptable to the customer's needs. This implies first that needs have to be expressed, that is, that needs have already and accurately been defined. That expression of the needs must moreover be made taking into account a high level of integration : a system must not be seen as a stand-alone way to realise a function, but as a part of a global process, allowing quality improvements and which is completely integrated in the conventional operational chain. A kind of credo : **« Think global, act local »** must be pursued.

To allow a smooth integration of these systems, various parameters will definitely have to be taken into account and carefully managed. And human factors is the most crucial of them.

ILP systems integration must be defined so as to be simple, and notably information sent by these kind of systems have to be carefully evaluated and managed, that is, filtered or ranked, so as to transmit information tailored to users' needs : in fact, **« just what they need to know »**.

In this way, information will be available and communication easy and possible : because,

if **« information is good, communication is better »**.

It's obvious that a specific but global methodology must be applied, which will allow to obtain **synergies between technological developments and organisation and procedures, optimising quality and accessibility criteria.**

4.8 ADVANCED HANDLING - TRANSHIPMENT, INTERNAL TRANSPORT AND STORAGE (WP 2.4)

The works which are summarised in the following, have technically been co-ordinated by Framatome (Workpackage Leader). Krupp, ERRI and Costamasnaga have contributed.

4.8.1 Introduction

The aim of the proposed work plan was to define and test new features required to increase the robustness of automated handling equipment, ensuring that it operates at maximum effectiveness, thereby increasing the overall efficiency of intermodal terminals.

If automation is to be introduced with an optimum safety and success rate, installations must be capable of dealing with handling operations where it is extremely rare for two successive operations to be the same; different types of ITU, different types of wagon, site data different from that allowed for in the management system (e.g. position or number of ITUs on the wagon), data that varies over a wide range (e.g. angle of inclination of the framework of the truck), etc. It is still essential for the handling crane (once correctly positioned) to be able to configure itself correctly for each particular handling case and for the mechanical behaviour of the crane (both static and dynamic) to be controlled during the operation.

The research programme addressed a number of coherent themes and work areas required to improve or increase robustness of automated handling.

The most commonly encountered requirements for automation are :

- Increasing market volume on intermodal terminals
- Improvements of terminal organisation in terms of
  Transhipment rail - road and rail - rail,
  intermediate buffer,
  depot,
  storage
  sorting
- Enlarged and flexible opening hours and short staying times of trains and trucks
- Improved Utilisation of equipment
- Optimal placing in gravity zone (logistics)
- Improved personnel safety
- Increased environmental awareness (space, noise)

The basic technologies (technological bricks) available for innovative terminal design have been studied. These technological bricks are divided into seven groups :

- The first group comprises the identification/location systems for world-wide tracking and tracing (A1),
- The second group consists of handling equipment

- The third group includes the anti-sway systems, the semiautomatic equipment control systems
- The fourth group comprises technologies to speed up train access in the terminal.
- The fifth group includes the in-cabin screen-based communication systems and the EDI-based information systems for terminal pre-planning
- The sixth group deals with stackable ITUs.
- The last group contains rolling stock related technological bricks

A1	**Identification/location systems for world-wide tracking and tracing**
A2	**ITU based identification systems within the terminal**
A3	**Stand alone identification systems witin the terminal**
A4	**Location systems within the terminal**
B1	**Reach stackers / fork lifters**
B2	**Gantry cranes on pneumatic tyres**
B3	**Rail mounted gantry cranes**
B41	**Krupp automatic fast handling equipment – basic**
B42	**Krupp automatic fast handling equipment – single area variant**
B5	**Automatic fast handling equipment – Commutor concept**
C1	**Anti-sway systems**
C2	**Semiautomatic equipment control**
C3	**Cabin disconnected from the spreader**
C4	**Robot for wagon pins change**
D1	**Use a slewing catenary on the loading track**
D2	**Allowing the train to coast from main line into position with momentum**
D3	**Special handling equipment that can load/unload under the catenary**
E1	**In cabin screen-based communication systems**
E2	**EDI based information systems for terminal pre-planning**
F1	**Stackable ITUs**
G1	**Wagons with automatic pins adjustment/locking**
G2	**Groups of wagons permanently coupled with an automatic coupling at each end**
G3	**One cabin at each train end enabling bi-directional movement**
G4	**Fixed train configuration using the same wagon types**
G5	**New wagons for all ITU types (Kombiverkehr wagon)**
G6	**Automatic train coupling**
G7	**Self-propelled wagon groups**

Fig. 4.8.1: Technological Bricks

On the context of the IMPULSE project we have focused our attention on some of these innovative features :

- The overview and analysis of the automated or semi-automated transshipment systems under test in Europe,
- The definition and test of a laser sensor based system allowing automated loading and unloading operations
- The study of anti-sway systems : the different technological solutions, their advantages and drawbacks
- The exploitation of the KRUPP's fast handling plant for testing technological solutions for advanced handling operations.

4.8.2 Transhipment Systems

Despite the relatively high performance of the conventional cranes, there are many situations in which the market requirements impose significantly higher standards.

Demand for faster service also exists in small and medium stations, serving liner trains, which make intermediate stops for transhipment of loads.

In addition to accelerating the transhipment procedures, it is necessary to automate them, in order to reduce operational costs and to increase efficiency and labour utilisation rates.

Pilot applications have been developed and proved that many aspects of the transhipment chain can be automated. Some not solved problems remain, but they are in continuous progress .

These technologies are show in Figure 4.8.2.

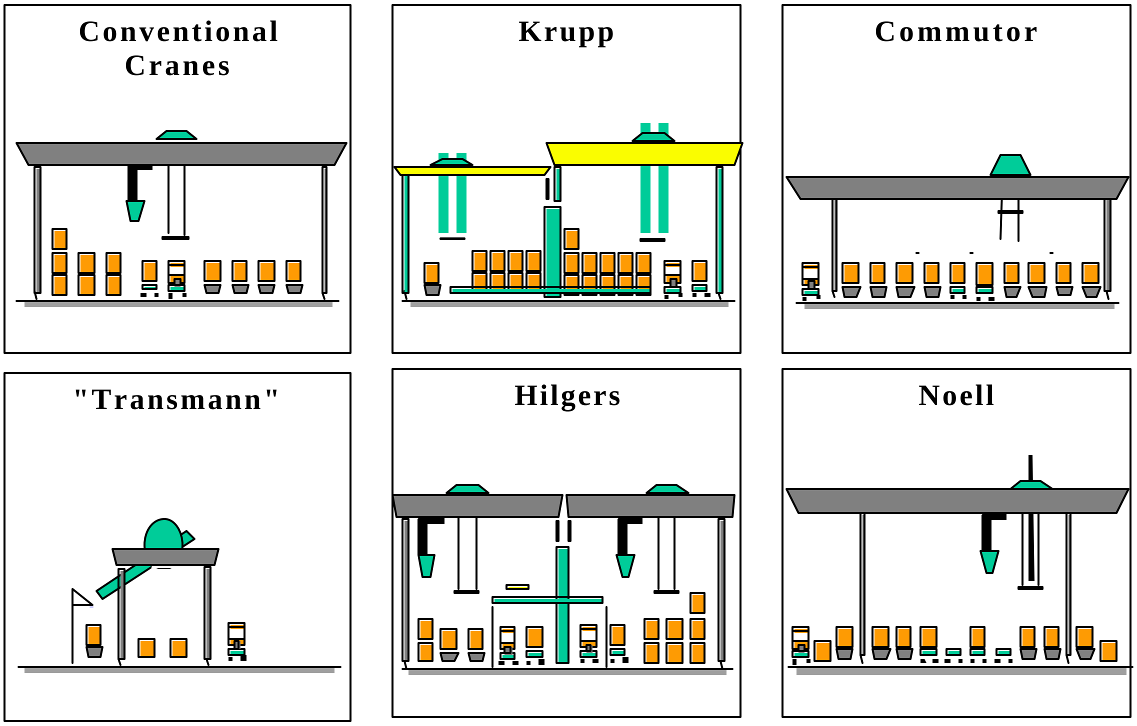


Fig. 4.8.2: Transhipment Systems (Overview)

Krupp technology : The main difference between the Krupp fast handling system and all other systems is that transhipment is undertaken from a slowly moving train. The system works fully automatically

Automated transhipment between trains (Technicatome and Preussag Noell) : Automated train-train transhipment systems are represented by two pilot applications, the first developed by Technicatome, the second by Preussag Noell. Both systems can be used at mega-hubs, especially during night shifts.

The Technicatome Commutor system was designed for a hub railway station with nine tracks, each capable of receiving seven trains of 33 wagons per day (the system operates 14 hours/day). The system comprises two additional tracks for the shuttles; one additional railway track and ten buffer lines (330 places). There are 33 cranes, moving perpendicular to the railway tracks. Each crane runs over nine wagons, ten buffer places and the two shuttle tracks. The shuttles allow the ITU to be moved longitudinally to the trains.

The Commutor 2 system is designed for rail-rail and rail-road transhipment and can operate on wagons of different designs and different lengths. .

Transmann system : Mannesmann Transmodal, now renamed Dematic, has developed a rail-borne, fully hydraulic transhipment device called Transmann, which can handle containers and swap bodies underneath the overhead line. The system is operated semi or fully automatically.

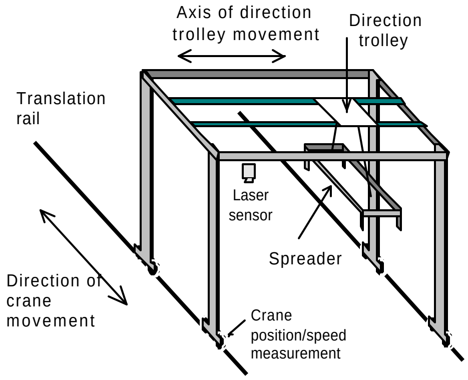
Hilgers technology : The German company Hilgers offers a solution using two parallel craneways with a shared raised craneway between them.

4.8.3 System Architecture 2D-Laser Scanner

One of the technological brick tested on the IMPULSE contest concerns "The Laser Scan system" which uses lasers in conjunction with computer processing to obtain an overview of wagons and load units.

To perform automation the crane has to be sure that the good object to be handled (planned by the management system) is on the good position and that the good destination object (truck or wagon) is also at the good position

The principle involves acquiring a 2D image of ITUs and platforms using a sensor on the crane frame. The image is generated from the sensor scan; as the crane moves along the crane track, the sensor can execute a total scan of the area below the crane. Information on target size and position is extracted from this image by means of geometric operators (pattern recognition).



Real-time information on:

- Type and status of wagon
- Type of wagon and height control
- Type, status and orientation of lorries
- Status of storage area
- Undefined objects warning

Fig. 4.8.3/1: “Configuration Setting Module”

Extensive practical tests have been carried out. Here we can see how the system identifies and recognises , in the first view, a lorry (shape, position, orientation, cabin position, …, and state) and in the second view, a wagon and a container. The data are made available for the crane pilot (human, or automated system) to allow him to give the best configuration to the spreader for loading or unloading operation

Fig. 4.8.3/2: *Picture and Scanned Image of an Empty Lorry with Semi-Trailer*

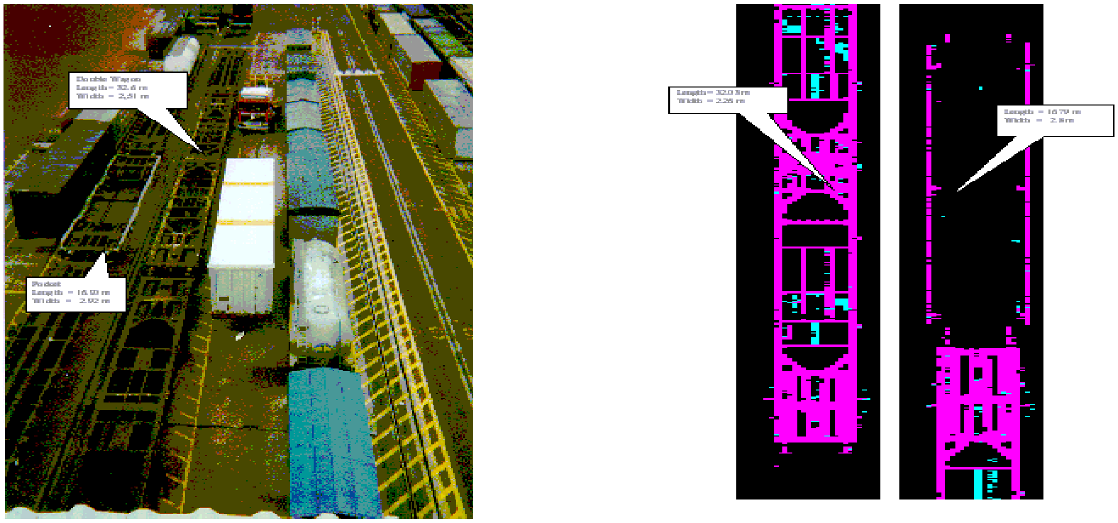


Fig. 4.8.3/3: *Picture and Scanned Image of Trailer and Wagon*

4.8.4 Anti-sway Systems

An anti-sway system is required, to prevent secondary motion (sway) that could affect the operation of the crane.

The anti-sway system becomes necessary when the relative speed of the lifting module with the spreader becomes high with respect to the crane. This may be due to various factors (high speed handling or aerodynamic forces).

For automatic handling, in particular, precise principal movements are essential, regardless of secondary movements.

Anti-sway devices fall into three classes:

.A rope anti-sway system, implemented in different ways on different cranes, with the ropes arranged in a variety of manners (diagonally inside the spreader perimeter, or outside the spreader perimeter). This is the most common solution.

.A system of vertical mechanical guides on the crane and on the lifting apparatus that guide the movement. An example of this is the Transmann.

.A system of articulated beams connecting the crane with the lifting apparatus in order to limit secondary movement without limiting the principal movement. This is the approach adopted by, for instance, the Nelcon cranes in the Rotterdam ECT terminal.

4.8.5 The Krupp Fast Handling System

The Pilot Installation at Duisburg-Rheinhausen composes of one rail track, cross conveyor, storage lanes and lorry service place.

Besides the unloading and loading of moving trains to and from the cross conveyor, service of the storage area was demonstrated.

The following tasks are possible on the test site:

?? Indirect transhipment via cross conveyor

?? Direct transhipment to and from train

?? Placing in storage locations (ground slots)

?? Stacking ISO containers two-high

?? Placing swap bodies on their legs and semi-trailers on their rests

Fig. 4.8.5/1: Krupp Fast Handling System – Pilot Plant in Duisburg

Other technical components are :

- ?? The identification and location system in the pre-zone as well as two alternative measuring systems along the track.
- ?? The semi-portal crane moves on a craneway which is only 56m long.
- ?? By means of the rigid hoisting mechanism it is possible to handle all kind of standardised ITU and intermodal wagon in use in Europe.

Extensive practical test carried out during the IMPULSE Project have shown the technical feasibility of the components and the whole system.

Amongst others - the automatic unloading of a complete semi-trailer from the moving train could be shown as well as the automatic storage of swap bodies in the storage area of the plant.

Fig. 4.8.5/2: Automated Unloading of a Semi-Trailer

Fig. 4.8.5/3: Automated Service of Storage Area from Moving Train

These demonstration were done in different environmental and operational conditions resulting in measured handling times of about 65 seconds in average.

The experience gained will lead to further reduction in conjunction with future plants.

The handling device is structurally and dynamically designed to carry out orders from the central material flow unit automatically and in short time with high accuracy and reliability.

4.8.6 Conclusions for Future Systems and Application

The safety and productivity gains from the use of semi-automatic control are clear, which makes operators positive about investing in these technologies.

There are, however, some restrictions:

?? Implementation of these technologies has to take the human factor into account. In other words, they should be implemented where real benefit can be derived *now*. In order to derive real benefit, social acceptance has to be ensured.

?? These technologies have to be implemented in accordance with operating modes

?? It appears difficult to use this kind of technology anywhere other than in a terminal with a high capacity/throughput

The conclusion is that these systems can significantly increase the productivity of handling operations, but that their integration presents some constraints.

4.9 MODIFICATION OF ROLLING STOCK (WP 2.5)

The works which are summarised in the following, have technically been co-ordinated by Costamasnaga (Workpackage Leader). Krupp, ERRI and Technicatome have contributed.

4.9.1 Objectives

The objective of this Workpackage is to demonstrate the extent to which transhipment efficiency can be improved by using a wagon developed/modified specifically for new automated transhipment plants.

The main goal is to obtain optimum use from the railway vehicle fleet (rolling stock), including modifications to existing wagons, to meet the requirements of new terminal concepts and production forms resulting from the demands of automated service.

New forms of train construction and the new intermodal Trans-European Network with high-speed freight trains are having an influence on the design of new wagons.

Automated operations require easy and safe fastening of ITUs to wagons so that manual operations that limit the efficiency of automated transhipment can be avoided.

Automated operations require the precise positioning of wagons in relation to the loading equipment. This is a further aspect that can be significantly enhanced by mounting special devices on the wagons and by identifying the wagons.

Automated equipment requires the precise identification of the loading position on the wagon and this can be obtained by making specific adaptations to the wagons.

The main objective is to re-design wagon components to improve or solve the problems described above. A new design of fastening system is a particular requirement, together with other improvements to load/wagon interfaces. The introduction of new solutions is a further option.

4.9.2 Activities and Technical Approach

This Workpackage consists of the following work steps performed by the partners involved in the project:

1. Analysis and specification of wagon requirements
2. Study of the interfaces between wagon and transhipment system
3. Design of prototypes
4. Construction of prototypes
5. Tests at pilot installations

4.9.2.1 Analysis and Specification of Wagon Requirements

The object of this work step was to produce technical specifications for wagons and to plan test activities at the selected sites. This formed the basis for the subsequent work steps.

Starting with the requirements identified in the previous Workpackages, checks and studies were undertaken to obtain preliminary wagon specifications.

These specifications contain all performance requirements specific to the railways, but particular attention was given to the loading interfaces (height and dimensions of the platforms, fastening characteristics, positioning of the wagon in automatic transhipment equipment and wagon interfacing with transhipment equipment).

Parallel activities were carried out relating to the analysis and development of new concepts for identification and positioning (derived from other Workpackages) and analysis of fastening devices.

The following data was produced for the purpose of improving the interfacing between wagon and ITU, both in service and in transhipment terminals:

?? Inventory of fastenings in use today
?? Study of defined fastening parameters
?? Evaluation of performance obtained with fastenings used today
?? Performance of fastenings required by automated equipment

To achieve a complete definition of the wagon/load interface, a study of the possible positions of load units should result in the provision of loading surface dimensions (height, width and length). This data can be used to define basic wagon dimensions.

The technical specification was completed using the data from the previous work step which formed the basis of the design, manufacturing and testing activities.

Appropriate contacts and meetings with the main intermodal operators were planned in order to verify the specification requirements.

4.9.2.2 Design of Prototypes

The object of this work step was the drafting and preparation of drawings for new and modified wagons.

Work steps were completed to obtain the following necessary material:

- Preliminary drawings
- General calculations of structures and mechanical components
- Executive drawings
- Calculations and documents for approval
- Procurement and manufacturing documents

4.9.2.3 Construction of Prototypes

The prototypes were produced in this work step.

Rules and methods in accordance with ISO 9001 standards were applied for the construction of prototypes.

Registration or registration modifications were obtained.

Inspections and acceptance testing were carried out before the vehicles were admitted to service.

4.9.2.4 Tests at Pilot Installations

The object of this work step was to carry out loading and unloading tests at the selected sites, in all operating conditions.

The complete test plan was executed subsequent to the identification of specification requirements for tests to verify functionality, safety and efficiency of transhipment operations. The data obtained from these tests was used to verify the correspondence of prototype performance with the requirements indicated in the specification.

With reference to more specific railway characteristics, performance details were derived strictly from railway experience rather than tests. The values were verified by transporting load units between two test sites.

4.9.3 Technical Specification for Test Wagons

4.9.3.1 Technical Overview of Wagons

The efficiency of an automatic transhipment system can be increased if wagons specially adapted to operate in automatic terminals are available and have been developed in close co-operation with the same system.

Owing to the differences between terminals (most are not yet automatic), innovative wagons must be apt to operate equally well in terminals with low automation and manual operation.

The shape of wagons apt to operate in different terminals is linked also to the solutions adopted for fixing ITUs.

The work was therefore conducted in four different fields of activity:

- Analysis of existing fixing solutions for ITUs
- Analysis of existing intermodal wagons

- Analysis of future intermodal wagons
- Analysis of innovative solutions for ITUs

4.9.3.2 Definition of Technical Requirements for Wagons

Costamasnaga decided to modify three wagons (Low-floor type, for 20’ and 40’ containers, as shown in Table 1) with different solutions to load and fix ITUs.

The three wagons were identified using code numbers 111, 222 and 333.

Wagon No. 111 – Transversal Locking at two fixing points

This wagon was equipped with six guides (four at the corners and two in the middle).

Four fixing points for ITUs were provided at the four corners, as indicated in Table 2, so that the 20’ ITU can be transported fixed at two points only, while the 40’ ITU is fixed using the conventional four points.

This solution provides lateral pins that are currently being operated manually by means of a longitudinal bolt to latch and unlock these pins.

This system can be easily automated in the future.

Evaluation:

- Relatively cheap mechanical technique
- The technical guides for lateral and longitudinal guiding of the ITU must on principle be designed for a specific width. The wagon has been equipped with a 2.44 m span for ISO containers.
- Unlocking for loading must be done manually, an alternative solution drafted during the meeting would avoid this, but this requires a terminal-based system to perform the actions.
- The principle of lateral locking is limited to the lower corner castings of ISO containers, whereas the side wall of lower corner castings of all other types of ITU do not have standardised holes.
- Wagon impacts during transport could jam the ITU against the fixing tool and hamper manual unlocking without the aid of a lifting device
- The yellow block should be modified (narrower, nose with chamfer) for easier access to the opening
- Owing to the limitations referred to, the application of this principle is very restricted

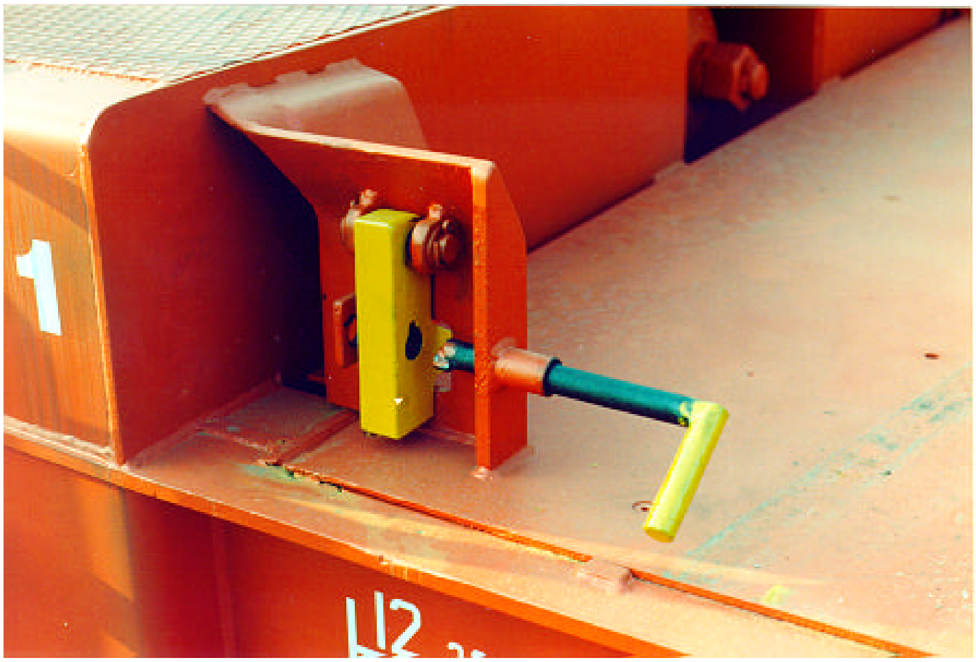


Fig. 4.9.3.2/1: Detail of Modified Wagon 111 – Transversal Locking

Fig. 4.9.3.2/2: Modified Wagon 111

Wagon No. 222 – Fixed Pins

This wagon was equipped with two guides in the middle and four turntable twist locks at the corners. This solution was provided to establish whether conventional or automatic transhipment systems develop problems during loading operations with only two points for centring ITUs on the wagon.

The twist locks can be placed in a transverse pocket by manual rotation by 90°.

Evaluation:

?? One pair of pins per ITU and lateral guides without further locking are not acceptable from a safety point of view on the railways.

Fig. 4.9.3.2/3: Modified Wagon 222

Fig. 4.9.3.2/4: Detail of Modified Wagon 222

Wagon No. 333 – Additional Frame with Vertical Twist Locking

This wagon was equipped with an additional frame with an innovative system to secure the ITU using two pivoting twist locks.

The pivoting movement is supplied by a system of levers on the frame (Tables 6, 7 and 8), and the command comes from a single contact between two fixed lateral guides beside the track and the respective frame.

Evaluation:

?? Mechanical solution that does not require an on-board medium (air, electricity,...)

?? Mechanical link between two sides of a wagon can be avoided if both sides are approached from the side inside the terminal

?? A mandatory requirement is that the width of the wagon including its frame should remain inside the profile. It has therefore been proposed to change the mechanism into push-to-lock or contractory spring (for transport) and pull-to-unlock (for loading).

?? A terminal-based selection device “switch” to pull individual pairs of twist locks for locking was proposed during the discussion.

?? Safety ensured by two twist locks per ITU

?? Separate control of each pair of twist locks necessary

?? Control of locking and gauge conformity after transhipment

?? Load model with 40’ wagon possible (1x40’, 2x20’, 2x7.82 SB)

?? Load model with 60’ wagon requires a “central” pair of twist locks which could be removed for loading with 40’

The tests conducted at Costamasnaga showed that an additional device needs to be fitted to the wagon for the purpose of handling the system in cases where the zone in which the wagon is unloaded does not have the required lateral guides.

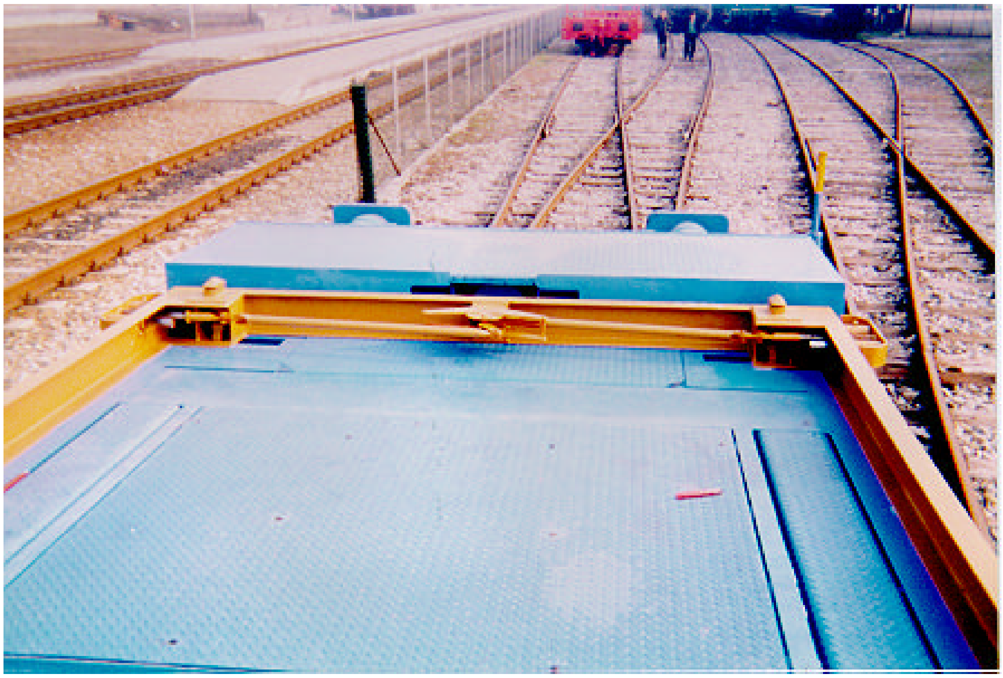


Fig. 4.9.3.2/5: Additional Frame on Wagon 333

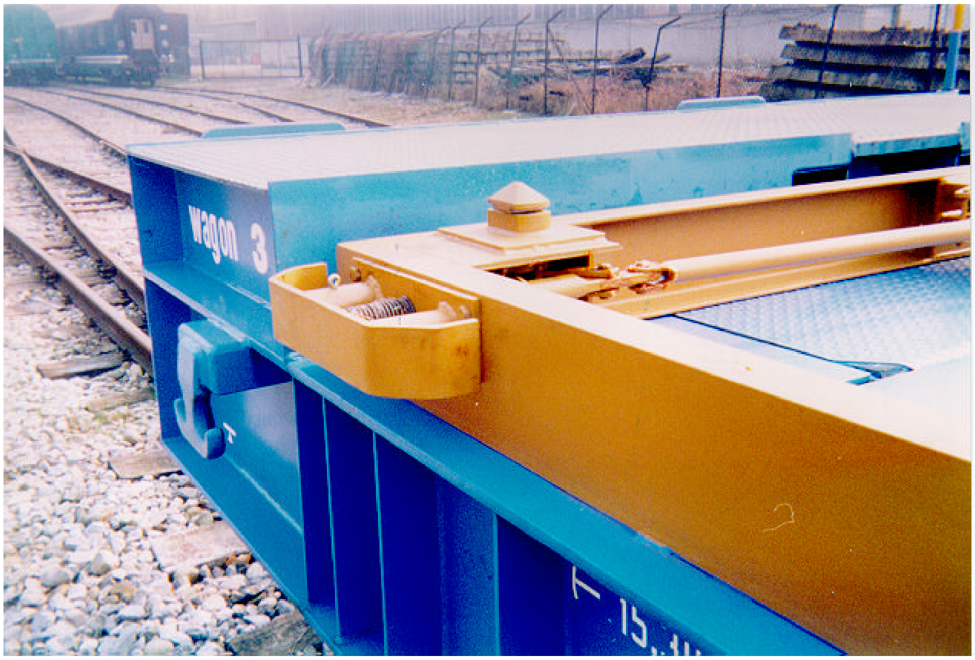


Fig. 4.9.3.2/6: Lower Twist Lock with Levers on Wagon 333

4.9.4 Test Results in Conventional Terminal

The following operations were executed on wagons bearing the identification numbers 111, 222 and 333:

1. Loading of first 20’ container
2. Loading of second 20’ container
3. Unloading of first 20’ container
4. Unloading of second 20’ container
5. Loading of 40’ container
6. Unloading of 40’ container

Wagon No. 111 and 222

Fig. 4.9.4/1: Loading Wagon 111 with 20’ Container by Fork Lift Truck

The opinion of the operator is that the guides provided in the middle of the wagon help to centre the ITU on the wagon. Moreover, the presence of only two pins is not a problem.

Fig. 4.9.4/2: Loading Wagon 222 with 20' Container by Reach Stacker

Wagon No. 333

The opinion of the operator is that the twist locks provided on the test wagons (different from the common pivoting twist locks used on most intermodal wagons) eliminate the frequent phenomenon of intermittent lifting of the ITU together with the wagon.

4.9.5 Test Results in Automatic Terminal

The following operations were executed on the wagons with identification numbers 111, 222 and 333,:

1. Loading of first 20' container
2. Loading of second 20' container
3. Unloading of first 20' container
4. Unloading of second 20' container
5. Loading of 40' container
6. Unloading of 40' container

Wagon No. 111

The wagon requires an area where the opening operations (removing the lateral pins manually) can be performed.

Fig. 4.9.5/1: Loading 40' Container on Wagon 111 in Automated Terminal

Fig. 4.9.5/2: Unloading Wagon 111 in Automated Terminal

Wagon No. 222 and wagon No. 333

No difficulties encountered.

Fig. 4.9.5/3: Wagon 222 in Automated Terminal

4.9.6 Conclusions

The number, type-diversity and age of the current intermodal fleet is decisive in the search for new solutions for wagons due to the long life and thus lengthy depreciation time of the equipment. For at least one generation, totally new wagons and conventional wagons will operational in parallel on the track and in the terminals. In view of this background conditions, the aim has been to propose technical measures to modify the wagon / ITU interfacing rather than to develop completely new types of wagon.

A further requirement is the capacity to operate with modified wagon in both conventional/manual and innovative/automated terminals. Therefore test have been performed in both types of terminals.

The requirement is to transport all kinds of ITU, such as ISO and inland containers and swap bodies. Standardisation of ITUs in particular those parts that represent the interfaces with the load surface have been based on UIC leaflet 571-4.

Standardisation of the corner fittings, i.e. the dimensions and their tolerances, allows the use of vertical pins only. The openings in the vertical walls cannot be used to secure ITUs. The non-uniform shape of the bottom frame of an ITU, especially in terms of width, reduces the number of guiding and fixing solutions.

The shape of the lower corner castings, which is standardised for all ITUs with respect to the down-side, would indicate that a solution could be a fixing mechanism actuated form underneath. The specific shape of the UIC pin in conjunction with four pins per ITU and the tolerances of the bottom corner casting allows the safe fixing of empty ITUs in all operating conditions. However, flexibility to accommodate different combinations of ITU requires a large number of pin positions per wagon and modification to the current load model. This can cause multiple problems for automated adjustment both from inside and outside the wagon.

A reduction can only be achieved by locking the ITU using two pins per ITU, so that safe operation during the main haul is guaranteed. All solutions must be base on pins as per UIC leaflet 571-4. The locking mechanism may correspond to familiar and accepted road-side twist locks. They are activated either by means of an additional medium on board the wagon (air pressure, hydraulics, electric motors) or by forces from outside the wagon installed in the terminals. The first principle requires completely new wagon design equipping each wagon with additional technologies and control units. These solutions increase the investment and maintenance cost for wagon. They can be introduces on in conjunction with a BUS system linking all the wagons and the locomotive together. The second principle requires mechanical installations in the terminal. Whichever is chosen, safe and error-free locking must be guaranteed for consignment within the limits of the structure/loading gauge during transport.

The general specifications for such a system have been outlined and successfully tested in the framework of the Project.

The innovative wagon for the intermodal transport has the following characteristics:

- A mechanical solution not requiring a medium (air, electricity,...) on board the wagon
- A mechanical link between two sides of the wagon can be avoided if both sides are accessed from the side inside the terminal
- It is mandatory that the width of the wagon including its frame must remain inside the profile. It has therefore been proposed to change the mechanism into: push-to-lock or contracting spring (for transport) and pull-to-unlock (for loading).
- A terminal-based selection device “switch” to operate individual pairs of twist locks for unlocking was set out during the discussion.
- Security is ensured by two twist locks per ITU
- Separate control of each pair of twist locks is necessary
- Control of locking and gauge conformity after transhipment
- Load model 40’ wagon possible (1x40’, 2x20’, 2x7.82 SB)
- Load model 60’ wagon requires a “central” pair of twist locks which could be put out of service to be loaded with 40’

An analysis of the wagon characteristics with their respective advantages and shortcomings suggests that solutions incorporating vertical locking by means of twist locks represent the most promising method.

Due to the number of wagons and their complexity, a mechanical solution on the wagon plus an additional device in the terminals to initiate locking/unlocking shall be considered in future research work.

Adaptability to all standard ITUs and conformity in the area of railway safety and gauges are important factors governing design concepts.

4.10 WORKING CONDITIONS IN AUTOMATED TERMINALS (WP 2.6)

The works which are summarised in the following, have technically been co-ordinated by ERRI/DB AG (Workpackage Leader). Krupp and Euretitalia have contributed.

4.10.1 Aim of the Investigations

In intermodal traffic, the terminals are the connecting link between the modes of transport involved in intermodal traffic. The technical configuration of the terminals and the organisation of operational management, which have a considerable impact on the efficiency of the transport chain, are influenced to a significant degree by the rules to be observed with regard to the safety and health protection of the staff working in the terminal.

The aim of the study in WP 2.6 was to determine on the basis of the safety rules in force in existing modern transhipment facilities what measures have to be provided for with regard to the safety of the staff in advanced transhipment facilities with innovative technologies.

4.10.2 Volume and Structure of the Investigations Performed

At the outset of the investigations concerning WP 2.6, the Working Group established that the regulations in the individual countries concerning occupational safety and health protection are very extensive and that it would be beyond the scope of the investigations concerning WP 2.6 to analyse all of the regulations with regard to their applicability for intermodal traffic transhipment facilities. For that reason, it was decided only to deal with labour protection rules for fully or partly automated transhipment facilities. Since, however, also existing safety rules have recently been subject to reconsideration on account of organisational alterations at DB AG, it was not possible fully to adhere to this procedure. Consideration was therefore also given to rules which, although being new, can also be applied to conventional transhipment terminals.

The measures concerning labour protection for the staff but also safety for the cargo entrusted by the client in an intermodal traffic transhipment terminal fundamentally concern three areas:

a) the measures concerning the protection of the staff at the man/machine interfaces:
This includes the configuration of the workplace as a preventative measure to avoid or to minimise a safety risk and the establishment of rules of conduct for performing certain functions or agreeing on specific procedures for this purpose.

b) sufficient safety of the technical installations and equipment employed in the transhipment terminal:
For this purpose, the recognised technical rules - that is European and national standards/directives - with a preventative character must be observed by the manufacturer as well as by the party ordering. They eliminate or reduce the risk of hazard to the staff by technical means and this is to be given fundamental preference to stipulating measures.

c) the necessary precautions in order to ensure unrestricted access for the fire brigade or emergency services to the scene of the danger or accident in cases of emergency (e.g. fire, injuries): emergency case management.

4.10.3 The Directive of the Council of the European Communities Regarding Occupational Safety

The "Directive of the Council concerning the Implementation of Measures for Improving the Safety and Health Protection of Employees at Work" (89/391/EEC) was published in the Federal Republic of Germany in the Official Journal No. L 183 dated 29.06.1989.

The investigations showed that the Member Countries have enacted the necessary legal and administrative regulations in the meantime in order to comply with Article 18 of this Directive of the Council.

Section II of the Directive of the Council of the EC deals with the measures for the protection of employees at the man/machine interfaces (according to paragraph 2a of this summery).

Article 6, Sub-Section 2e, of the Directive of the Council of the EC deals with the regulations for sufficient safety of the technical installations and equipment (according to paragraph 2b of this summery) used in the transhipment terminal.

Article 8 of the Directive of the Council of the EC deals with emergency case management, i.e. the precautions required in order to be able to implement the relevant emergency measures in emergency cases (paragraph 2c of this summery).

In the meantime, it is evident that there is extensive harmonisation on the basis of the Directives of the Council of the European Communities 89/391 with regard to the minimum requirements for the safety of employees at the railways DB AG, SNCF and FS involved in the project. In all of the countries, a so-called occupational safety committee is to be set up by the operators with a large number of employees and is to comprise

?? the employer or a representative commissioned by him/her,
?? members of the company appointed by the works council,
?? members versed in law,
?? labour doctors and
?? labour inspectors (safety engineers).

The function of these occupational safety committees is to discuss concerns of labour protection and accident prevention and to submit proposals for improving occupational safety to the operator.

The organisation of occupational safety and health protection is similar in the countries of the railways involved in the project. Apart from the ministries of labour and health, the so-called national accident insurance funds play a major role in this connection.

On the basis of national legislation, which in turn takes the directives of the Council of the European Communities for the safety and health protection of employees into consideration, all of the railways have prepared or are preparing codes of practice for occupational safety for their transhipment terminals.

There are, however, noticeable differences in the safety rules themselves between the different railways. In the SNCF and FS terminals, staff is not permitted to remain under the crane. For the DB AG area, the Railway Accident Fund (EUK) has stipulated that, in the case of program-controlled cranes, working and traffic areas must be safeguarded in such a manner for protection against being hit and the dropping of loads that persons cannot be injured either by the crane movement or by falling loads. In supplement to this, special safety regulations apply to cranes. According to the stipulations of Sub-Section b) of Section 2, the risk for staff working in the terminal is significantly lower when additional safety measures on the crane are implemented to avoid hazards instead of providing regulations of conduct alone for this risk area.

There are also deviations on the various railways with regard to the configuration of the workplaces in the transhipment terminals. For example, there are differences in the distances between tracks which are to be provided for working paths between the tracks.

4.10.4 Occupational Safety at the Man/Machine Interface in Intermodal Transhipment Terminals

Objective and purpose of automation are to

- reduce the number of staff and
- speed up the work process with high reliability. (Automated transhipment facilities are therefore also known as "rapid-handling facilities" among specialists).

The elimination of the employment of staff by automation avoids the risk of accident for the relevant function and thus there is a lower necessity for providing regulations. With the exception of supervisory staff and staff for maintenance and servicing, there are no employees present in a fully automated facility. However, the problem did arise during the investigations in connection with WP 2.6 of finding provisions for the interface between auto-mated and manual operation. This is present

- in the case of partly automated facilities; for example:

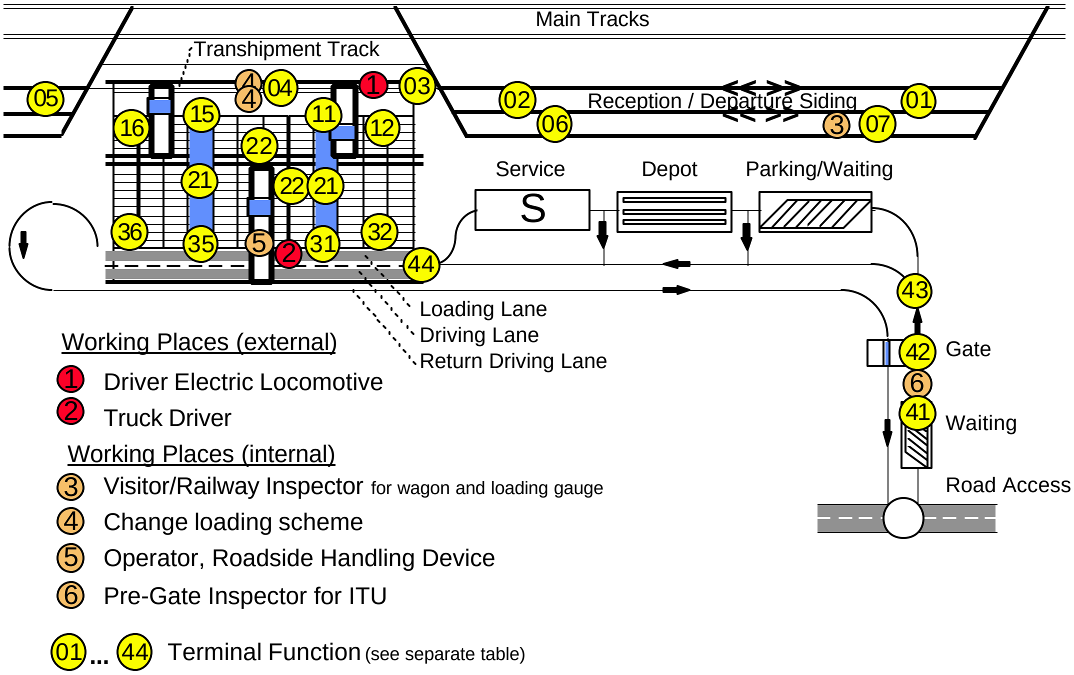
?? fully automated transhipment rail/rail and manual or partly automated transhipment rail/road in connection with the lorry-drivers remaining within the transhipment area and/or

?? manual positioning of the securing devices on the carrier-wagon for re-loading

?? during repairs, maintenance and servicing.

It was possible to make use of the DB AG experience gained during the planning work in connection with setting up automated transhipment facilities (e.g. co-operation with Krupp Fördertechnik with DB AG for the development of the Krupp "Rapid-Handling Facility" or the DB AG planning work for setting up a rapid-handling facility on the basis of proposals and development work by Noell in Lehrte/Hannover) for the analysis of the man/machine interface in automated terminals and for stipulating the relevant safety rules. The following illustration provides an example for identifying the man/machine interface in a rapid-handling facility.

According to this, the following areas must be given due consideration for the safety of the staff at the man/machine interfaces in automated terminals:



(01) to (07)	Railway operation
(11) to (17)	Exit departure siding
(21) and (22)	Internal transport/Buffer/Storage
(31) to (34)	Transhipment roadside
(41) to (44)	Road traffic

Fig. 4.10.4: Operational Sectors of an Intermodal Terminal

In this connection, the Project Group prepared a form which can be used as a checklist for the identification and classification of risks in intermodal traffic terminals to be carried out in accordance with Article 9, Sub-Section 1, of the Directive 89/391 EEC.

For the safety of internal and external staff, it is however particularly important that instruction and information are provided (see also Article 6, Sub-S. 1, Article 10, Sub-S. 1 and 2, and Article 12 of the Directives of the Council 89/391 EEC).

During the interface investigation, it was necessary to distinguish between a

- **stationary facility** (transhipment on the stationary train) and a
- **through facility** (transhipment on a train being conveyed through the facility).

A modular structure was selected for the safety rules drawn up for the man/machine interfaces so that the relevant elements of the safety rules can be utilised depending on the type of transhipment facility to be planned later.

4.10.5 Safety of the Installations and Equipment in Intermodal Transhipment Facilities

In the course of the development work in connection with the Krupp rapid-handling facility, numerous discussions were held between Krupp Födertechnik, DB AG, the Federal Railway Office (EBA) and the Railway Accident Fund (EUK) which resulted in the stipulations for the safety of the technical installations in a rapid-handling facility. Since such facilities have not yet been implemented for practical, every-day operations, it is natural that numerous rules agreed upon concerning occupational safety and labour protection have not yet been embodied in standards and directives. The Project Group gives an overview of the existing European standards and directives, but also mentions the national regulations, rules and standards so that

- the standardisation work still to be performed by the European standardisation bodies can be derived from these, and
- they can provide points of reference with regard to giving due consideration to relevant laws and standards during the planning and construction of intermodal traffic transhipment facilities in another European country.

4.10.6 Planning Considerations for Fire Brigade and Emergency Services

For an emergency, i.e. in case of fire, accident, a person in distress or for an ecological emergency (release of substances hazardous to the environment), the transhipment facility - together with the functional areas - must be accessible for the fire brigade and the emergency services including the service vehicles.

In an emergency (e.g. fire or accident), the fire brigade or the emergency services must have unrestricted access to the scene of the emergency by means of a fire lane provided especially for this purpose within the transhipment facility. In addition, rescue routes must be provided in the cross-direction of the facility (minimum width: 1.25 m). In intermodal traffic transhipment facilities, the tracks, storage areas for ITUs and conveyors (e.g. longitudinal conveyors or sorting facilities and cross-conveyors) primarily present an obstacle to the rescue staff crossing the facility.

The fundamental principle is that measures for fire protection and for the emergency services must be co-ordinated with the local authorities responsible and the fire brigade during the planning stage of the construction work. In order to avoid rail crossings, the lorry driving and loading lanes are generally located on one side and the transhipment tracks on the other in intermodal traffic transhipment facilities. This means that fire brigade access is provided for on the road-side. On the rail-side, special provision must be made for this since otherwise this side would only be accessible via sufficient cross-direction routes in a spacing-grid that needed to be determined. In connection with the planning of automated transhipment facilities, discussions were held between DB AG and the local fire brigade responsible. The conclusions resulting from these can be utilised as a reference for the features to be considered in connection with fire protection and the emergency services.

4.10.7 Aspects of Labour Protection for the Carrier-Wagons

A pre-requisite for fully automated transhipment is also that manual operations at the carrier-wagon are not necessary during loading and unloading. At present, the securing devices on container carrier-wagons must be set manually in the proper loading position for reloading containers and swap bodies. Costamasnaga has performed a thorough investigation of technical solutions to avoid manual positioning of the securing devices. The proposal for a container locking device with a pivoted hammer-head seems most promising since

- this solution leads to a reduction in the number of spigots required due to the positive securing of the containers and
- it offers the possibility of retrofitting existing carrier-wagons (it is not necessary to wait for a new generation of carrier-wagons when the need arises). Safety tests do, however, still need to be performed. With positive test results, this solution means that the number of spigots per container can be halved. The result would be that loading on a two-axled carrier-wagon with
    - one 40' container
    - two 20' containers
    - two 7.82 m swap bodies

  would be possible without the position of the spigots having to be altered.

However, investigations are still necessary in order to demonstrate the consequences for handling these carrier-wagons in existing transhipment facilities without automated equipment and to make proposals for relevant solutions.

4.10.8 Conclusions

In connection with the further development of the technology for intermodal traffic transhipment terminals with a view to automation, continuation of European standardisation work and further harmonisation especially of directives for workplaces in European countries are purposeful targets.

4.11 DESIGN AND ORGANISATIONAL ASPECTS OF THE INTERMODAL TERMINALS (WP 3.1)

The works which are summarised in the following, have technically been co-ordinated by Framatome (Workpackage Leader). Krupp, ERRI, Costamasnaga and NTUA have contributed.

4.11.1 Aim of the Investigation and Technical Approach

The aim of WP 3.1 was to present and analyse the design and organisation of combined rail-road and rail-rail terminals. The approach has been to identify the consequences for the operation of such terminals of adopting advanced transhipment equipment, rolling stock and supporting systems/devices. The analysis was divided into three sections. The first section consisted of utilising the results of earlier IMPULSE WPs. During the second section, the principles and rules applied to the design and operation of intermodal transport terminals were gathered by means of interviews with specialists in these areas from organisations both inside and outside the IMPULSE consortium. The third section was Delphi operation. The first round aimed at analysing and assessing a number of intermodal transport technologies in terms of usefulness and market penetration potential. The second round identified efficient “technological parcels” – combinations of these technological bricks – and efficient combinations of technological parcels and advanced forms of rail operation.

4.11.2 Overview of Intermodal Transport Terminals

Intermodal transport terminals provide the space, the equipment and the operational environment for transferring ITUs between the different transport modes. Intermodal transport terminals can be classified into different categories according to cargo volume, terminal location/access, handling equipment used, types of mode served, main ITU types served (ISO containers, inland containers/swap bodies and semi-trailer) etc. Despite the variety of existing terminal types, the vast majority of intermodal transport terminals follows typical rail procedures (engine exchange, wagon siding/shunting, loading/unloading procedures) and suffers from the associated inconveniences (train sharing over two or more tracks, train shuffles between transhipment and shunting/changeover tracks, broken wagon replacement etc).

4.11.3 Design and Organisation Issues

The planning of a intermodal transport terminal requires a good background on basic design parameters and organisational issues. This issues includes advanced terminal access techniques (slewing catenary on the loading track, allow the train to coast into position), alternative transhipment layout designs, rules concerning the distance between tracks, management of shunting locomotive and work teams as well as train, wagon and loaded cargo tests (procedures and timing of WU1K/2K/3K, braking tests etc) as well as he lorry arrival behaviour/patterns and the organisation of road side activities.

4.11.4 Conventional Handling Technologies

The use of suitable lifting equipment for the transhipment of load units is directly linked to the arrival of containers on the European transportation market in the mid-sixties. We can distinguish between high-volume and low-volume technologies.

Many low-volume handling systems have been developed over the last few decades, some of them only on paper or in pilot demonstrations, others tested under real-life conditions. A small number of these systems have found a place on the market (self-loading lorries/trailers, fork-lift and small transtainer-based systems, horizontal transhipment systems, transhipment technologies based on special ITU types).

Current medium/high-volume technologies for intermodal transport terminals are based on the following equipment types or combinations:

- Rail-borne gantry cranes (pure system)
- Combinations of gantry cranes and reach stackers/fork lifts
- Combinations of gantry cranes, reach stackers/fork lifts and transport devices (e.g. the multi-trailer system)

The conventional handling systems can be enchanted by the use of advance add-on technological devices (advanced rail access systems, identification, location and positioning devices, semi-automatic control, information systems for terminal preplanning, shunting robots and rolling-stock related technological bricks).

Despite the relatively high performance of the above-mentioned conventional systems, there are many situations in which the requirements impose significantly higher standards in terminal productivity (e.g. in the hub and spoke system) or in the handling speed (e.g. fast service of linear trains). A number of innovative/advanced handling technologies have been developed to overcome this limitation. (Hilgers technology, Krupp's moving train technology, Transmann system, Technicatome and Preussag Noell automated transhipment systems, Thyssen technology etc)

4.11.5 Trends in Conventional Intermodal Terminal Design

4.11.5.1 Guidelines for intermodal Terminal Designs in France

When the first and second generation terminals (i.e. the majority of existing terminals) were built, few managers thought intermodal transport had a future. This in turn explains the low level of investment in such terminals and the lack of willingness to provide terminals with really efficient equipment and ideal locations. This situation seems to be reversed. In all terminals built in the coming years, the following points will be therefore be taken into consideration:

- The tracks should be 750 m long, so as to be able to receive the longest trains in one piece

?? Each yard should have three such tracks

?? There will be large areas dedicated to storage

?? There will be no dead end. This will allow access to the terminal via two rail access points.

?? There will be two sets of points, to allow two locomotives to enter and leave the terminal at the same time.

?? Ideally, a number of sidings will be attached to the terminals so that idle trains (i.e. those that have already been loaded or unloaded) can be parked outside the terminal. Ideally again, these sidings will be located behind or in front of the terminal, rather than next to it, so as to limit locomotive movements.

Since many shunting yards are no longer in use, the terminals will be built on these sites. This will allow existing infrastructure to be used. Furthermore, these old shunting yards generally already have numerous long tracks. They therefore look like ideal sites for the terminals of the third and following generations. The drawing below shows how a terminal should look in the future.

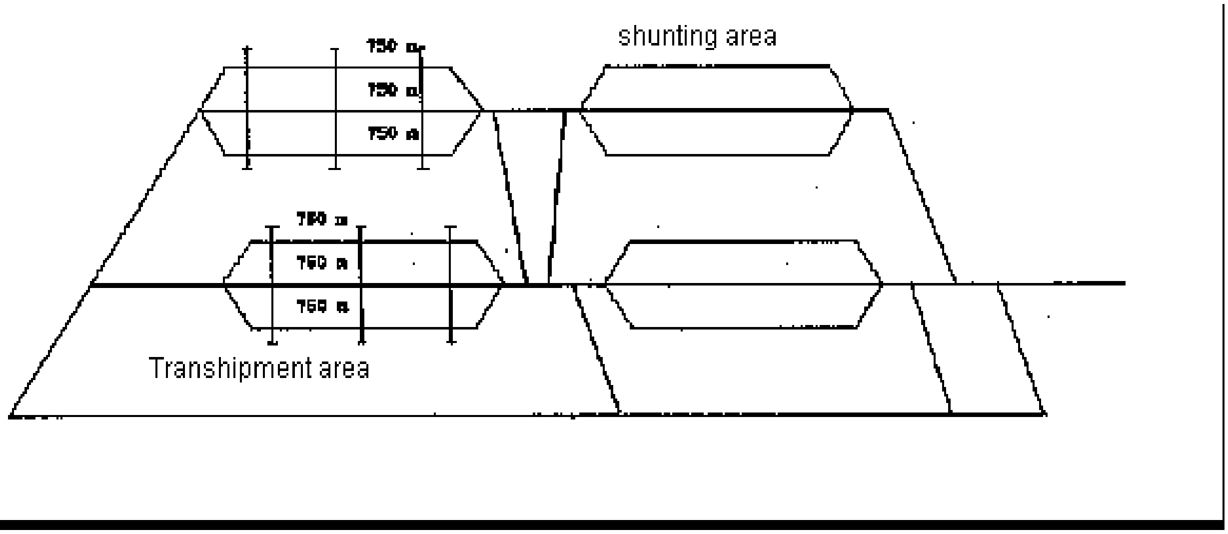


Fig. 4.11.5.1: Arrangement of Rail Tracks in an Intermodal Terminal

4.11.5.2 The DB planning Criteria for Intermodal Transport Terminals in Germany

The basis for the planning of intermodal transport transhipment terminals at DB is the Standard Module which was coordinated with the EBA and the EUK regarding its cross-section (crane bearing distance, distances between tracks, driving and loading lanes, storage lanes) on 23 January 1998. A standard module (see Figure) consists of three gantry cranes with a bearing distance of 39.80 m (centre of crane rail to centre of crane rail). These gantry cranes span four transhipment tracks with a length of 700 m each, one loading lane, one driving lane and three ITU storage lanes. Outside the crane area and depending on the location, there are the driving lane for entry or exit to/from the transhipment area and the tracks for exchanges, by-passes and for stabling damaged wagons.

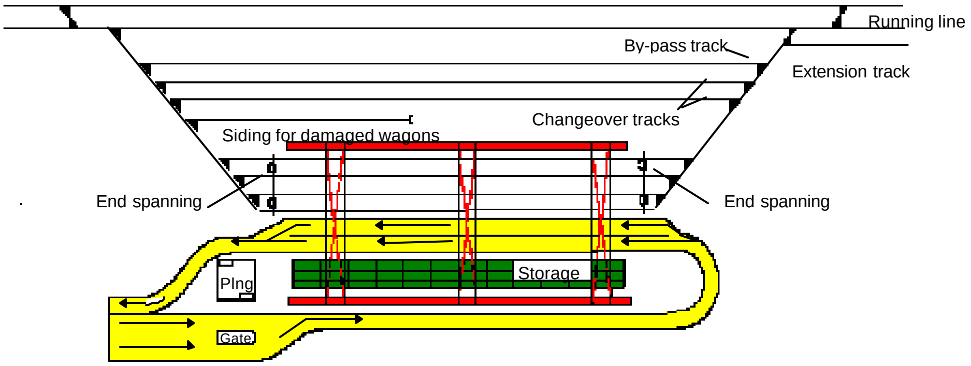


Fig. 4.11.5.2: Layout of Deutsche Bahn (German Railways) Standard Module

4.11.6 Advanced Terminal Designs

4.11.6.1 Designs Based on the Krupp Fast Handling Technology

The transhipment plant comprises the rail transfer area, the materials handling equipment, the intermediate stabling area and the loading and travel lanes. The remaining area includes the HGV approach road and the area made available for any congestion, the reception and departure gates, the traffic area (parking spaces and waiting areas, turning area and reversing lane), buildings and technical installations and service areas and depots where applicable.

The crucial innovative factor in Krupp's fast handling plant is that loading and unloading is effected by "overtaking". As the train moves slowly through the transhipment plant, the position, identity and dimensions of the load units are checked by electronic sensors in the preliminary zone, amended where necessary and the appropriate instructions scheduled for the equipment located further down the line.

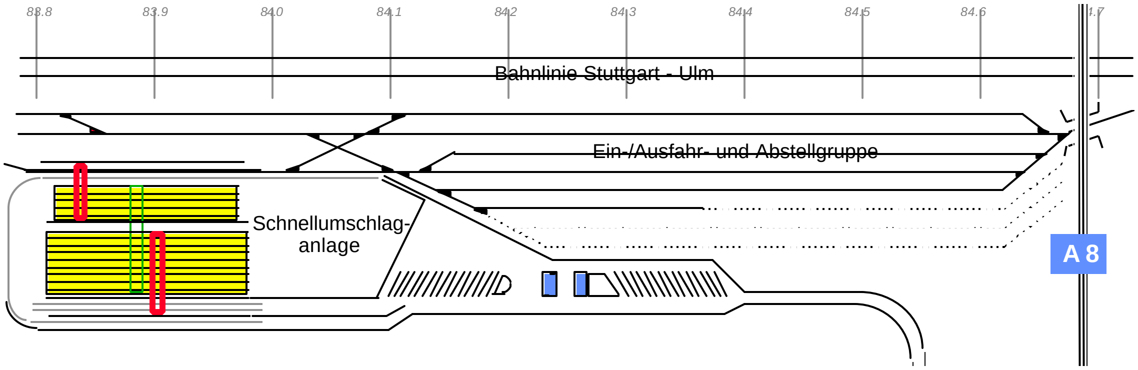


Fig. 4.11.6.1: Layout of Krupp Fast Handling System

In the next transfer area, high-speed transfer equipment moving alongside the train picks up the load units to be unloaded, lifts them from the wagon and deposits them on the cross conveyor. The load units are either transported directly to the HGV loading and unloading area or into the store via the shortest route possible. Now carrying newly added load units, the train exits the plant. Rail transfer and inter-company transport is fully automatic, transfer to the HGVs partially automatic. By separating the two different functions, the trains and HGVs are operated independently of each other, thus cutting out any waiting times.

The design of the equipment used in both road and rail transfer is based on a semi-portal crane with a one-sided, spandrel-braced crane gantry. The cross conveyor aisle arranged between the storage modules is used for transporting the load units between the road and rail transfer areas and to the appropriate row in the store.

Two storage modules are provided in the form of a compact storage system in order to store containers, swap bodies and semi-trailers inside the fast handling plant. The storage modules are subdivided into five rail storage lanes and nine road storage lanes, making a total of 155 spaces available. The store is managed using the cross conveyor and the rail or road transfer equipment. The containers may be stacked in twos throughout the entire area and in certain pre-designated areas they may be stacked in threes. Swap bodies are deposited at ground level. Semi-trailers are placed on special supporting trestles at the top end of the high-density road store. The compact store is managed automatically.

4.11.6.2 The Single Area Variant of the Krupp Fast Handling System

The terminal consists of areas for servicing trains, handling, storage and roads. An example cross section is divided into three transhipment tracks, one loading and one driving lane and four storage lanes (width: approx. 42 m). These functions can be re-arranged according to local and other needs, e.g. safety. Depending on the percentage of direct rail-road transhipment, the roads may be located next to the tracks or, if there is a large percentage of automated train-train and train-buffer-train movements, the storage area may be located next to the railside crane column. This would mean a clear separation between manual and automated areas.

The entire transhipment system is very compact, owing to the use of rendezvous technology. The length can be reduced to approx. 100 m - 200 m or may be extended to achieve direct transhipment between two trains standing in parallel. All trains exceeding this length will be serviced as they pass through the transhipment area. This configuration allows a limited sequential and parallel hub-function to be offered in addition to the rail-road functions. The minimum length will be 100 m, depending on the lengths of the rafts or wagon groups, such as the German “Cargo Sprinter“.

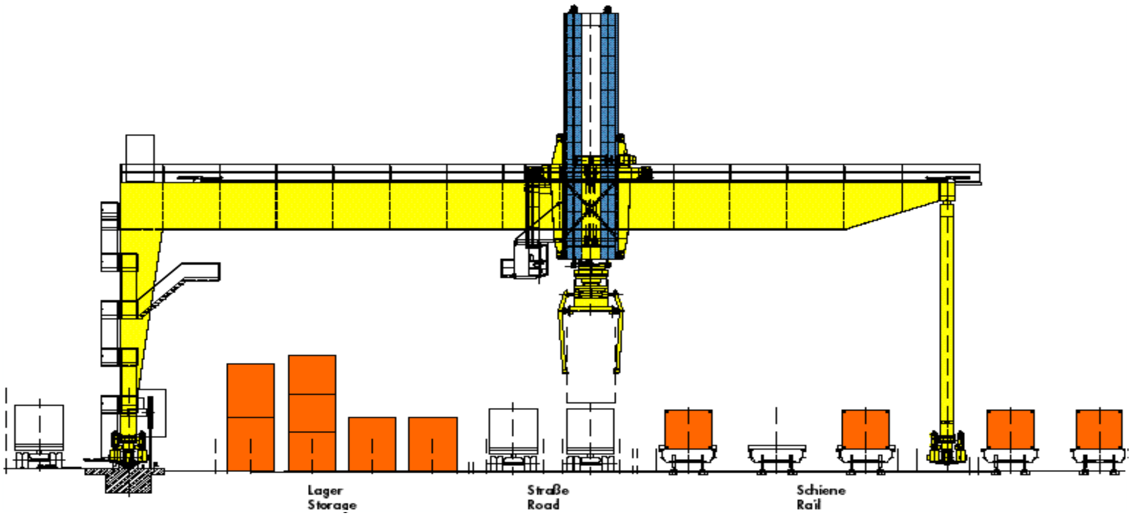


Fig. 4.11.6.2/1: Cross Section of Single Area Krupp Fast Handling System

For conventional transhipment, a combination with a reach stacker is possible. The handling device is able to perform all necessary handling tasks, such as train-buffer, train-train and train-lorry transhipment. Linking these functions enables optimal utilisation of the installed equipment throughout the day and fine-tuned servicing of the vehicles, with short dwell times.

The terminal concept described above is a good extension of the features of the Krupp Fast Handling System, such as automated fast transhipment in compact areas, while recognising the present cargo volumes, antiquated terminal layouts and limited willingness to innovate.

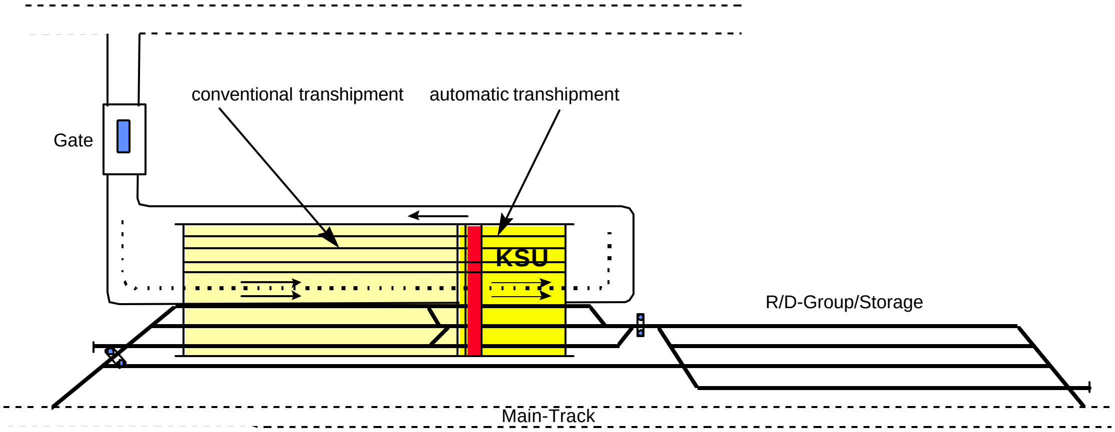


Fig. 4.11.6.2/2: Layout of Single Area Krupp Fast Handling System

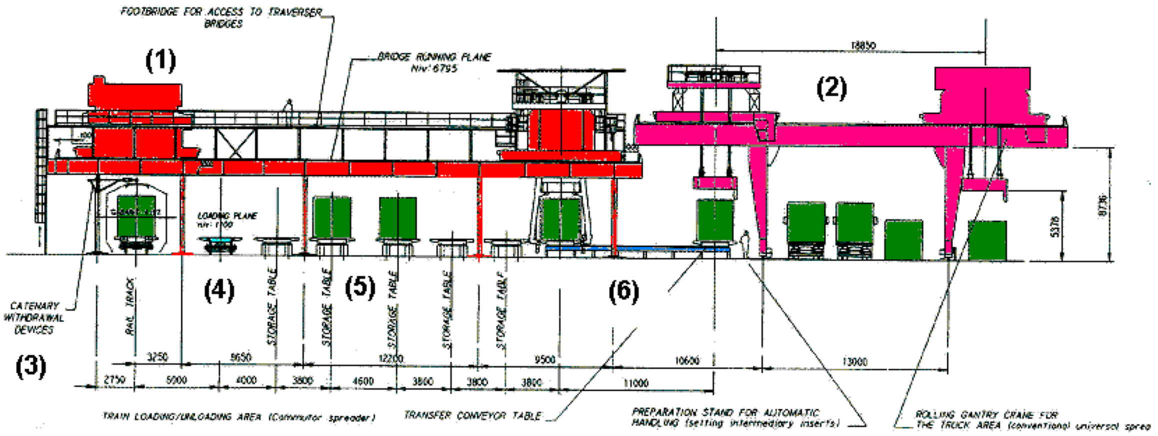
4.11.6.3 Advanced Terminals Based on the Commutor Concept

Terminal designs based on the Commutor concept allow automatic operation on most of the rail-road terminal logistic chain. The Commutor fast handling system offers a wide diversity of solutions, owing to its modularity and interfaces to other elements. The one requirement is that the wagons all have the same length. This section presents two rail/road terminal variants:

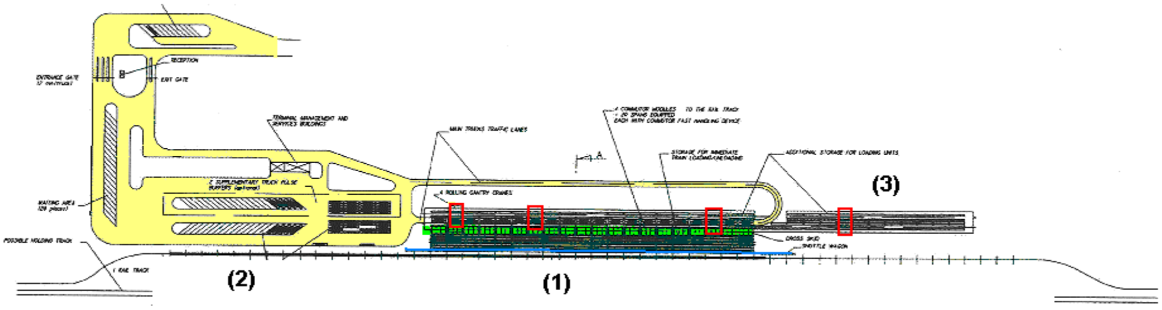
Technicatome Rail-Road Terminals (Variant 1)

Commutor transhipment equipment composed of unidirectional bridges perpendicular to the track to serve the rail side. A conventional gantry crane serves the lorry side. A cross skid conveyor is used between the Commutor bridge and the lorry gantry crane in order to link the rail and road sides, while allowing much better independent processing of the two types of equipment. A shuttle wagon is used for longitudinal movements from span to span. The train is quickly processed by the module, in several stop positions, depending on the number of modules. One module for this approach is composed of five unidirectional bridges and is able to unload/load five wagons.

This solution provides high flow rates and short train stopping times. Double stacking of load units is possible, both on handling tracks and under the crane on the lorry side.



(1) Fixed bridge with Commutor spreader
(2) Rolling Gantry cranes for the truck area
(3) Catenary withdrawal device
(4) Shuttle wagon
(5) Storage table
(6) Transfer conveyor table



□ **ROLLING GANTRY CRANES**

— **SHUTTLE WAGON**

🟩 **CROSS SKID / TRANSFER CONVEYOR TABLE**

(1) FIXED BRIDGE CRANE WITH COMMUTOR SPEADERS
(2) TRUCK LANES
(3) ADDITIONAL STORAGE FOR LOADING UNITS

Fig. 4.11.6.3.1: Technicatome Advance Rail-Road System (var. 1) Based on the Commutor Concept

Technicatome Rail-Road Terminals (Variant 2)

Commutor transhipment equipment composed of a bi-directional rolling gantry crane parallel to the track to serve the rail side and a conventional gantry crane to serve the lorry side. This solution might be more flexible at lower flow rates and perhaps cheaper.

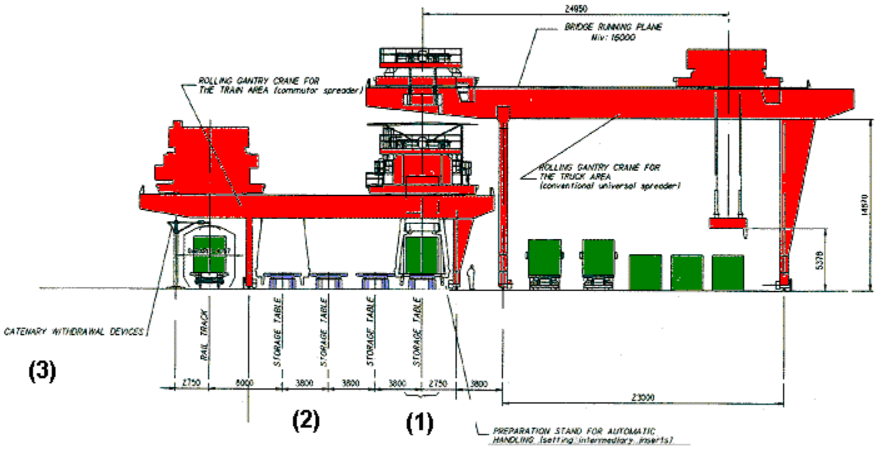
This variant may look similar to the two-gantry-crane variant, but the Commutor spreader on the rail side can handle all the load units on a wagon in one single move. In addition, load unit transfer is faster than with conventional gantry cranes, as the Commutor module is fully automatic and therefore offers higher performance.

The gantry travels along the whole train, which means the train is processed in one single stop position and that the length of the terminal is minimised. In order to reduce investment, the storage tables for automatic handling are not positioned in front of all wagons – most are grouped in front of the head of the train. In this variant, double stacking of load units is possible on handling tracks and under the crane on the road side.

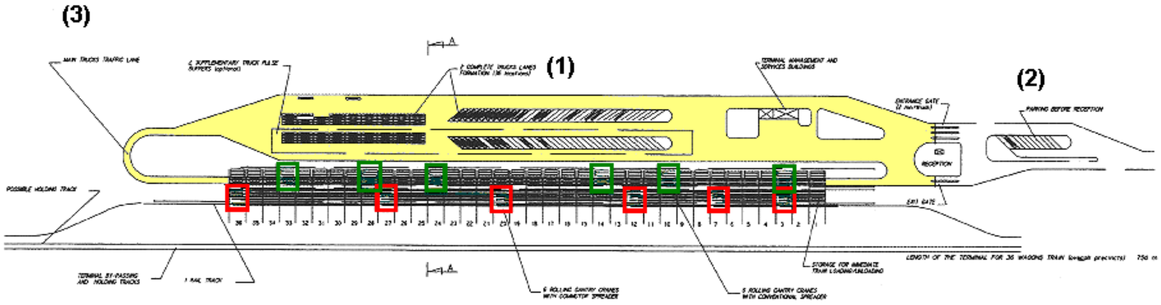
The link between the two gantries, on the rail side and on the lorry side, is direct, without cross skid, via overlapping and interlocking between the moves of the two gantries. This approach reduces the investment required, but cross skids could be added to enhance operation.

The characteristics of the solution depend upon the number of tracks under the area to be served by the crane. In order to obtain fast transhipment, the idea is to have only one track in the crane area. That gives minimum span, and thereby allows equipment to be used that is both lighter and cheaper for this performance level. Only one train is processed at any given time, and that one train is processed quickly. If it is not yet time for the train to leave, or if waiting is necessary for some other reason, the train must be placed in nearby sidings after processing in order to leave the track free for the processing of other trains. The terminal needs additional areas to hold trains, but the surface area in the transhipment zone – the area that requires expensive preparation – is minimised.

If several tracks are located under the crane area, the span will be wider and the equipment heavier, which means it will not be able to work as fast. The advantages are, however, that trains arriving during a given time interval can stay in the crane area and be processed without being parked. This keeps the total terminal surface to a minimum.



(1) Buffer lane served by both gantries
(2) Storage tables
(3) Catenary withdrawal device



☐ **ROLLING GANTRY CRANES WITH CONVENTIONAL SPEADER**

☐ **ROLLING GANTRY CRANES WITH COMMUTOR SPREADER**

(1) TRUCK LANES and SEMI-TRAILER LANES
(2) PARKING BEFORE RECEPTION
(3) MAIN TRUCKS TRAFFIC LANE

Fig. 4.11.6.3.2: Technicatome Advance Rail-Road System (var. 2) Based on the Commutor Concept

4.11.7 Technological Bricks and Efficient Combinations

A number of supporting technologies or add-on devices exists (technological bricks) which can for improve a terminal design. These technological bricks are divided into seven groups.

4.11.7.1 Identification/Location Technologies

The first group comprises the identification/location systems for world-wide tracking and tracing, ITU-based identification systems within the terminal area, standalone identification systems within the terminal area and location systems within the terminal area. Tracking & tracing technologies can contribute significantly to intermodal transport operations but general acceptance and wide market penetration are not conceivable for general cargoes at present. Technological solutions to the problems of power supply and transmission costs are still awaited. Some types of cargo are suitable candidates for tracking & tracing – high value goods, dangerous goods (ARGOS is very suitable) and reefers (and any load unit with a power supply).

Various systems will be set up to respond to customer-specific requirements. The tracking and tracing of transport vectors (rail wagons, ships, etc.) will allow goods to be traced more simply by the adoption of appropriate organisational procedures.

4.11.7.2 Handling Equipment, Anti-sway Systems, Semiautomatic Control Systems

The second group consists of handling equipment: reach stackers/fork lifts, gantry cranes on pneumatic tyres, rail-borne gantry cranes, the Krupp automatic fast handling equipment (basic and single area variants) and the automatic fast handling equipment based on the Commutor concept.

The third group includes the anti-sway systems, the semiautomatic equipment control systems and two other technological bricks: “Cabin disconnected from the spreader” and “Robot for wagon pin change”. These two bricks have been excluded from further analysis. The “Cabin disconnected from the spreader” is a proposed technological improvement for gantry cranes. It is effective but of minor importance for IMPULSE. The “Robot for wagon pin change” is theoretically efficient but there are technical inconveniences, especially when handling semi-trailers.

4.11.7.3 Advanced Rail Access Techniques/Systems

The fourth group comprises technologies to speed up train access in the terminal.

1. Using a slewing catenary on the loading track. The catenary is moved aside before the portal crane(s) or reach stacker(s) start unloading the units. The device obviates the necessity for a change of locomotive, and hence eliminates uncoupling/coupling of locomotives and braking checks prior to departure.
2. Allowing the train to coast from the main line into position on the transhipment line. The train enters the terminal with the pantograph lowered and stops when the electric locomotive is positioned under the overhead on the far side, so that it will be able to move off. This system can yield significant time savings but requires a terminal with separate entry and exit tracks. Studies and a pilot demonstration

have led DB to conclude that the "coasting" technique is feasible. Following a trial phase, such a system was introduced at München-Riem in 1994. Trains enter the zone at a rolling-in speed of 30 km/h and reach their target point at approx. 11 km/h. However, some specialists expressed doubts as to whether this rolling-in speed could be achieved in all terminals. The alignment of the access track in some French terminals imposes significant limitations, for instance, and high winds plus wagons rolling badly could also pose problems.

3. Electrify all track and use special handling equipment that can load/unload the train under the overhead. Within IMPULSE, this technique is only addressed in outline. It has been mentioned that handling systems capable of operating underneath the overhead line only confer significant advantages in the case of liner trains, for which short stop times are very important. The number of ITUs to be transhipped at a time is small, so the capacity of the system need not be particularly high as long as the rest of the intermediate stop procedure is fast – rail access from both sides plus no change of locomotive. Moreover, the static structure and dynamic behaviour of systems that can operate under the overhead line are not optimal – they will either be heavy and expensive, or else slow.

4.11.7.4 Advanced Rail Access and the Krupp Fast Handling System

However, since railway operations are to be improved, and since DB has practical experience with the "coasting" technique (on standard modules), the question was whether this would work in conjunction with the Krupp system. The answer was "yes". In such a situation, the same rules will apply with respect to signalling and safety. The electric locomotive would stop at the end of the transhipment track, under the overhead line, leaving the wagons on the transhipment track to be unloaded immediately, while the shunting robot is being coupled on. The remainder of the wagons are serviced as the shunting vehicle pushes them through the plant. Eventually, the head of the train reaches the "stop" sign and the electric locomotive can be re-coupled.

4.11.8 Technological Bricks: Compatibility and Relationships

The implementation of the technological bricks in the terminal design requires the knowledge of compatibility issues, efficient combinations and relation with the rail forms. The following Tables summarise the IMPULSE point of view on these issues.

Compatibility between technological bricks

		ITU based Identification systems within the terminal A2	Stand alone identification systems within the terminal A3	Location systems within the terminal area A4	Reach stackers/ Fork lifts B1	Gantry cranes on pneumatic tyres. B2	Rail mounted gantry cranes. B3	Krupp automatic fast handling equipment - basic B41	Krupp autom. fast handling equip. - single area variant B42	Autom. fast handling equipment (Commutor concept) B5	Anti-sway systems C1	Semiautomatic equipment control C2	Slewing catenary on the load. track (dead end access) D1
ITU based Identification systems within the terminal area	A2	■	A					E	E	E			
Stand alone identification systems within the terminal area	A3	A	■					I	I	VE			
Location systems within the terminal area	A4			■	E	E	E						
Reach stackers/ Fork lifts	B1			E	■		E				I	ED	
Gantry cranes on pneumatic tyres.	B2			E		■	A	A	A	A	E	ED	
Rail mounted gantry cranes.	B3			E	E	A	■	A	A	A	E	VE	
Krupp automatic fast handling equipment - basic	B41	E	I			A	A	■	■		I	I	
Krupp automatic fast handling equipment - single area variant	B42	E	I			A	A	■	■		I	I	
Automatic fast handling equipment (Commutor 2 concept)	B5	E	VE			A	A			■	I	I	
Anti-sway systems	C1				I	E	E	I	I	I	■		
Semiautomatic equipment control	C2				ED	ED	VE	I	I	I		■	
Slewing catenary on the loading track (dead end access)	D1												■
Slewing catenary on the loading track (bidirectiona access)					E	E	E	X	X	VE			■
Train coast with momentum (dead end access)	D2												A
Train coast with momentum (bidirectiona access)					E	E	E	X	X	VE			A
In cabin screen-based communication systems	E1			E	VE	VE	VE	I	I	I			
EDI based information systems for terminal pre-planning	E2			E	E	E	E	E	E	E			
Stackable ITUs	F1			E	E	E	E	E	E	E			
Wagons with automatic pins adjustment/locking	G1	E	E	E	E	E	E	VE	VE	New wagon types			
Groups of wagons permanently coupled with an automatic coupling at each end	G2												
One cabin at each train end enabling bi-directional movement	G3												
Train with fixed wagon configuration using conventional wagon types	G4							E	E				
New wagons for all ITU types (Kombiverkehr wagon)	G5				VE	VE	VE	VE	VE				
Automatic train coupling	G6												
Self-propelled wagon groups	G7						VE	VE	VE				

NOTE : The matrix is symetrical

I = INCLUDED IN THE BASIC DESIGN
ED = EFFICIENT COMBINATION BUT DIFFICULT TO BE IMPLEMENTED
E = EFFICIENT COMBINATION
VE = VERY EFFICIENT COMBINATION / SYNERGY EFFECTS
No mark = TECHNOLOGICAL BRICKS CAN COEXISTS CO-EXIST

Fig. 4.11.8/1: Compatibility Between Technological Bricks

EFFICIENT
TECHNOLOGY COMBINATIONS
(technology parcels)

		ITU based Identification systems within the terminal area	Stand alone identification systems within the terminal area	Location systems within the terminal area	Anti-sway systems	Semiautomatic equipment control	Slewing catenary on the loading track	Coast with momentum	In cabin screen-based communication systems	EDI based information systems for terminal pre-planning	Stackable ITUs
CODE	**Handling equipment**	**A2**	**A3**	**A4**	**C1**	**C2**	**D1b**	**D2b**	**E1**	**E2**	**F1**
Tech.Pars.#1A	Reach Stacker, basic				I						Applicable in most cases
Tech.Pars.#1B	Reach Stacker, optimal transshipment			Y	I		Y1	Y1	Y	Y	
Tech.Pars.#1C	Reach Stacker, optimal rolling stock			Y	I				Y	Y	
Tech.Pars.#3A	Rail mounted gantry crane					Y			Y	Y	
Tech.Pars.#3B	Rail mounted gantry crane opt. access					Y	Y1	Y1	Y	Y	
Tech.Pars.#3C	Rail mounted gantry crane opt. access					Y	Y1	Y1	Y	Y	
Tech.Pars.#3D	Rail mounted gantry crane full optimized			Y	Y	Y	Y1	Y1	Y	Y	
Tech.Pars.#3E	Rail mounted gantry crane full optimize + opt. wagons			Y	Y	Y	Y1	Y1	Y	Y	
Tech.Pars.#4A	Autom. fast handling (Krupp)		I		I	I			I	Y	
Tech.Pars.#4B	Autom. fast handling (Krupp) opt. pins		I		I	I			I	Y	
Tech.Pars.#4C	Autom. fast handling (Krupp) opt. wagons		I		I	I			I	Y	
Tech.Pars.#4D	Krupp - Single Area Variance		I		I	I			I	Y	
Tech.Pars.#4E	Krupp - Single Area Variance opt. pins		I		I	I			I	Y	
Tech.Pars.#4F	Krupp - Single Area Variance opt. wagons		I		I	I			I	Y	
Tech.Pars.#5A	Autom. fast handling (Commutor 2 concept) Rail-Rail			I	I	I	I1	I1	I	Y	NO
Tech.Pars.#5B	Autom. fast handling (Commutor 2 concept) Rail-Road			I	I	I	I1	I1	I	Y	

I = Included in the basic design by default
I1 = One of these systems is included in the basic design as default
Y = To be included in the technology parcel
Y1 = Only one systems will be included in each technology parcel
Y2 = Systems can be included one by one or in any combination

Fig. 4.11.8/2: Efficient Technology Combinations (technology parcels)

Code	Description and requirements	linear trains function (Fast train handling)	shuttle train function	shuttle-shuttle overnight function
Tech.Parc.#1A	Reach Stacker, conventional	possible	possible	
Tech.Pars.#1B	Reach Stacker, optimal transshipment (support by information system)	possible	possible	
Tech.Pars.#1C	Reach Stacker, optimal rolling stock	possible	possible	
Tech.Pars.#3A	Rail mounted gantry crane		efficient	
Tech.Pars.#3B	Rail mounted gantry crane opt. Access	efficient	efficient	possible
Tech.Pars.#3C	Rail mounted gantry crane fully optimized (incl. semi-automatic control)	efficient	efficient	possible
Tech.Pars.#3D	Rail mounted gantry crane full optimised + opt. wagons	efficient	efficient	efficient
Tech.Pars.#4A	Autom. fast handling (Krupp)	very efficient	efficient	efficient
Tech.Pars.#4B	Autom. fast handling (Krupp) opt. Pins	very efficient	efficient	very efficient
Tech.Pars.#4C	Autom. Fast handling (Krupp) opt. Wagon	very efficient	efficient	very efficient
Tech.Pars.#4D	Krupp - Single Area Variance	very efficient	efficient	very efficient
Tech.Pars.#4E	Krupp - Single Area Variance opt. pins	very efficient	efficient	very efficient
Tech.Pars.#4F	Krupp - Single Area Variance opt. wagons	very efficient	efficient	very efficient
Tech.Pars.#5A	Autom. fast handling (Commutor 2) Rail - Rail	efficient	efficient	very efficient
Tech.Pars.#5A	Autom. fast handling (Commutor 2) Rail - Road	efficient	efficient	very efficient

Fig. 4.11.8/3: Technical Efficiency Between Technological Parcels and Rail Operation Forms

4.11.9 Parameters that Affect the Terminal Design

4.11.9.1 The TEU/ITU Ratio

The TEU/ITU ratio converts the terminal volume into handling movements. The TEU/ITU ratio for maritime containers ranges from 1.5 to 1.8. Swap bodies represent 90% of the inland ITU market (about 60% Class C, 30% Classes A and B), while semi-trailers represent 10% of this market. The associated TEU/ITU ratio appears to lie between 1.4 and 1.5. The upper limit for terminal design calculations would therefore appear to be 1.5. It should be noted that the handling productivity expressed by the above TEU/ITU ratio refers to the number of incoming or outgoing ITUs, i.e. the number of "paid" ITUs processed per unit time. This may be smaller than the number of transhipments, because the latter includes all handling operations, including "re-shuffles" from the stack and serving of storage for the customer.

4.11.9.2 The Percentage of Stackable ITUs

ITU stacking reduces storage requirements and mean travel distance (for mobile handling equipment) or gantry span (for gantry configurations where the storage area is located between the gantry legs). On the other hand, ITU stacking increases handling activities, since it generates a number of shuffles (rearrangements required in order to provide access to the ITUs that are not on top of the stacks). Containers are stackable while semi-trailers are not, and nor are the vast majority of swap bodies. The ITU mixture served by a terminal is closely related to the terminal type. A rail terminal linked to a port handles more containers (and therefore tranships more stackable units) than an inland terminal. Terminal design needs to take account of future trends concerning stackable ITUs. Trade experts and standardisation committee members are convinced that the market requires a new series of stackable swap bodies (or European domestic containers), in addition to the current type of swap body.

Currently, the mean stacking height in the majority of rail terminals is very near to 1. Containers are usually stacked one or two high, while (exceptionally) an empty (box-type) swap body can be placed above a loaded one. This situation can be improved on.

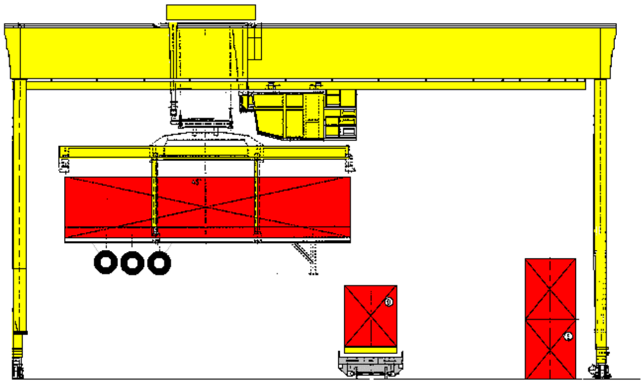


Fig. 4.11.9.2: Conclusion of Lifting Height (Semi-Trailer above loaded Wagon)

It should be noted that conventional gantry cranes have to leave a ground-to-spreader height of 9.9 m to allow a semi-trailer to pass over another semi-trailer on a pocket-wagon. This minimum crane height allows a stacking height of “2+1” in the storage area (two units stacked plus a pass through corridor one unit high).

Experience with maritime operations indicates that a mean stacking height of 1.5 can be achieved without significant time losses due to ITU shuffles, even with random pick-ups. As an absolute maximum, units can be stacked three high for storage-to-train activities (see the RSC terminal), but this requires an information-based system.

It must be noted that there are technical solutions (e.g. the fast handling “single-lane servers”) where ITU stacking is undesirable for operational reasons. Some future intermodal transport terminals will probably operate with a low stacking height ratio.

4.11.9.3 The Percentage of Semi-trailers

The loading/unloading of semi-trailers seems to be a very difficult task for all automatic handling equipment types. Pocket wagons can accommodate the trailer wheels but the king-pin support for the wagon must be moved to the correct position by hand. From the loading point of view, the semi-trailer “obstacle” is not much different from the pin changing “obstacle”. Human intervention is unavoidable. However, the results of the Delphi performed among the WP 3.1 partners indicate that the semi-trailer obstacle will not stop the introduction of automatic handling, for two reasons:

?? Semi-trailers represent a relatively small percentage of the combined transport market (about 10%)

?? Technical progress will solve the problem. The Kombiverkehr prototype wagon seems to be a solution. This wagon has a fixed king-pin support and an open, more flexible “pocket”, enabling fully automatic transhipment of the semi-trailers.

4.11.9.4 Terminal Length and Rail Access System

Many terminals have short transhipment tracks (450 m to 550 m), which means long trains must be split and serviced in two parts. This could continue to be the case for the majority of small and medium terminals in the near future. The reason for this approach is that during the terminal design phase, the infrastructure cost for a long transhipment area is compared with the infrastructure cost of a shorter transhipment area plus the additional operating cost for servicing the train in two parts. It seems that for small and medium-volume terminals this calculation comes out in favour of the shorter transhipment design.

The usefulness of the advanced rail access systems is strongly associated to the terminal length. Short loading tracks (300 m -400 m) made advanced (direct access) systems not very useful, as shunting procedures are necessary to split the train. Long loading tracks (600 m -750 m) but with dead end tracks reduce the effectiveness of the "Coast using momentum" system (but not of the "Slewing catenary" system). Both techniques require complicated installations on site, such as signalling of transhipment tracks, electrified switches and overhead junction crossings.

4.11.9.5 Terminal Working Hours

Currently, most intermodal transport terminals operate a two-shift system – morning and afternoon. Large maritime terminals, on the other hand, operate night shifts, and their experience can therefore be valuable. The Rotterdam ECT terminal, for instance, uses two systems to cope with the extended working period.

4.11.9.6 Handling Equipment Productivity

Equipment handling productivity is the result of many factors, including the following:

?? Basic service cycle (uninterrupted). This is dependent on equipment capabilities and ITU type, weight and sequence. Spreaders will need to be adjusted between successive containers of different length and between containers and swap bodies.

- Conflicts between equipment working in the same area. A 10% productivity loss was assumed. If the cranes are working individually (e.g. 250 m apart) there are no losses due to conflict, but there *are* losses due to imbalance of work.
- Conflicts between equipment and lorries. The involvement of lorries in the handling operation is a negative factor. As a result, store-to-train operations (and vice versa) are always faster than lorry service operations. Moreover, random ITU service (as opposed to sequential service) creates equipment travel times between successive activities..
- Operator skill. An experienced operator can “compete with” the productivity of an automatic system but cannot sustain this productivity for the whole shift. Productivity can be reduced by weather conditions, fatigue, mistakes, etc.
- Productivity losses due ITU re-shuffles in the storage area. If ITUs are stacked in the storage area, shuffles may be needed for handling ITUs that are not on top of the stack.

The following Table shows a comparative evaluation of alternative handling equipment based on a Delphi procedure conducted among the IMPULSE partners. The values associated with conventional equipment (reach stackers, gantry cranes, etc.) are based on real-world experience while the values for the advanced systems are based on simulations and pilot demonstrations.

	Reach stackers	Conventional crane	Krupp Fast Handling (rail side)	Krupp Fast Handling (road side)	Krupp Single Area Plant	Commutor 2 Rail-Rail	Commutor 2 Rail-Road (rail side)	Commutor 2 Rail-Road (road side)
Basic productivity (uninterrupted operation, typical ITU mixture)	24 ITUs per hour Strongly depended from transport distances.	30-32 ITUs per hour	65 Container per hour 69 Swap-bodies per hour 42 Semi-trailers per hour	79 Container per hour 58 Swap-bodies per hour 40 Semi-trailers per hour		300 ITUs per hour using 9 cranes		170 ITUs per hour using 4 or 6 modules
Productivity loses due to conflicts between equipment working in the same area	10%	10% Productivity loses In case that the cranes are working individually (e.g. 250 m distance) there are no losses due to conflict but due to imbalance of work	0% No losses due to conflicts with other equipment due to anti-collision equipment and the rail-side gantries are build to serve to neighboring swap bodies	10% Similar to conventional cranes		0%	0%	10% Similar to conventional cranes
Productivity loses due to conflicts between equipment and trucks	5%	5 % for both reasons		5% Truck deduction applies only to the roadside device as well as the				5% Similar to conventional cranes
Productivity loses due to operator skill (reduced productivity due to weather conditions, fatigue, mistakes)	10%		0% automatic operation			0% automatic operation	0% automatic operation	
Productivity loses due to storage area re-shuffles	Depending from mean stacking height. (Calculated by model)					0% No stacking		
Productivity loses due to ITU "searching"	10%	5%		Searching shall be neglected due to the in-build software tool for terminal		0%	0%	Searching shall be neglected due to the in-build software tool for terminal
	Values based on real world experience		Values based on simulation results and pilot demonstrations					

Fig. 4.11.9.6: Comparative Evaluation of Alternative Handling Equipment

4.11.10 Conclusions

This section aims to present and analyse basic design and organisation issues of combined transport terminals. The approach has been to incorporate "technical bricks" presented in previous workpackages of the project as well as in additional information gathered by means of interviews with specialists (both inside and outside the IMPULSE consortium) in related areas. Delphi operations carried out among the members of the IMPULSE consortium to identify the consequences of adopting advanced transhipment equipment, rolling stock and supporting systems/devices. The conclusions arisen from this analysis are:

Combined transport terminals consist of a wide range of installations, ranging from simple terminals providing transfer between two or three modes of transport, to more extensive centres providing a number of value-added services such as storage, empties depot, maintenance, repair, etc. However, the main terminal activity is the efficient (and cost-effective) ITU transhipment.

Effective terminal design can increase the capacity of a terminal and/or reduce its operating cost. The current work has addressed many design/operation parameters (rail-side access, terminal length, distance between tracks, shunting operations, train/wagon/cargo inspections/checks, truck arrival patterns, conventional and advanced handling technologies for low and medium/large terminals, anti-sway systems, semi-automatic equipment control, handling equipment productivity, terminal working hours etc).

Focus was given in the identification of “technological bricks” that can increase the productivity of the terminals. The compatibility between the above “technological bricks” was investigated, efficient combinations among technological bricks (technological parcels) was detected and in addition, efficient combinations between technological parcels and advanced forms of rail operation have been identified.

The main results arisen from the analysis are presented below.

4.11.10.1 Rail-side accesses and advanced access techniques

Terminal access from the rail side is organised by the railways. The specific local situation will determine the configurations of mainline reception/delivery sidings, storage sidings and transhipment tracks. Preferable, the terminal should be accessible from both ends, with trains entering from both directions but many terminals exist that have dead-end tracks (only one access direction). Rail access is not usually electrified, which implies a change of locomotive. However, this is required, as the loading tracks of the terminal cannot be electrified because the units are lifted by portal cranes or reach stackers and it is therefore advisable to install an overhead line due to limited accessibility. Time is clearly lost, firstly by the change of locomotive (a shunting locomotive replaces the electric locomotive and vice-versa) and secondly by the move from the reception track to the loading track. Two ways of improving this situation have been further analysed:

- Use a slewing catenary on the loading track. This system yields significant time savings. Following the arrival of a train hauled by electric traction, the catenary withdrawal device line to one side (over the entire length of the train) and allows work to be carried out above the train in complete safety. One weak point of this system is that the usual configuration of tracks under the crane permits only one loading track per crane to be equipped with such a system. A new terminal design, however, can incorporate many slewing catenary devices (e.g. the Commutor concept).
- Allow the train to coast from the main line into position on the transhipment line. The train enters the terminal with the pantograph lowered and stops when the

electric locomotive is positioned under the overhead on the far side, so that it will be able to move off. Studies and a pilot demonstration have led Deutsche Bahn (German Railways) to conclude that the "coasting" technique is feasible. Following a trial phase, such a system was introduced at München-Riem in 1994 and in Hamburg-Billwerder in 1996.

Some specialists expressed doubts as to whether this rolling-in speed could be achieved in all terminals. The alignment of the access track in some French terminals imposes significant limitations, for instance, and high winds plus wagons rolling badly could also pose problems. Another disadvantage is that the system requires a terminal with separate entry and exit tracks. Otherwise (e.g. in half modules with a dead end) the electric locomotive will be stuck in the transhipment area dead end.

Both techniques require complicated installations on site, such as signalling of transhipment tracks, electrified switches and overhead junction crossings. Moreover, both techniques have limited effect when the trains have to be cut in two in order to fit into the transhipment area, which is determined according to the terminal length. The issue is analysed in the following paragraph.

4.11.10.2. Terminal length and Associated Inconveniences

Most of the existing terminals have short transhipment tracks (450 m to 550 m), which means long trains must be split and serviced in two parts. This could continue to be the case for the majority of small and medium terminals in the near future. The reason for this approach is that during the terminal design phase, the infrastructure cost for a long transhipment area is compared with the infrastructure cost of a shorter transhipment area plus the additional operating cost for servicing the train in two parts. It seems that for small and medium-volume terminals this calculation comes out in favour of the shorter transhipment design, because many trains will not exceed this length in the initial phase of operation.

The usefulness of the advanced rail access systems is strongly associated to the terminal length. Short loading tracks made advanced (direct access) systems not very useful, as shunting procedures are necessary to split the train. Long loading tracks but with dead end tracks reduce the effectiveness of the "coast using momentum" system (but not of the "slewing catenary" system).

4.11.10.3 ITU Stacking – Potentialities and Trends

ITU stacking reduces storage requirements and mean travel distance (for mobile handling equipment) or gantry span (for gantry configurations where the storage area is located between the gantry legs). On the other hand, ITU stacking increases handling activities, since it generates a number of shuffles (rearrangements required in order to provide access to the ITUs that are not on top of the stacks). Currently, the mean stacking height in the majority of rail terminals is very near to 1. Containers are usually stacked one or two high, while (exceptionally) an empty (box-type) swap body can be placed above a loaded one.

This situation can be improved on. It should be noted that conventional gantry cranes have to leave a ground-to-spreader height of 9.9 m to allow a semi-trailer to pass over another semi-trailer on a pocket-wagon. This minimum crane height allows a stacking height of “2+1” in the storage area (two units stacked plus a pass through corridor one unit high). Experience with maritime operations indicates that a mean stacking height of 1.5 can be achieved without significant time losses due to ITU shuffles, even with random pick-ups. As an absolute maximum, units can be stacked three high for storage-to-train activities (see the RSC Rotterdam terminal), but this requires an information-based system and dedicated stacks.

It must be noted that there are technical solutions where ITU stacking is undesirable for operational reasons. Some future intermodal terminals will probably operate with a low stacking height ratio.

4.11.10.4. Train, Wagon and Loaded Cargo Inspection/Checks

A number of safety controls are carried out in terminals: Technical inspections on empty container wagons before they are loaded again (Test WU 1K), test for conformity with load/gauge/vehicle specifications (Test WU 2K), test for damage caused by marshalling (Test WU 3K) and braking test. Despite the fact that some test can be performed in parallel, the total time required for safety checks related to combined traffic loading and train formation is quite long (about three hours using two people). An allowance of some minutes should be made in case an irregularity is discovered on a wagon, which a member of staff can eliminate on the wagon or in the train set. An additional allowance of some minutes should be made in case damaged wagons have to be removed from service or returned to the transhipment yard for correct loading.

If the trains only stop and are not split up and re-composed in the terminal – e.g. if shuttle trains are used – the vehicle test can be limited to checking the positioning of the load (providing tests on ITUs from the local dispatch are carried out by an inspector). It is sometimes also possible to carry out this positioning test using a camera and monitor on a stationary train (during loading) or on a train passing by slowly. Approximately 15 minutes must be allowed for this check when carried out by two people on a train 700 m long.

4.11.10.5 Conventional handling technologies for medium and high-volume terminals

Current medium/high-volume technologies for combined transport terminals are based on rail-mounted gantry cranes (pure system), combinations of gantry cranes and reach stackers as well as in combinations of gantry cranes, reach stackers and transport devices (e.g. the multi-trailer system)

The reach stacker is a low cost, very flexible equipment but the fact that cannot stack very densely, requires a great deal of space for manoeuvring and robust pavement significantly, reduces its value for medium-volume and high-volume terminals.

Gantry cranes on rubber tyres are cheaper to purchase and maintain than rail-mounted gantry cranes and are more flexible (no rail tracks). However, there are limitations on their span and they are less capable of being automated. All experts/terminal operators interviewed for the purposes of this report expressed negative views on this equipment in comparison with reach-stackers and gantry cranes.

Electrically operated rail-mounted gantry cranes are currently the dominant equipment for high-volume combined transport terminals. The development and use of new types of ITU on the European market (swap bodies and semi trailers) led to the modernisation of cranes and to their being fitted with grapple-arms to permit the handling of the corresponding ITU from underneath.

4.11.10.6. Guidelines for Future Combined Transport Terminals

The present inconveniences due to inadequate terminal infrastructure revealed the need for improvement terminal designs.

In France, in terminals built in the coming years, the following points will be taken into consideration:

The tracks should be 750 m long, so as to be able to receive the longest trains in one piece. (*)

Each yard should have three such tracks

There will be large areas dedicated to storage

There will be no dead end. This will allow access to the terminal via two rail access points.

There will be two sets of points, to allow two locomotives to enter and leave the terminal at the same time.

Ideally, a number of sidings will be attached to the terminals so that idle trains (i.e. those that have already been loaded or unloaded) can be parked outside the terminal. Ideally again, these sidings will be located behind or in front of the terminal, rather than next to it, so as to limit locomotive movements.

Since many shunting yards are no longer in use, the terminals will be built on these sites. This will allow existing infrastructure to be used. Furthermore, these old shunting yards generally already have numerous long tracks. They therefore look like ideal sites for the terminals of the third and following generations.

In Germany, the basis for the planning of intermodal transport transhipment terminals at Deutsche Bahn (German Railways) is the "Standard Module" which was co-ordinated with the Eisenbahnbundesamt (EBA, Federal Railway Authority Office) and the Eisenbahnunfallkasse (EUK, Railway Insurance Office) regarding its cross-section (crane bearing distance, distances between tracks, driving and loading lanes, storage lanes) on 23 January 1998. A standard module consists of three gantry cranes with a bearing distance of 39.80 m (centre of crane rail to centre of crane rail). These gantry cranes span:

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[*] It must be noted that this selection increases the terminal investment cost but reduces the train and terminal operating cost.

- Four transhipment tracks with a length of 700 m each
- One loading lane
- One driving lane
- Three ITU storage lanes

Outside the crane area and depending on the location, there are the driving lane for entry or exit to/from the transhipment area and the tracks for exchanges, by-passes and for stabling damaged wagons.

With a track occupation factor of 1.5, such a module has a capacity of 750 incoming and outgoing ITU per day in the flow procedure. For smaller traffic volumes, half a module is used to start with, i.e. length of the transhipment track = 350 m (dead-end track with connection at one end) and one or two gantry cranes.

This solution offers remarkable features:

- Direct train-to-road and train-to-train transhipment (up to 4 trains can be performed effectively).
- Reasonable compromise as it matches efficiently the operational requirements for block/group train service, limited gateway and (small) hub functions.
- Good utilisation of handling equipment – used both for rail and lorry service operations.

However, the service of rail and road in same area, and with same equipment, can create conflicts (productivity losses) and increase accident risk.

4.11.10.7. Identification and Location Devices

Rail and combined transport need identification and location systems to balance the advantages of their road transport competitors, and many systems are under development or have reached the pilot phase. In addition, the automation of handling equipment requires the use of this type of system/device. An inventory of the relevant systems includes Radio Frequency data transmission using terrestrial readers and tags on ITU, satellite systems, infra-red systems and optical systems. Different technological bricks are available and have partly been tested in the framework of IMPULSE, e.g. Digital Global Positioning System for fine positioning, Light Barrier Curtain, Video Cameras.

Even if one technology (or a combination of technologies) finally dominates the market, it will need a long introductory period before it is suitable for use with the majority of the world ITU fleet. The automatic handling sector is therefore focusing on optical identification and location systems (vision and laser based) which have the advantage of not needing tags on the ITU.

4.11.10.8. Advanced Handling Technologies and Pilot Applications

Despite the relatively high performance of the above mentioned conventional cranes, there are many situations in which the requirements impose significantly higher standards. In addition to accelerating the transhipment procedures, it is necessary to automate them, in order to reduce operational costs and to increase efficiency and labour utilisation rates. For example, the large central stations in the hub-and-spoke system can be equipped with automatic high-performance systems that allow manual transhipment from wagon to lorry (and vice versa) during the day, and transhipment from wagon to wagon during the night. This yields a significant increase in the time for which the terminal is operational. Demand for faster service also exists in small and medium stations, serving liner trains, which make intermediate stops for transhipment of loads. In these cases, serving the train in a short time allows it to continue its journey significantly sooner and at the same time permits the use of the installations by a larger number of trains.

A number of pilot installations are in operation, at which a continuous programme of improvements is being followed, aiming at the elimination of all existing technical deficiencies. The present work focuses in the advanced systems developed by Krupp and Technicatome due to the fact that both industries have participated in the project and provided the necessary information.

The main difference between the Krupp fast handling system and all other systems is that transhipment is undertaken from a slowly moving train. The system works fully automatically (except for lorry operation). Based on the “moving train” technique the company developed the “Single Area Variant of the Krupp Fast Handling System” suitable for medium volume terminals.

Both Krupp designs offer significant advantages:

- Flexible layout - Area savings can be achieved
- Under the assumption that the trains can be used immediately (for other transport activities), this service maximises utilisation of rolling stock and shunting area
- High handling productivity due to specialised equipment but reduced equipment utilisation factor due to separation of activities and extended transport distances
- Elimination of conflicts between train and lorry transhipment operations
- Improved safety conditions in the transhipment area

The Technicatome’s Commutor system was designed for a hub railway station with nine tracks, each capable of receiving seven trains of 33 wagons per day (the system operates 14 hours/day). The system includes 33 cranes which are moving perpendicular to the rail tracks as well as shuttle-wagons that operate longitudinal. The company has developed also “lighter” versions, for rail-rail and rail-road transhipment where a train is processed in approximately two hours. All the above Technicatome designs offer significant advantages:

- Very fast handling (due to multispreader system)
- Fast rail-side access (due to overhead slewing catenary)

However, the need for specialised wagon and limitation to containers and swap bodies has hampered inauguration of the system.

4.11.10.9. Technical Deficiencies and Associated Improvements

The experience of the above mentioned pilot systems (as well as relevant information concerning other pilot systems) reveals that further development is necessary to overcome some technical deficiencies. These “weak” points are:

- The automation of the positioning of the wagon pins that keep the ITUs on the wagons. The positions of pins on wagons have to be changed during the unloading and re-loading phase if the ITUs to be transferred have different lengths. Research is concentrating on automated devices located on wagons and on the development of a special robotics system.
- The need for compatibility between all existing rail stock and all existing types of ITU. Despite standardisation efforts, the European intermodal network still includes many types of wagon and ITU, (ISO containers, inland containers, swap bodies, grapple arm semi-trailers) of various sizes.
- The lorries service. Although the transhipment of cargo between trains or between trains and storage area can be automated, there are significant difficulties in the automation of transhipment to/from lorries, as the drivers cannot always park with the precision required by automated systems.
- The loading/unloading of semi-trailers that seems to be a very difficult task for all automatic handling equipment types. Pocket wagons can accommodate the trailer wheels but the king-pin support for the wagon must be moved to the correct position by hand. However, the semi-trailer obstacle will not stop the introduction of automatic handling, for two reasons:
  - Semi-trailers represent a relatively small percentage of the combined transport market (about 10-12%, dependent on corridor).
  - Technical progress will solve the problem. The Kombiverkehr prototype wagon seems to be a solution. This wagon has a fixed king-pin support and an open, more flexible “pocket”, enabling fully automatic transhipment of the semi-trailers.

The (pilot) advanced systems faces the above weak points by allowing a minor human intervention (e.g. for wagon pin positioning, king-pin adjustment, semi-automatic operation of the road-side cranes) and balancing their weaknesses by offering high productivity. They are capable to operate with high speed and they are supported by advanced/automatic control systems. The storage area in Krupp system -for example- is managed automatically in that a storage management program optimises the routes taken by the operating equipment and therefore prevents, as far as possible, any re-stacking procedures being necessary by taking into account train time tables. A comparison between conventional and advance system –in terms of productivity- is presented in the following paragraph.

4.11.10.10 Handling Equipment Productivity

Equipment handling productivity is the result of many factors, including the following:

- Basic service cycle (uninterrupted). This is dependent on equipment capabilities and ITU type, weight and sequence. Spreaders will need to be adjusted between successive containers of different length and between containers and swap bodies.

- Conflicts between equipment working in the same area. If the (conventional) cranes are working individually (e.g. 250 m apart) there are no losses due to conflict, but there *are* losses due to imbalance of work.
- Conflicts between equipment and lorries. The involvement of lorries in the handling operation is a negative factor. As a result, store-to-train operations (and vice versa) are always faster than lorry service operations. Moreover, random ITU service (as opposed to sequential service) creates equipment travel times between successive activities. Advanced systems that offer separate service modules for rail and road are not suffer from these conflicts.
- Operator skill. An experienced operator can “compete with” the productivity of an automatic system but cannot sustain this productivity for the whole shift. Productivity can be reduced by weather conditions, fatigue, mistakes, etc.
- Productivity losses due ITU re-shuffles in the storage area.

An evaluation of alternative handling systems (based on a Delphi procedure conducted among the IMPULSE partners) resulted in values in the range of 15 to 24 ITUs/hour for the conventional equipment (taking into account all the above mentioned productivity losses). On the other hand, the advanced handling systems “achieved” values in the range of 42 to 67 ITUs/hour. However, it must be noted that the values associated with conventional equipment (reach stackers, gantry cranes) are based on real-world experience while the values for the advanced systems are based on simulations and pilot demonstrations.

4.11.10.11 Compatibility Analysis – Efficient Combinations

A compatibility analysis among the above mentioned “technological bricks” reveals that the advanced handling systems are well match with the other advanced “bricks” (rail-access, identification/location, advanced control systems etc) and in many cases there are essentially connected (forming efficient technological parcels). However, these advance systems –even thought they can operate in the today’s operating environment- need advanced rail operation forms in order to provide their optimal performance.

4.12 TECHNICAL-ORGANISATIONAL EFFECTS ON THE INTEGRATED TRANSPORT CHAIN (WP 3.2)

The works which are summarised in the following, have technically been co-ordinated by ERRI/SNCF (Workpackage Leader). Krupp, ERRI, Costamasnaga, NTUA and ETH IVT have contributed.

The aim of this document is to identify the technical and organisational effects of already existing technologies and operation forms as well as new ones on the integrated transport chain. The objective is to demonstrate the consequences of improved advanced transhipment equipment and rolling stock on the management of integrated terminals and their effects on the performance, cost-effectiveness and quality of service of the integrated transport chain. A cost accounting methodology will be introduced for future comparative and trade-off analysis. This is a first step towards the design of a macro-model. This macro-model will be used so as to identify transport scenarios which optimise door-to door flows in such a way that the competitive position of combined transport compared to road transport is improved.

4.12.1 Identification of Parameters

4.12.1.1 Cost Centres Along the Transport Chain

The following diagram gives a brief overview of the sequence of operations taking place between the consignor and the consignee. All along the rail haulage part of the integrated transport chain, three main cost centres can be distinguished:

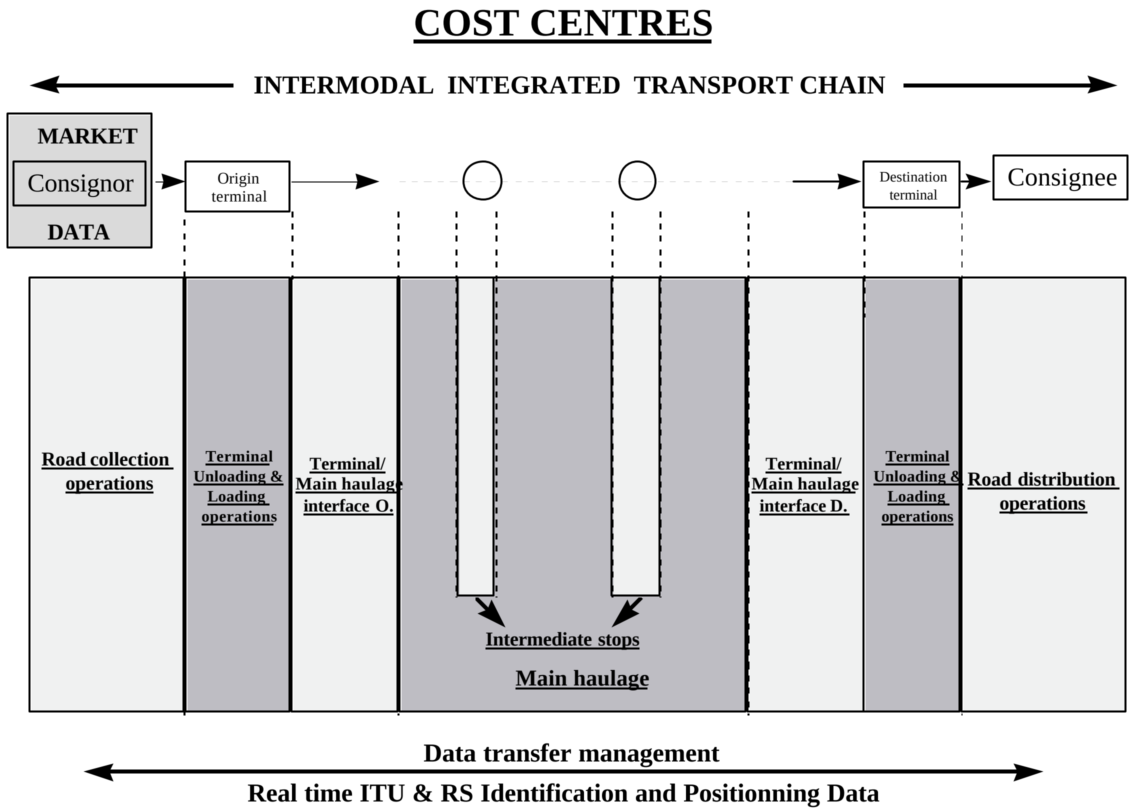

Fig. 4.12.1.1: Cost Centres

Road collection and distribution

The type of rotation defines if the road haulage correspond to triangular operations, distribution of empty ITUs at the customers, and the groupage freight operations The models of exploitation are different. The operators can have their own motor vehicle and realise themselves the distribution of ITUs at customers or, several companies are loaded by the operator of the distribution. In specific cases, road haulier uses the terminal that facilitates long transport distances. The composition of the vehicle intervene in the calculation of capital costs and in variable costs such as the consumption in energy or maintenance.

Main haulage railway lines sections

In case of intermediate stops (change of locomotive, liner train, nodal point, etc.), the rail haulage can be made up of several smaller rail haulages, the train composition (locomotive and wagons) being modified during these intermediate stops.

Intermediate stops along the main haulage

In what concerns what we called intermediate stops, three types of intermediate stops can be distinguished:

a) - A change of locomotive that can be caused by a border crossing, different voltage levels or the use of a non electrified railway line section.

b) - An "en route" stop of a liner train during which some sets of wagons are removed from the train and delivered to the local terminal or left there waiting for being picked up by other trains coming later, while other sets coming from this local terminal are added to the train.

c) - A stop at the nodal point of a hub and spoke or gateway system where some marshalling and shunting operations take place (ex: Qualitynet of Intercontainer in Metz Sablon, CNC nodal point of Villeneuve Saint George).

Terminal/main haulage interface

The operations taking place along the Terminal/Rail haulage interface can be the following ones:

?? Because of non electrification of terminal rail tracks, the electric locomotive is replaced by a diesel locomotive which have to deliver to the terminal a such number of wagons.

?? If the terminal rail tracks are not enough to receive the whole train in one piece, the train is uncoupled in several batches of wagons.

?? After trains' arrivals and before trains' departures, the safety procedures take place inside the terminal which consist in checking the suitability of the ITU to the wagon, brake test, and the optimal composition of the train.

4.12.1.2 Inputs

To carry out all the operations taking place in each cost centre, there is a need for inputs. Among the required inputs, we can distinguish:

?? ***The employees*** : road drivers, distributor ("le répartiteur"), mechanics, administration, responsible of communication, railway drivers, unskilled workers in charge of manoeuvres, maintenance workers, administrative workers, etc.

?? ***The material:*** lorries, trailers, wagons, locomotives, ITU (containers, swap bodies, semi-trailers), spare parts

?? ***The infrastructure:*** rail tracks, catenaries, signalling systems, land, buildings, civil engineering structures, communication structures, etc.

Since the European 91/440 directive has been passed, the infrastructure (maintenance, new investments) is managed separately from the running operations. One company is in charge of the infrastructure. Its revenues come from state subsidies and the price paid by the railway companies for the use of the infrastructure.

That is why we will consider the infrastructure separately from the other inputs. The average cost of each operation taking place in each cost centre depends on inputs. The following diagram gives a brief overview of how these inputs are integrated as direct charges in the cost of each operation.

4.12.1.3 Parameters

Road distribution

Problem of congestion: Collection and distribution operations take place on areas of market of short or average distances and generally near or inside the great cities. Operations are realised during the day between departures and arrivals of trains to the terminal. Intensities of trade raise during the day, the distribution can be undertaken during peak hours. This implies a slowing of the commercial speed of the road transport and thus limits the number of possible journey between the terminal and consignors.

City or motorway toll: During the distribution, drivers can take road axes of lower intensity of trade and where ruptures of load are less numerous. These axes limit the number of stops linked to the road signalling but have a cost per km to take into account in the total operation costs of distribution.

Transit time and commercial speed: Transit time depends on the distance covered. Outside the necessary time for the transhipment of ITUs, the time of driving depends directly on the covered distance but also on the commercial speed. Transports on short distances are made with commercial speeds lower than for the long distance. The time of transit will be nevertheless lower on shorter distances, due to distances covered.

According to forms of operations, the volume of stuffing of an ITU varies in function of the volume of goods to transport for a client. To minimise costs of transport by tons-km, a same ITU can be filled at several clients: it is an operation of groupage freight. The operation of stuffing is then fractioned in several stages, with periods of driving, loading and unloading of ITUs for each client. The numerous ruptures of load linked to stops at clients lower the commercial speed for an operation of collection of an ITU.

Existing goods flows: Location of the customers and market area.. In general, the combined transport is used on distances between 500 and 600 km. Clients are localised near terminals at relatively short distances. Terminals have areas of influence limited contrary to the road transport . Operators have to find their customers in areas of market closer to terminals minimise their costs of distribution. They can not widen areas of market either.

Number of ITU used: Drivers can leave ITU empty at clients for the stuffing of swap bodies and gain time for a additional rotation. Thus, the number of necessary ITUs on the totality of rotations is superior to number of ITU loaded and unloaded at the terminal. ITUs are rented by distributors. They are taken into account in the calculation of rental costs. Empty ITUs represent then a non negligible cost for the operator.

Number of journeys with empty ITUs: During a day, road hauliers are going to transport empty swap bodies at clients for their stuffing, then they are going to go to pick up an ITU at an other consignee with not loaded trailer. In certain case, the driver will be with only lorry to return to the terminal. On average, one observes that 37% mileages are undertaken with the alone lorry or to void, 51% in cost, 12% in groupage freight (when the vehicle is partially loaded). 37% of journeys are unproductive due to the mode of exploitation and to constraints of distribution operations.

Distance is going to intervene on the totality of organisational and technical parameters. On long distance, the average commercial speed is lower. Breaks of load are more numerous and slow the average speed of hauliers although concerning the road network, it is best quality and allows higher top speeds. Maintenance costs will have a lower share in the average total cost, costs being calculated in function of number of covered kilometres. Conversely, costs linked to energy consumption will have a greatest share. The importance of the distance will necessitate in some cases supplementary drivers according to the legislation of work and norms of security in different countries (time of rest , limited time of driving, ...)

Contrary to railway transport, there can not be flow massification on long distances. This implies an average total cost per ITU higher and limits the number of journey frequencies.

On short distance, road hauliers are more competitive in term of service quality and in term of prices. Thus, they multiply their number of journeys and optimises their round trip with the help of triangular transport operations. Journeys to empty are less numerous than they would not be for the railway transport, the railway network not favouring this operating mode.

Main haulage

Rail track profile: By the rail track profile, we mean the longitudinal section and the cross section of the rail track. If the rail track is not linear due to natural obstacles or due to other reasons, the commercial speed will decrease. If there are high slopes along the rail track, then, a powerful locomotive will be required so that the train can easily moves off after having stopped in the middle of a steep slope. Sometimes, it is even necessary in such cases to add a second locomotive so as not to restrict the tow weight. This will increase the capital cost linked to locomotives as well as the maintenance costs, hence higher costs/unit. The presence of high slopes will also decrease the commercial speed, hence a longer transit time.

Structure gauge: A low structure gauge will limit the height of the Wagon/ITU couple, leading to a lower tons/wagon ratio, hence a higher cost/t-km ratio. Low floor wagons can be used to carry standard ITU but because of their smaller wheels, the maintenance costs will increase and the train speed will be restricted, hence a lower commercial speed.

Is it an electrified rail track? Some rail tracks are still not electrified. This means that at a junction point between a non electrified and an electrified line, a change of locomotive will be necessary. Diesel engines are not necessarily a lot cheaper than electric locomotives but their maintenance costs are a lot higher (more or less 65% higher on average). On the opposite, the energy consumption level is lower for diesel engines (more or less 60% lower on average). The life expectancy of diesel engines is also considered a bit higher than for electric locomotives (35 against 30 years on average), hence higher capital expenses. But because the electric locomotives are largely more powerful than diesel engines, their commercial speed is much more important, hence lower driving costs. For commercial reasons, electric locomotives are mainly used today. Nevertheless, because of the electrification cost, there are still many non electrified rail tracks. The fact that non electrified and electrified rail tracks coexist on the railway networks implies additional costs and a loss of time. The loss of time is due to the break of load. The additional costs are linked to the fact that two different locomotives are necessary where only one would be enough. They are also linked to the necessary presence of unskilled workers for coupling and uncoupling the locomotives to the wagons.

Electrification system: Different electrification systems coexist along the European railway network. This is due to the lack of interoperability between the European countries but this situation can also exist within the countries. This implies again a loss of time due to the necessary change of locomotive and additional costs. Multi-power locomotive exist but they are much more expensive (more or less by 20-30%). There are some high quality and high speed international passenger train services that use such locomotives (e.g.: Thalys and Eurostar) for crossing borders without stopping at the frontier but their use is still very limited.

Signalling system: Different signalling systems coexist in Europe. This, again, implies a change of locomotive, and also sometimes a change of drivers at the border. In theory, "main haulage" drivers can be appointed anywhere. Nonetheless, for safety reasons, because they know some railway line sections better than other drivers do, due to their past experience, they are in general always appointed to the same railway line sections because of their good knowledge of the rail track profile and because of their good knowledge of the signalling system configuration along this railway line section. This eventually limits the movements of "main haulage" drivers between different passenger train services, between passenger train services and goods train services as well as between different goods train services.

Loading gauge: There are different loading gauges within Europe, implying the transhipment of ITU between trains (rail/rail transhipment) or a change of axles of the rail cars. These are lengthy operations that take a lot of time and that imply additional costs.

Traffic patterns: These ones will affect the commercial speed of trains. Different train services can run on the same railway line sections. Near and inside the bigger towns, the traffic density is very high. Furthermore, it increases during the peak hours. The commercial speed of a train will then depend on the number of trains running on the same railway section, on the train speed, and on the speed of other trains running on the same railway line section. If different trains with different speeds run on the same rail track, the slower one will have to park in a passing track while waiting for being passed. Because passenger trains go faster that goods trains, they have the priority on the rail track.

Passing track length: This will limit the potential length of the train which won't have to be longer than the passing tracks, hence a lower volume/train ratio, and a higher cost/tkm ratio.

Transit time: Several services are defined according to different speed limits. In France, trains can run with the following speed limits: 100km/h, 120 km/h, 140 km/h and 160 km/h. The higher the speed limit, the lower the driver costs and the higher the maintenance costs (especially for wagons). Nonetheless, if after arrival, the driver cannot be re-appointed to a new service, it is possible to consider that the driver costs are fixed, whatever the speed limit, given that the driver's daily salary is fixed, whatever the number of driving hours.

The traffic patterns will influence the commercial speed. The higher the traffic density, the lower the commercial speed. The more different trains with different speeds run on your railway line section, the lower the commercial speed. The higher the speed of the trains running on your own railway line section, the lower your commercial speed. The sequence of departures of the trains going out of a terminal can influence the commercial speed. If the traffic going out of a terminal is not smooth because of peak hours, it is possible that the commercial speed may decrease due to an overcrowded railway line section.

The operation form will influence the global commercial speed. The more intermediate stops there are between the departure point and the arrival point, the lower the commercial speed. Intermediate stops can be classified in the following way:

- Intermediate stop at a nodal point with marshalling (horizontal marshalling) operations or transhipment (vertical transhipment) operations. This is the case in "hub and spoke" systems and in gateway systems.
- Intermediate stop(s) where some ITU are removed from the train while some new ITU are also added to the train. We can consider whether vertical transhipment from/to the wagon to/from the truck or the storage area, or shunting operations (horizontal marshalling of wagons). This can be the case for some ITU in liner trains, circle trains and feeder systems but also for "hub and spoke" systems and gateway systems.
- Intermediate stops due to the lack of interoperability that implies a change of locomotive and sometimes of driver (different electrification and signalling systems, junction point between an electrified and a non electrified rail track), a change of axles or a rail/rail vertical transhipment (different loading gauges).

These intermediate stops will also involve additional costs linked to the unskilled workers in charge of manoeuvres and to the dedicated equipment.

Direct trains, block trains and shuttle trains do not imply intermediate stops.

The average use of the train capacity will depend on the potential volume that can be attracted and on the frequency of the service. If we consider that drivers costs, energy consumption and maintenance costs linked to the maintenance of the locomotive are fixed on a certain origin-destination relation, then, the cost per wagon, per ITU or per ton will evolve according to the average use of the train capacity. The following diagram shows the effects of different potential volumes and frequencies on the cost per wagon, per ITU, or per ton.

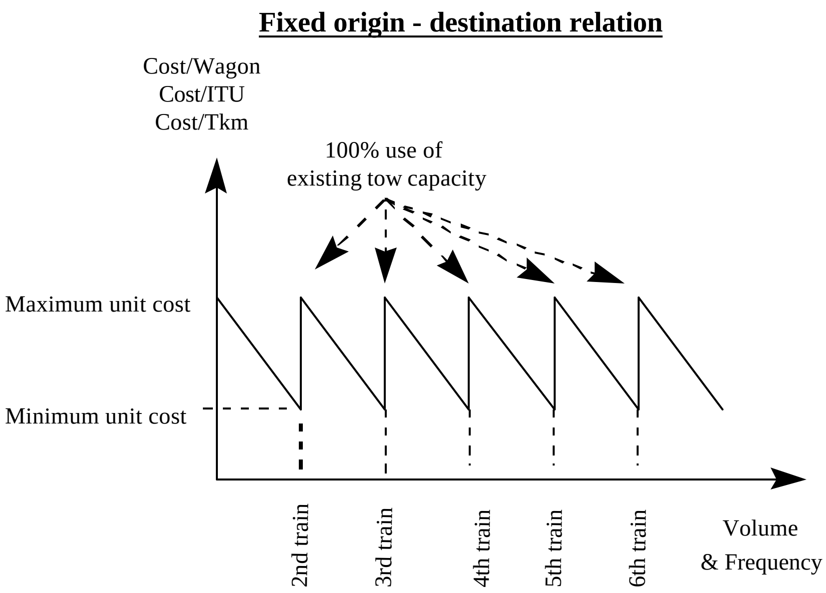

Fig. 4.12.1.3/1: Available Capacity of the Train and Frequency

Departure time window: This time window will depend on the operation form, terminal layout (small or big storage area, number of loading/unloading rail tracks, etc.) and organisational procedures of the terminal.

A short departure time window (this can be the case during an intermediate stop where some wagons are removed from the train while other ones are added to the train) could lead to an increase in employees' costs. For example, in a case of an automatic train coupling and sharing system used for a liner train service, a feeder train service, a "hub and spoke" system or a gateway system, or in case of an automatic vertical transhipment system, because of the short time window during which the operations take place, there is a need for more supervisors for quickly checking the train(s) before departure(s) according to safety procedures.

Price: Because price is one of the principal criteria taken into consideration by customers when choosing a specific mode of transport, it will have a great impact on the combined transport market share and then, on the volume of ITU carried by combined transport operators.

Sequence of departure times: The number of ITU, wagons and locomotives required to move the goods on the whole national and European network highly depends on the required carriage capacity during peak demands. If all departures take place in a short period of time, then, the required carriage capacity at this moment will be very important. This means that after arrival, many wagons and locomotives will be left idle. The higher the ITU, wagons and locomotives' idleness ratio is, the higher the capital costs per carried unit. This is a very important point given that combined transport services are organised around overnight jump schedules so as to offer a competitive transport service compared with the overnight transport services of their main competitors. Nonetheless, on long origin-destination relations where the journey takes more than ten hours, it is not possible to perform overnight services. In this case, implementing transport services during the day instead of the night will lead to a lower ITU, wagons and locomotives' idleness ratio, hence a lower cost/unit ratio. Some combined transport operators already perform such services but this is not the case in all countries.

Existing goods flows: The higher the volume, the higher the transport services' frequency, the better the quality of the service. The average use of the train capacity will also depend on the volume of ITU that have to be carried. The higher the average use of the train capacity is, the lower the cost/unit ratio. High volume goods flows are necessary to perform direct trains. At the opposite, "hub and spoke" systems, gateway systems, liner trains, feeder trains and circle trains are more suitable network operating schedules when coping with low volume goods flows.

Distance: Within the cost of a transport service, we can distinguish fixed expenditures (= F) and variables expenditures (= V). If, "d" stands for covered distances, and UC stands for unit cost, then:

$$UC/km = (F/d) + ((V*d)/d) = (F/d) + V$$

Given that F and V are fixed numbers, the higher the distance, the lower the cost/unit ratio. Furthermore, the distance can have a great impact on the wagons and locomotives' idleness ratio. If there is a train that performs a return service on a medium distance origin-destination relation (between 200 and 400 km) where there is no possibility to perform this service twice a day because of the existing level of good flows on this relation, then the wagons and locomotives' idleness ratio will be higher on services covering medium distances than on services covering long distances (more than 400 km). If, on the opposite, there is a possibility to perform a "twice a day" service on medium distances, then the wagons and locomotives' idleness ratio will be lower on services covering medium distances than on services covering long distances (more than 400 km).

Balanced/Unbalanced good flows: Because of the characteristics of combined transport (lack of flexibility), it is not easy to implement triangular service schedules, which is not the case of road transport. This means that intermodal transport is more easily exposed to the negative consequences of unbalanced flows. When flows are unbalanced, many trains have to run without carrying any goods. The higher the imbalance is, the higher the cost/unit ratio. This is why some combined transport operators such as Novatrans require from their customers (there are all road haulage companies) to have balanced flows before accepting to carry their goods.

Border crossing or not: Border crossing will imply additional costs due to necessary shunting operations and to the fact that two locomotives are needed where one would be enough. It also involves a longer transit time due to a lengthy break of load.

Demand patterns (seasonally patterns): The number of wagons and locomotives required to move the goods on the whole national and European network depends on the required carriage capacity during peak demands. In case of seasonally patterns, many ITU, wagons and locomotives will be left idle during the off-peak season. This involve high capital costs, hence a higher cost/unit ratio.

Are the ITU coming from outside Europe or going to other continents?: The customers requiring intercontinental carriage of goods generally have a specific logistics organisation. Because of the characteristics of intercontinental transport, it is often hard to implement a just in time logistics policy. So as to cope with irregular transit time patterns, they carry high buffer stock levels. This means that they are less sensitive to the transit time and more sensitive to prices. Furthermore, the arrival time of the ITU coming from other continents depends on the shipping companies' time schedules. Because of the tendency of "overpanamax" ships (these ships can carry up to 6 000 twenty feet equivalent units) to limit the number of stops on a same continent, and because of the tendency to build bigger and bigger container-carriers, there is a movement of concentration of the flows coming from outside Europe on a limited number of ports being able to cope with the unloading and loading operations of such ships. This leads to a huge peak demand for continental inland transport during some peak hours. This involves a higher cost/unit ratio (see above: "demand patterns" and "sequence of departure time") and a longer transit time due to a higher traffic density on the railway network (see above: "transit time").

All the previous elements can be summarised in the following diagram.

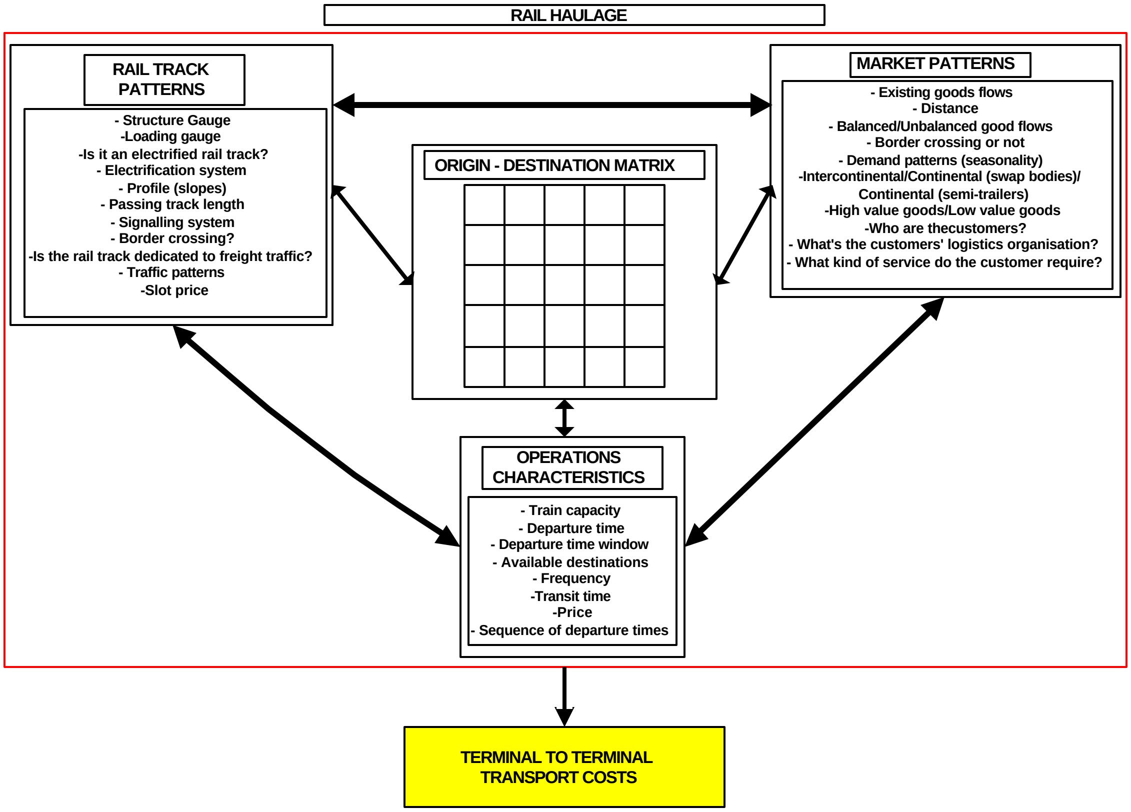

Fig. 4.12.1.3/2: Terminal to Terminal Transport Costs

4.12.2 Development of a Cost Accounting Methodology

4.12.2.1 Approach

Because of the aim of the workpackage 3.2, it seems useful first to describe conventional systems and their associated costs. This will be a reference point for studying different systems. This will also provide useful information for the future modelling tasks.

As stated in part 3 of this document, the integrated combined transport chain can be considered as a sequence of different operations. From an accounting point of view, a different cost centre can be associated to each sequential operation. Within each cost centre, different inputs have to be considered. Most of the time, these inputs are dedicated means. That is to say that the employees and material costs associated to one cost centre are dedicated to the basic operations taking place in the framework of these cost centres. Nonetheless, two exceptions have to be considered: the ITU that are used all along the integrated transport chain and the wagons that are used all along the railway part of the transport chain as well as in the combined transport terminals.

It is better to study marginal costs than complete accounting cost prices because the latter include indirect expenses that have to be spread among the basic operation units according to more or less arbitrary rules. That is why we will left apart indirect expenses such as overheads, administrative expenses, salesmen expenses, etc. The development marginal cost accounting methodology, as defined in the ECMT survey, is a good tool to study how the total direct operating costs would evolve according to different scenarios. In our cases, we will consider each cost centre separately. As stated in the ECMT survey, because marginal costs are highly dependent on some variables, considering a global average marginal cost is a nonsense. Nonetheless, considering global average costs of input units for each operation taking place within each cost centre is useful to identify the "global weight" of each basic input unit within basic operation unit cost.

That is why we will first consider the average cost of each input unit linked to one operation taking place in each cost centre and leave apart indirect expenses. Then, we will carry out a fixed/variable costs analysis that could be the basis for studying marginal costs in specific case studies, considering the evolution of both the level of activity and the introduction of new technologies.

With this methodology, we will be able to calculate the totality of costs for precise cases that will be studied in next works. A comparison of costs according to some different scenarios will allow to propose solutions adapted to flows and various layouts.[2]

4.12.3 Application

Although the goods transport database which has been elaborated in the Project covers whole Europe it has been evaluated to be more practical to concentrate on specific cases or corridors for the application of new train operation forms and study them more precisely rather then trying to propose a Europe wide system which must consequently be rather theoretical. In this sense a couple of candidate ”corridors” with potential interest have been evaluated and confronted with the database results to be finally grouped and selected. The Map is showing a draft location of the routes.

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[2] The above methodology was developed to late to be fully use in the project so that in parallel a more applicable cost accounting system was performed. It is reported in Chapter 4.13.

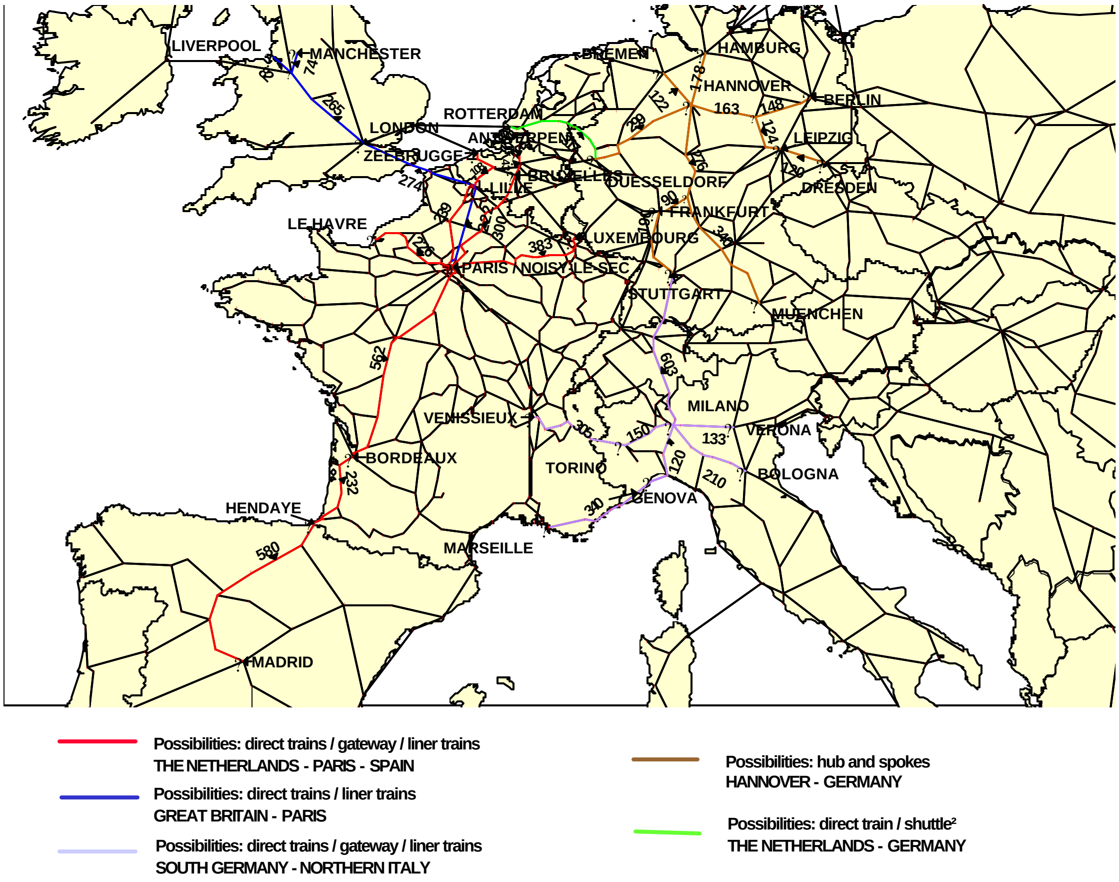
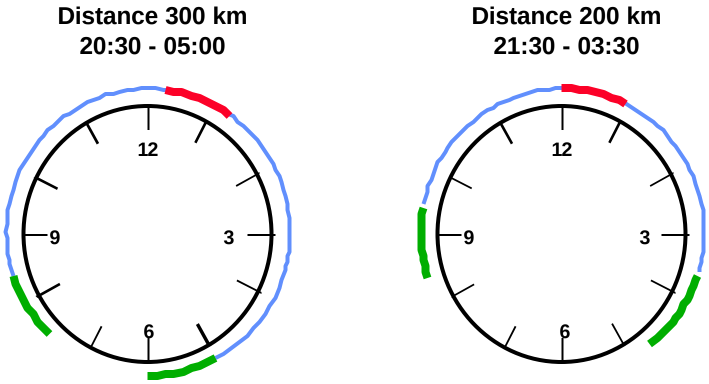


Fig. 4.12.3/1: *Location of Case Study Corridors*

In parallel, criteria have been discussed how to define the minimum volume required for a certain train service. For an innovative shuttle train the following has been agreed: 64 ITU per train, 75% utilisation, 10 tons per ITU, 20% market share of combined transport (”containerised-”) versus ”containerisable” goods, 2 load directions per night (“daily service”), 250 traffic day per year, 200- max. 400 km distance between terminals. This means, that all itineraries with more than 448 000 tons per year in the relevant distance range should be studied as potential relations.



Distance 300 km
20:30 - 05:00

Distance 200 km
21:30 - 03:30

Fig. 4.12.3/2: Time Windows – Innovative Shuttle Train

For the other train services like liner or group trains similar values can be given.

A further activity is the definition of cost places relevant for intermodal transport along the integrated transport chain including pre- and on-carriage. IMPULSE applies a transparent, analytic cost accounting with investment, depreciation, interests, maintenance, energy and personnel or - if not available - market prices or rental charges for specific issues.

4.13 COST-EFFECTIVENESS OF THE INTEGRATED TRANSPORT AND THE TERMINAL (WP 3.3/WP 3.4)

The works which are summarised in the following, have technically been co-ordinated by NTUA (Workpackage Leader). Krupp, ERRI, Framatome, Technicatome, Costamasnaga, Euretitalia, NTUA, ETH IVT, SGKV, DUSS have contributed.

4.13.1 Introduction - The Cost Issue in Intermodal Transport - The IMPULSE Approach

The cost issue in the Intermodal Transport was always a “grey” area. There is no commonly accepted cost methodology in the railways sector and very little information available concerning the breakdown of the operation costs. In many cases the rail prices include large overheads, internal cross-subsidy or are determined according to the highest price that the market can bear. In the pre- and post haulage legs the cost elements are more easily identified but the fuzziness of many operating/economic parameters does not allow a strait-forward conversion from costs to profits.

The IMPULSE project approaches the Combined Transport cost from a specific point of view. The identification of the effects that advanced technologies and advanced rail operational forms can have in the cost effectiveness and therefore in the associated market share. The relevant analysis was performed using a set of analytical and simulation models. The Figure 4.13.1/1 presents the subsystems analysed in relation to the modelling approach.

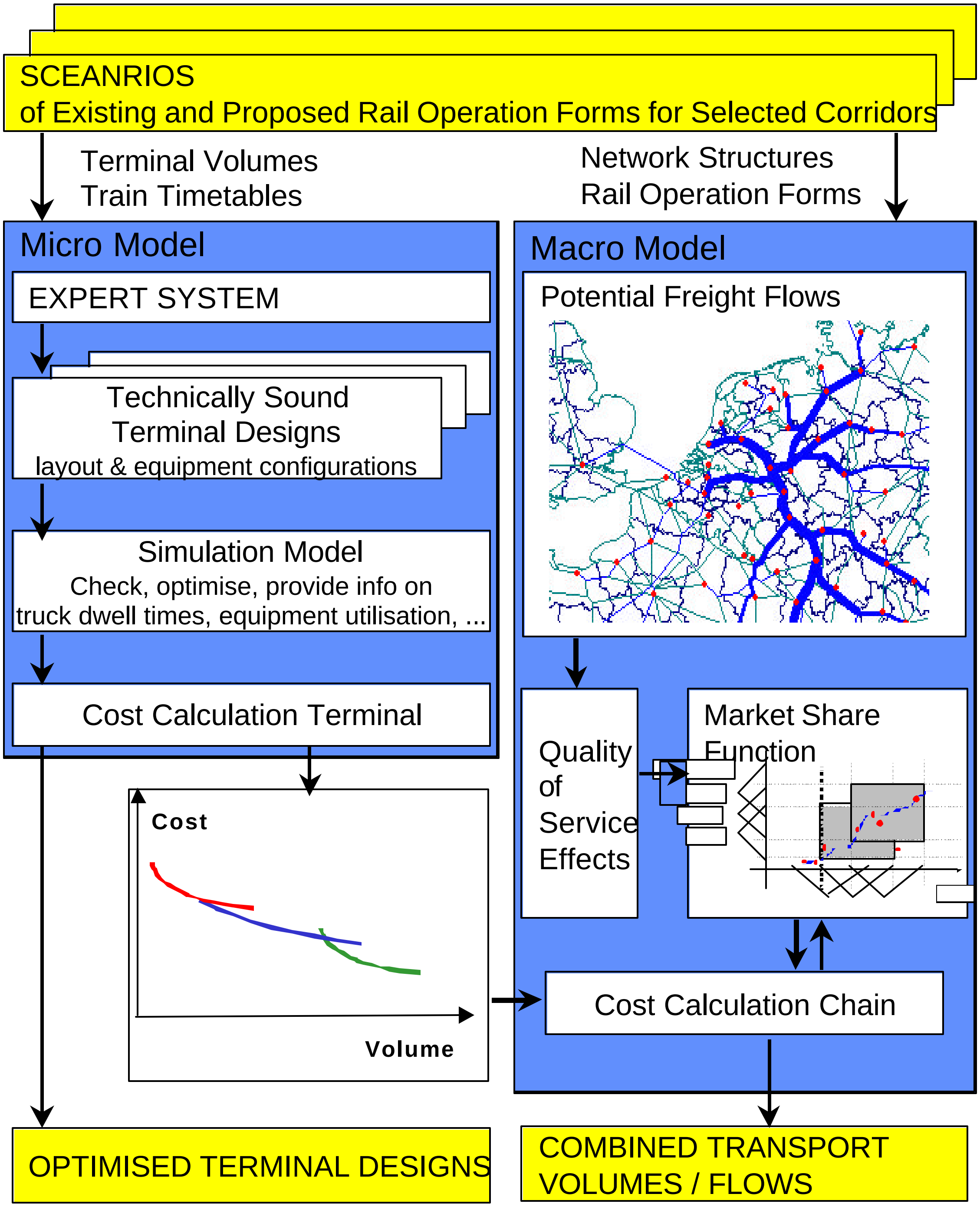


Fig. 4.13.1/1: The Modelling Approach

The pre- and post-haulage subsystem was analysed by use off analytical models (in logistic sheet form). The analysis was performed into two steps. In the first step fixed and variable costs are identified/calculated for alternative vehicle and ITU types, alternative collection/ distribution schemes and alternative transport ranges/distances combinations. In the second step the conversion of costs into market prices was performed using "reasonable" assumptions

The cost in the main haulage was split in two elements: Infrastructure cost and rolling stock cost. The infrastructure cost was calculated based on the "train path price" scheme according to associated train-kilometres and ton-kilometres. The rolling stock cost was calculated using analytical formulas for the following cases: Cost per hour for the marshalling operations and cost of running train (incl. wagons)

The terminal cost calculation was based on a micro-model that consists of an expert system and a terminal simulation module. The interface between the macro and the micro model has been established through "cost versus volume" curves for different rail forms and technologies.

The scope of the expert system is to produce alternative "technically sound" terminal designs while the role of the simulation model is to check, optimise and provide information about truck dwell time, equipment utilisation, queues at the gates for every design proposed by the Expert system. A "train arrival scenario" including train arrival times, number of ITUs to be unloaded/loaded and train departure times is used to "activate" the simulation. The output results are statistically processed and the resulting values are compared with pre-defined "quality of service" criteria.

The results of the cost calculations for the above mentioned sub-systems (or parts) of the transport chain are bring together in case studies demonstrating the potential of advanced train operation forms. The attractiveness of multi-modal transport chain from a multi-regional up to an European scale was calculated by using of a Macro model that allows the user to define networks, operational forms, terminal costs etc. and finds the optimal flows allocation.

In the following paragraphs a more detailed description of each of the above modelling block is presented.

Subject	Technical Approach	Results
Pre- and post-haulage	The analysis was based on analytical calculations and performed by use of logistic-sheets Step 1: Identification/ calculation of fixed and variable costs among technically-sound combinations of the following cost elements: ?? Three alternative vehicle types ?? Four alternative ITU types ?? Six alternative collection/ distribution schemes ?? Alternative transport ranges/distances Step 2: Conversion of costs into market prices by use of the assumptions in the following operating/ economic parameters: ?? ITU occupancy ?? Lorry utilisation factor ?? Transport company profit ?? ITU demand pattern during the day ?? ITU distribution in the terminal catchment area	Estimation of Market prices Sensitivity analysis
Main Haulage	The infrastructure cost was calculated based on the “train path price” scheme according to associated Train-kilometres and ton-kilometres The rolling stock cost was calculated using analytical formulas for the following cases: ?? Cost per hour for the marshalling operations ?? Cost of running train (incl. wagons)	The calculated cost elements are used in case studies demonstrating the potential of advanced train operation forms
Terminal operations	The terminal cost calculation was based on a micro-model that consists of an expert system and a terminal simulation module. The scope of the expert system is to produce alternative "technically sound" terminal designs while the role of the simulation model is to check, optimised and provide information about truck dwell time, equipment utilisation, queues at the gates etc.	Results concerning the terminal cost-efficiency for alternative technology configurations "Cost versus volume" curves for different rail forms and technologies to be used in the Macro Model
Whole transport chain	The results of the cost calculations for the above mentioned sub-systems (or parts) of the transport chain are bring together in a case studies demonstrating the potential of advanced train operation forms. The attractiveness of multi-modal transport chain from a multi-regional up to an European scale was calculated by using of a Macro model that allows the user to define networks, operational forms, terminal costs etc. and finds the optimal flows allocation.	Results on cost-effectiveness of advanced technologies and advanced rail operating forms

Fig. 4.13.1/2: Explanation of Basic Modelling Blocks

4.13.2 Cost Model for Pre- and Post-haulage

The analysis of pre and post haulage of the combined transport was performed by use of an analytical model developed by ETH. The model “recognises” three types of vehicles (single lorry, road-train[3] and articulated vehicle) and four basic types of ITUs (type C swap body with supporting legs, type A swap-body as well as 20' and 40' containers). Three different models/forms of distribution and collection of ITUs are analysed:

?? Operated by the terminal operator with his own fleet of road vehicles

?? The terminal operator uses/charges one or more road transport companies

?? A road haulier uses the terminal for long distance transport

For each of the above models/forms, three basic strategies/possibilities to collect and distribute ITUs are examined (wait for ITU stripping/stuffing, pick-up/deliver ITU on semi-trailer or supporting legs, combined two customers for pick-up/deliver activities) each one having two options (transport of one or two ITUs per round trip) thus leading to six cases. The cost calculation took into account alternative transport distances/ranges (10, 25, 50 and 75 Km for the models/forms number 1 and 2 while long distances (ranged from 200 to 400 Km) are used for the model/form number 3.

The cost calculations was performed between all “reasonable” combinations of the above parameters (models/forms, collect/distribute cases, transport ranges) while –in addition- sensitivity analysis was performed for some of the above parameters. Since the calculation results represents costs and not prices additional economic parameters (ITU occupancy, lorry utilisation factor, transport company profit, ITU demand pattern during the day, ITU distribution in the terminal catchment area) was assumed to give an indication of the market prices.

4.13.3 The Expert System

The scope of the expert system is to produce alternative "technically sound" terminal designs. The Figure 4.13.3 presents a screen view of the Expert system/model. The input fields enables the user to define the terminal design parameters (cargo volume, percentage of stackable ITUs, percentage of semi-trailers, length of loading tracks, cost of terminal land and maximum land available, mean stacking height, rail operational form), as well as handling equipment/systems (reach stackers, gantry cranes, transport devices, the Krupp's “moving train” technology -basic and single area variants- Technicatome's fully automatic rail-rail and rail-road configurations etc). Furthermore, the Expert system enables the implementation of a number of advance add-on technological devices that include advanced rail access systems, identification, location and positioning devices, semi-automatic control, information systems for terminal preplanning, shunting robots and rolling-stock related technological bricks.

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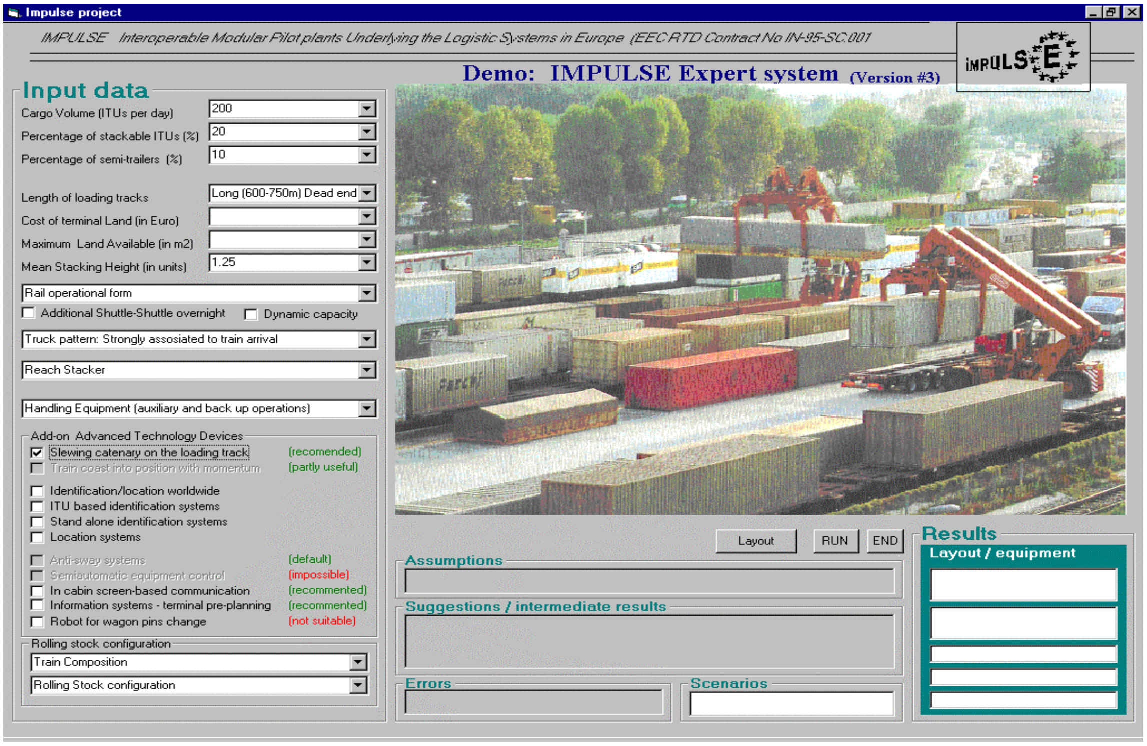
[3] Lorry with trailer.



Cargo Volume (ITUs per day): 200
Percentage of stackable ITUs (%): 20
Percentage of semi-trailers (%): 10
Length of loading tracks: Long (600-750m) Dead end
Cost of terminal Land (in Euro):
Maximum Land Available (in m2):
Mean Stacking Height (in units): 1.25
Rail operational form
☐ Additional Shuttle-Shuttle overnight ☐ Dynamic capacity
Truck pattern: Strongly assosiated to train arrival
Reach Stacker
Handling Equipment (auxiliary and back up operations)

Add-on Advanced Technology Devices
☑ Slewing catenary on the loading track (recomended)
☐ Train coast into position with momentum (partly useful)
☐ Identification/location worldwide
☐ ITU based identification systems
☐ Stand alone identification systems
☐ Location systems
☐ Anti-sway systems (default)
☐ Semiautomatic equipment control (impossible)
☐ In cabin screen-based communication (recommented)
☐ Information systems - terminal pre-planning (recommented)
☐ Robot for wagon pins change (not suitable)

Rolling stock configuration
Train Composition
Rolling Stock configuration

Fig. 4.13.3: Screen View of Expert System

4.13.4 The Simulation Model

The role of the simulation model is to check, optimised and provide information about truck dwell time, equipment utilisation, queues at the gates for every design proposed by the Expert system. The simulation model "includes" transhipment, siding and departure tracks as well as in and out gate, truck waiting and serving areas and ITU storage areas. The simulated equipment serves both rail and road sides according to a predefined service strategy. A “train arrival scenario” that include train arrival times, number of ITUs to be unloaded/loaded and train departure times is used to “activate” the simulation. For each train served, the model generates a number of associated truck arrival patterns. The output results are statistically processed and the resulting values are compared with pre-defined “quality of service” criteria.

4.13.5 The Macro Model

The macro-model was developed in order to analyse the attractiveness of multi-modal transport chain from a multi-regional up to an European scale. It allows to the user to define networks, operational forms, costs and delays calculations rules and a range of transhipment terminals. A freight demand is defined between regions and the model compute the flows carried by each operational forms simulated in the model.

The solver procedure try to find the optimal flows allocation on the operational forms and the optimal choice of terminal at the transhipment nodes in order to minimise the global operation cost taking into account the model constraints. As the costs depend on flows and that the distribution of flows depends on the costs, the model is formulated as an equilibrium problem.

4.13.6 Case Studies

Case studies undertaken in the framework of the IMPULSE Project have shown the potentiality of these train operation forms on short and medium distances. In particular the Shuttle²-train seems to be a very economic method of transport: It is defined as a fixed composition of wagon which is running twice a night between two terminals replacing one complete set of wagon. Besides the origin-destination volume of the terminal regions such trains benefits from an enlarged catchment area and transfer from other destinations (regional hub). Advanced handling optimally supports such logistics, which is fully automated and able to serve these trains in the night.

4.13.7 Cost Calculation: Method, Simulation Output and Results

4.13.7.1 The Method Used for the Cost-versus-volume Curve Production

The production of cost-versus-volume curves for various terminal designs is the core of the IMPULSE cost calculations. Figure 4.13.7.1 presents graphically the method used for the production of a typical cost versus volume curve.

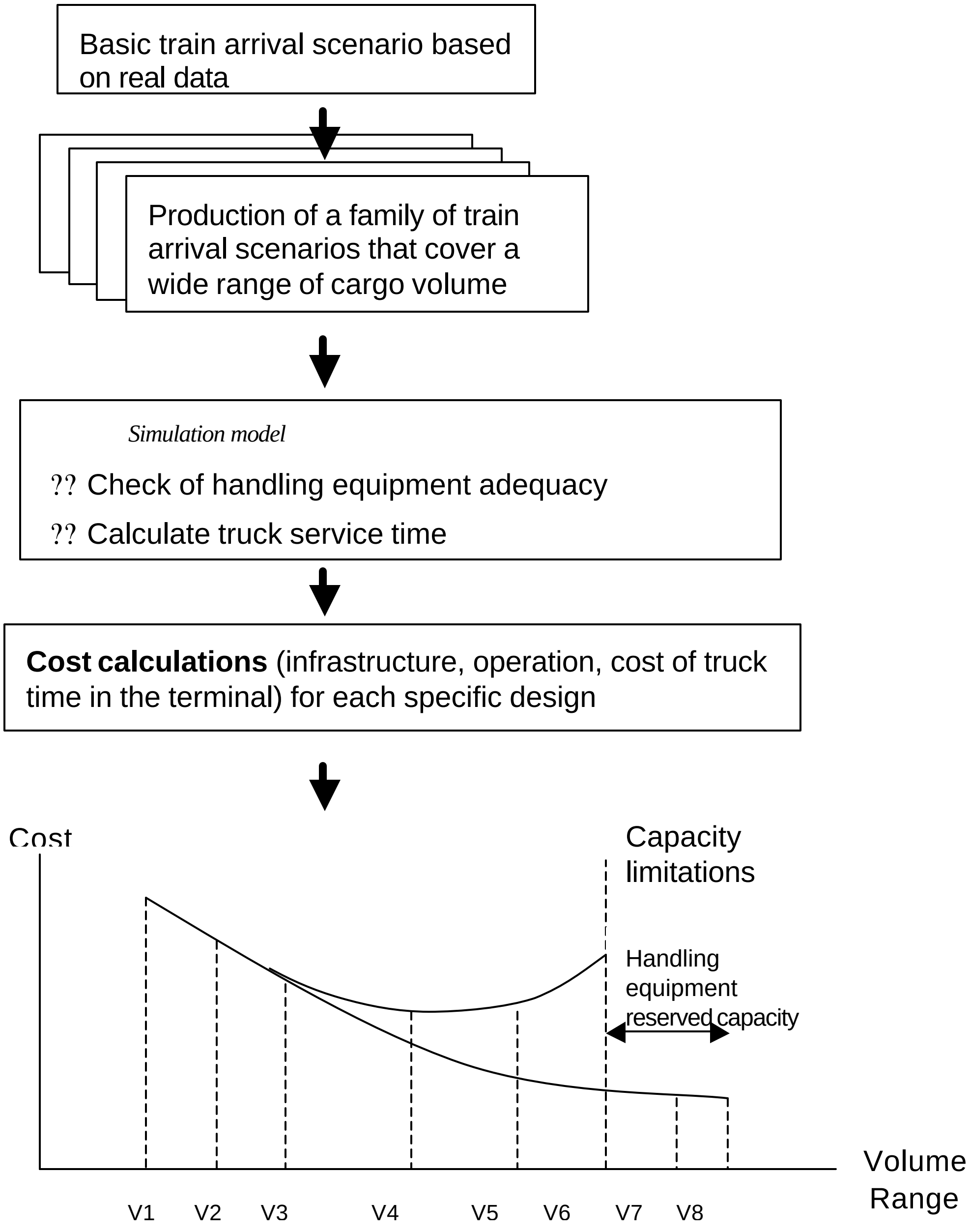


Fig. 4.13.7.1: Method Used for the Production of a Typical Cost Versus Volume Curve

The typical curves have two branches. The lower branch presents the system performance with a truck arrival pattern adapted to ITU **availability** while the upper branch presents the system performance with a truck arrival pattern adapted to train **arrival**. (the paragraph 4.13.8 contains information on this subject).

Normally each cost-versus-volume curve is ending in the volume where the terminal capacity limitations define. These limits are imposed either by track capacity limitations or by the inadequacy of the handling equipment to serve the trucks within a specific quality of service criterion.

Exceptionally, and in order to theoretically analyse the terminal performance, the simulation ignores the capacity limitation due to inadequacy of the transhipment/waiting track sub-system and continue to see the “reserved” performance of the tested handling system.

The procedure starts with a basic train arrival scenario. These scenario’s had been retrieved from the IMPULSE case studies for three categories: small, medium and large terminal. The train scenarios are rather conventional with majority of trains arriving during the morning and leaving in the evening.

Based on these basic scenario’s a family of train arrival scenarios that cover a wide range of cargo volume had been created (by considering less ITUs per train or less trains for each volume category).

Each scenario had been “imposed” to a terminal design for simulation. Both conventional and advanced technologies are used to serve all scenarios. They had to fulfil the quality criteria "95% of arriving trucks served within 20 minutes" for truck arrivals under an “adjusted to ITU availability” arrival pattern (see 4.13.7.4)

4.13.7.2 Capacity Limitations of Alternative Designs

As in most complex/multiple systems, the capacity limitation of the intermodal transport terminal is defined by its weakest sub-system. In practice, there are two major sub-systems that usually affect terminal capacity:

1. The capacity of the (rail-side) transhipment tracks.
2. The capacity of the terminal’s handling system.

In static capacity terms (trains arrive in the terminal in the morning and depart late afternoon) the terminal can serve only two trains per day and per (long) track (one coming, one going). Therefore the terminal capacity is restricted to 120 ITU/track (60 incoming plus 60 outgoing ITU per transhipment track).

Besides transhipment tracks, it is also possible to include additional rail tracks for the train that is waiting (these are called waiting tracks). For example, 2waiting tracks can be added to a 4-transhipment track, gantry-crane based configuration. That allows a “dynamic capacity” where more than two trains per day can be served on a given transhipment track. This of course requires enough volume to allow for further trains and it also presupposes that the trains arrive and leave during the day (a floating system). As already mentioned, the disadvantage of the flow system is that the incoming train has to be unloaded totally before it can be taken out of the transhipment area.

Additional capacity can be found in an adequate train timetable. This hypothetical situation can also be implemented if a significant number of liner trains visit the terminal and stay only during their service time.

As already mentioned, in order to analyse the effects of the above “additional capacity” as regards terminal performance, the simulations ignored the capacity limitation due to an inadequate transhipment/waiting track sub-system and the simulations were continued to show the additional performance of the handling system.

4.13.7.3 Calculation Principals/Basic Assumptions

The train schedules are based on 3 real train arrival patterns (for small, medium and large terminals) that had been identified in the Rotterdam-Duisburg corridor case study. A number of ITU were added (or subtracted) to create other (intermediate) train arrival scenarios that resulted in the desired terminal volume (between 150 and 1200 ITU/day).

The cost calculations for the Commutor-based designs were based on Technicatome’s information/calculations without a detailed check and making certain specific assumptions for this technology.

All the other designs were tested with the same simulation model and the cost calculations were performed in a standard way to enable comparison. Each design was tested to its limits. These limits are imposed either:

?? by track capacity limitations or

?? by the inability of the handling equipment to serve the trucks within a specific quality of service criterion.

The track capacity limitation is imposed by the terminal layout, the handling equipment capabilities and the rail operating form. For example, a terminal served by conventional gantry cranes that straddle four 700 metre transhipment tracks and serve direct trains (entering in the morning and leaving in the evening) has a maximum (static) capacity of 4 trains/day ? (60 outgoing ITU/train + 60 incoming ITU/train) = 500 ITU/day. The same terminal operating with a floating factor of 1.5 has a (dynamic) capacity of 500 ? 1.5 = 750 ITU/day.

The handling equipment limitation is imposed by the capabilities of the handling system (amount and type of equipment) together with a quality of service criterion for the truck sub-system. The associated service time is calculated from the time the truck is presented at the terminal gate until the end of the transhipment phase. The time from the transhipment phase to the terminal gate is calculated separately because it is determined by the length of the terminal and the exact position of the exit gate.

4.13.7.4 Terminal Performance Indicators

The above-mentioned quality of service criterion is “95% of the arriving trucks are served within 20 minutes”(4).

This criterion has some weak points:

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[4] This criterion was used in the EU research project SIMET and was confirmed by the operators who were interviewed.

?? It is a “threshold” that indicates that the terminal design or handling equipment configuration (amount and/or type) must change but terminal performance below this threshold can not be evaluated.

?? The criterion is “strict” (ERRI information indicates that certain terminals can operate with a limit for average truck service time of 20 minutes).

?? If the additional capacity requirements are not great, the terminal capacity can be expanded through small measures (e.g. by adding a reach-stacker in a gantry-crane based system).

Therefore a mixed approach was used. If a terminal design performs differently with different truck arrival patterns (cost curves with two branches) the quality of service criterion is imposed for the more “convenient” truck arrival pattern (lower branch). The system performance for the “less convenient, more realistic” truck arrival pattern was taken into account in the increased truck dwell time in the terminal.

Therefore the cost of truck time is used in two respects:

?? To take into account the cost of delays imposed on the trucks;

?? As a cost indicator that describes the additional cost due to the terminal operating above the quality standards. The terminal operator can accept the reduced level of service or he can apply measures (e.g. adding one auxiliary reach-stacker in a gantry-crane based system, as mentioned above).

4.13.8 Cost Elements Included in the Calculation

Before any cost calculation, the general framework should be set. In the IMPULSE project the following “cost views” were identified:

1. Full cost calculation covering the costs of terminal infrastructure, terminal operation and truck service time.
2. Partial cost calculation covering the costs of terminal operation and truck service time.
3. Partial cost calculation covering only the costs of terminal operation.

The first approach is useful for an internal comparison of different terminal designs. The second approach reflects the fact that some countries subsidise terminal infrastructure and the third assumes that the truck waiting time is already included in the pre-and end-haulage costs.

As a result of the above, the following cost elements were taken into account in the calculation:

?? Infrastructure (land acquisition, track formation, rail tracks, switches and signals, crane track, road lanes, gates, building, lighting, fencing, etc.);

?? Handling and other terminal equipment, e.g. communication equipment;

?? Maintenance and power;

- Personnel for the purely terminal operations. The personnel requirement is defined according to the terminal's volume: small (up to 250 ITU/day), medium (250 to 500 ITU/day) and large (above 500 ITU/day). It was assumed that this personnel also adjusts/locks the wagon pins (which is related to "handling"), but does not carry out the "inspection" work because that is related to "train operation" and was calculated separately.

- Train access (from main line to terminal sidings), which was assumed to cost 60 Euro/train (1 Euro/ITU) even though this cost can be a lot greater for terminals that are far away from the main electrified line or which require complicated marshalling manoeuvres. Further analysis (with respect to case study results) shows that the cost to enter from the main line into the transhipment tracks could be up to 3 Euro/ITU.

  It was also assumed that the cost of the short brake test (which is needed when the group of wagons is connected to the E-locomotive) is included in the train access cost.

- Rolling stock and cargo "inspection" (brake tests, cargo tests, etc). These tests are normally performed by the railway companies. If the trains only stop and are not split up and re-composed in the terminal, the vehicle test can be limited to checking the position of the load(5). We can distinguish between two cases:
  1. The conventional procedure where inspectors perform the operation. Assuming ½ work for 2 persons (including non-productive hours, additional work to identify damage, etc.(6)) gives 37.5 Euro/train (0.63 Euro/ITU) for the purposes of the IMPULSE model.
  2. Carrying out the positioning test using a camera and monitor on a stationary train (during loading) or on a train passing by slowly. Krupp (basic) Fast Handling Equipment follows that procedure. We assume that the crane supervisor is able to perform this operation (in parallel to his duties) and therefore no additional personnel or costs are charged.

- Truck service time. This was calculated taking into account the truck service time in the terminal and a rate per truck of 0.625 Euro/minute (300 Euro/day) (7).The truck service time was calculated by simulation. Two cases were considered:
  1. Terminal operation with a truck arrival pattern "adjusted to ITU availability". For example, this is the case with the Krupp (basic) fast handling system where the truck arrivals should be synchronised according to the ITU availability in the

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[5] Information collected for Deliverable D 11 "Design and organisational aspects of combined transport terminals", Chapter 2.6 Train- wagon and loaded cargo tests.

[6] According to D11 (see above), approximately 15 minutes must be allowed for this check if it is carried out by two people on a 700 m long train.

[7] A truck rate of 300 Euro/day was used. This complies with the German rate of DM 70,- per hour, which is practically 35 Euro/hour for pre- and on-carriage driving (incl. fuel, maintenance and wear & tear). The waiting rate should be less.

(one) transhipment track or in the storage area (and not according to the train arrival pattern in the terminal).

2. Terminal operation with a truck arrival pattern "adjusted to train arrival" (or the terminal opening hours if the train arrives during the night). This is the typical pattern in today’s terminals and schedules.

When a cost curve consists of two branches the upper one is system performance with the truck arrival pattern "adjusted to train arrival" while the lower one is system performance with the truck arrival pattern “adjusted to ITU availability".

The above distinction makes no difference for certain terminal designs. For example, in a terminal design (equipped with gantry cranes) that operates at its static capacity (e.g. trains are served in the 4 transhipment tracks and there is no train in the waiting tracks) all ITU are available all the time.

On the other hand, when a terminal operates at its dynamic capacity, the truck arrival pattern affects the truck dwell times and the terminal performance. With the truck arrivals "adjusted to train arrival", a mixed situation occurs. Some trains enter, are served and depart in a transhipment track while others need to be exchanged/swapped between transhipment and waiting tracks. When a train has to be moved from the transhipment area to the waiting area, a "clear the train" operation is necessary (ITU are unloaded from the train into the storage area). There are two effects of this "clear the train" operation:

1. Additional cost for shunting trains (shunting locomotive and personnel involved). The shunting cost (locomotive depreciation, maintenance, power, personnel and marshalling control) is 135 Euro per working hour (28 +6 + 75 + 3 + 44.2/2). Assuming 30 minutes for switching the 2 trains (including the intermediate locomotive travelling time) gives 78 Euro/working hour. In a recent French study(8) the cost of this procedure (working and non-productive hours) was estimated as 500 FF per action (about 80 Euro). Taking into account the above values, an additional cost of 40 Euro (80/2) was assumed for each train involved in the shunting operation. However, since the train switch has to be done twice (once in the unloading phase and once in the loading phase) each “train visit” is assumed to cost 80 Euro.
2. The other effect of the “clear the train operation” is truck delays because the same handling equipment is used for truck service and the "clear the train" operations. The truck delays in question were calculated by simulation (for three discipline rules). It should be noted that the organisational and discipline rules in a real terminal are more complicated than the ones assumed in the simulation (for example, in a real terminal, two short trains can be placed in one long transhipment track and/or trains can be moved to waiting tracks before the "clear the train" operation is completed, so the remaining ITU are not available at all).

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[8] SNCF, “Etude d’ analyse de la Valeur sur Le projet de Terminal De Transport Combiné de Vaires”, Organisation Litaudon Consultants, June 1998

The simulation performed for the IMPULSE project should be considered as an approximation that is sufficient for the modelling purposes.

The above truck delays are reduced/eliminated if a truck arrival pattern "adjusted to ITU availability" is used. This means that the terminal should pre-plan and announce the period when the trains will enter the transhipment area (and therefore the ITU will be available) so that the terminal visits of the relevant trucks can be programmed accordingly.

Alternatively, the terminal and the truckers must be synchronised using a “visit by appointment” system that enables the terminal to organise the pre- and on-carriage operations accordingly.

4.13.9 Simulation Model Results and Associated Cost Calculations

4.13.9.1 Simulation Output: Cost-versus-volume Curves

Figures 4.13.9.1/1 and 4.13.9.1/2 show the overall outcome of the simulations and the associated statistical activities. The cost-versus-volume curves shown cover a traffic volume that ranges from 150 to 1200 ITU per day.

Each cost-versus-volume curve represents one terminal design (layout and equipment configuration) operating according to a particular organisational scheme. The train arrival patterns are based on real data observed in the Rotterdam-Duisburg corridor while the truck arrival patterns are according to typical German experience.

Figure 4.13.9.1/1 shows a cost calculation that takes into account infrastructure, personnel, train access and truck waiting time (details of all the cost elements included in the calculation can be found in section 4.13.8).

The same signs are used in each figure to indicate a "continuation of technology". A particular technology can be followed through its performance in various situations: e.g. a transhipment module with gantry cranes can be seen in #4 through #6 through #8 to #12. Design #3 is a variation of #4, but for less volume, and #9 is a variation of #8 for a greater volume (higher performance).

Some curves have two branches. The lower branch is the system performance with a truck arrival pattern adapted according to ITU availability while the upper branch is the system performance with a truck arrival pattern adapted according to train arrival (section 4.13.8 contains more information on this subject).

Figure 4.13.9.1/3 shows a “composite curve” that can link up the terminal simulation with the macro-model. It is a kind of “minimum cost curve” that reflects a series of optimum technologies for various terminal designs and specific volume ranges based on a given conventional rail schedule.

Figure 4.13.9.1/2 shows a subset of cost elements (only operating costs).

Fig. 4.13.9.1/1: Comparative Cost Analysis for Alternative Terminal Designs (includes infrastructure, personel & truck time)

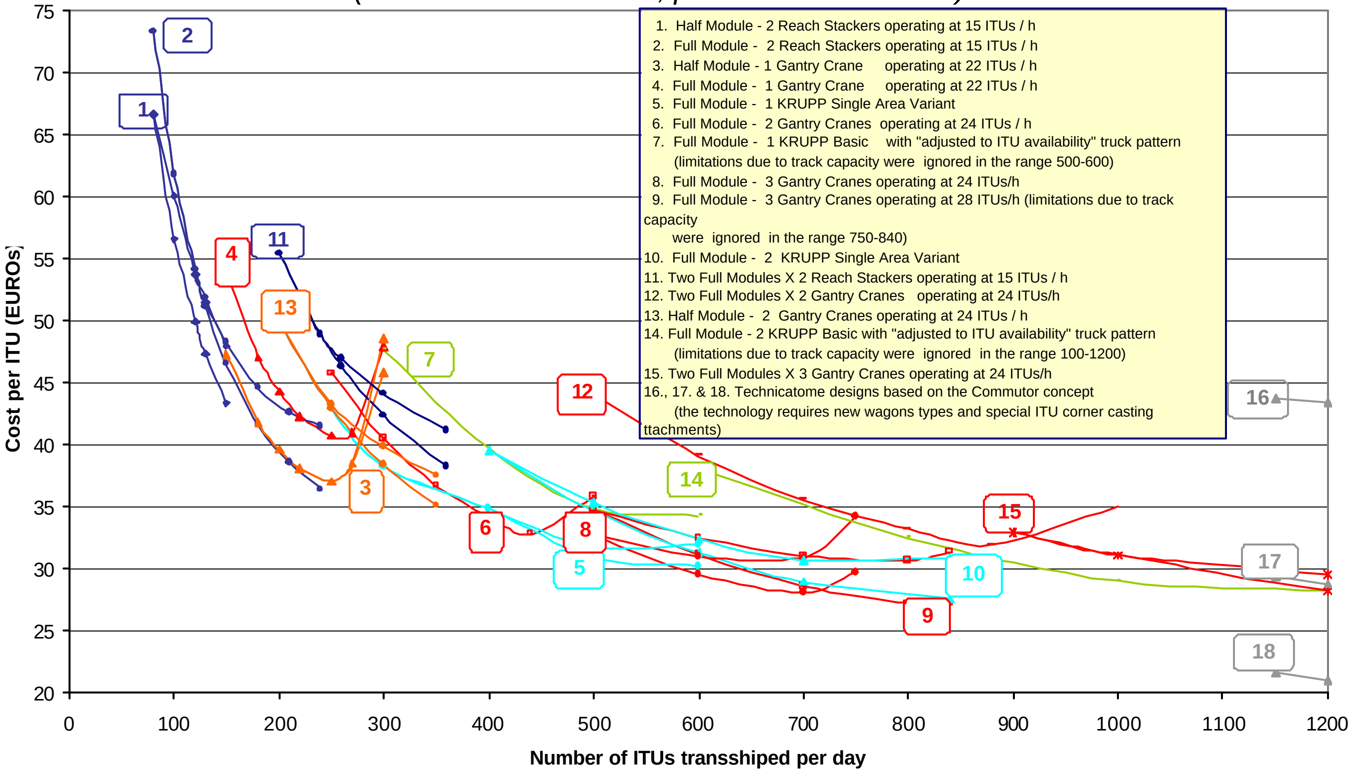


Fig. 4.13.9.1/2: Cost Analysis for Alternative Terminal Designs (only terminal operating costs)

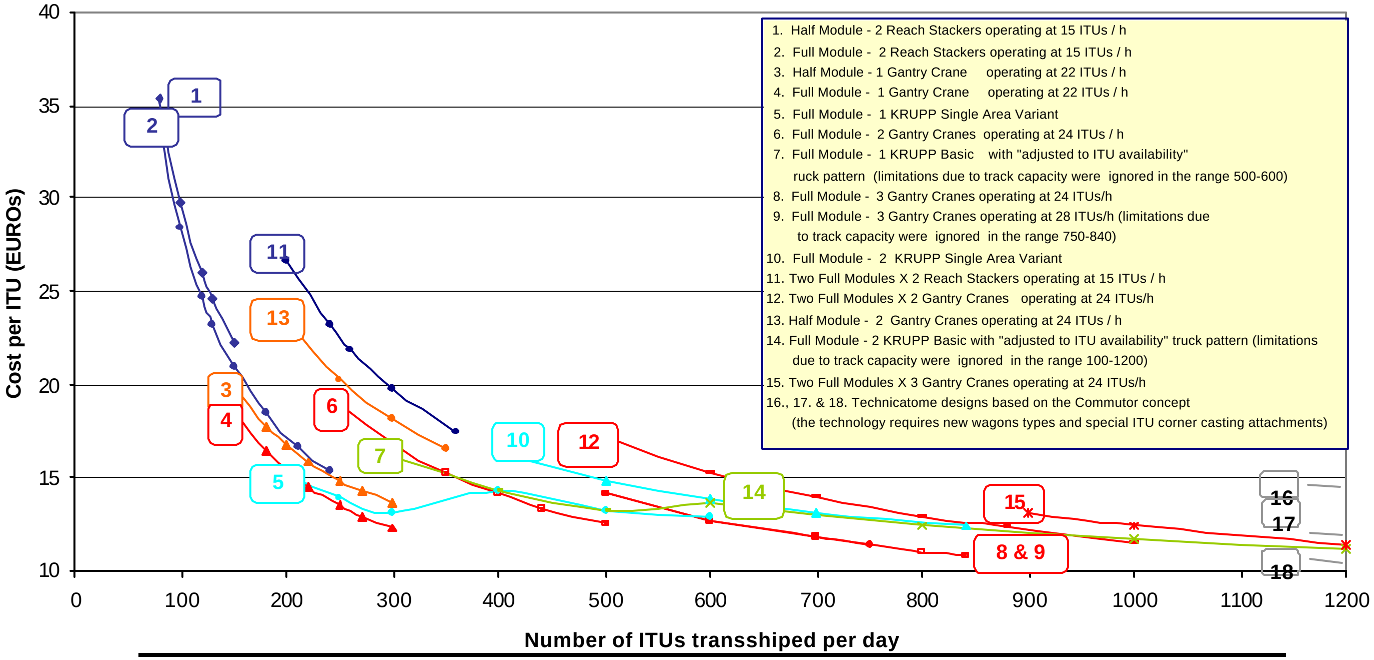
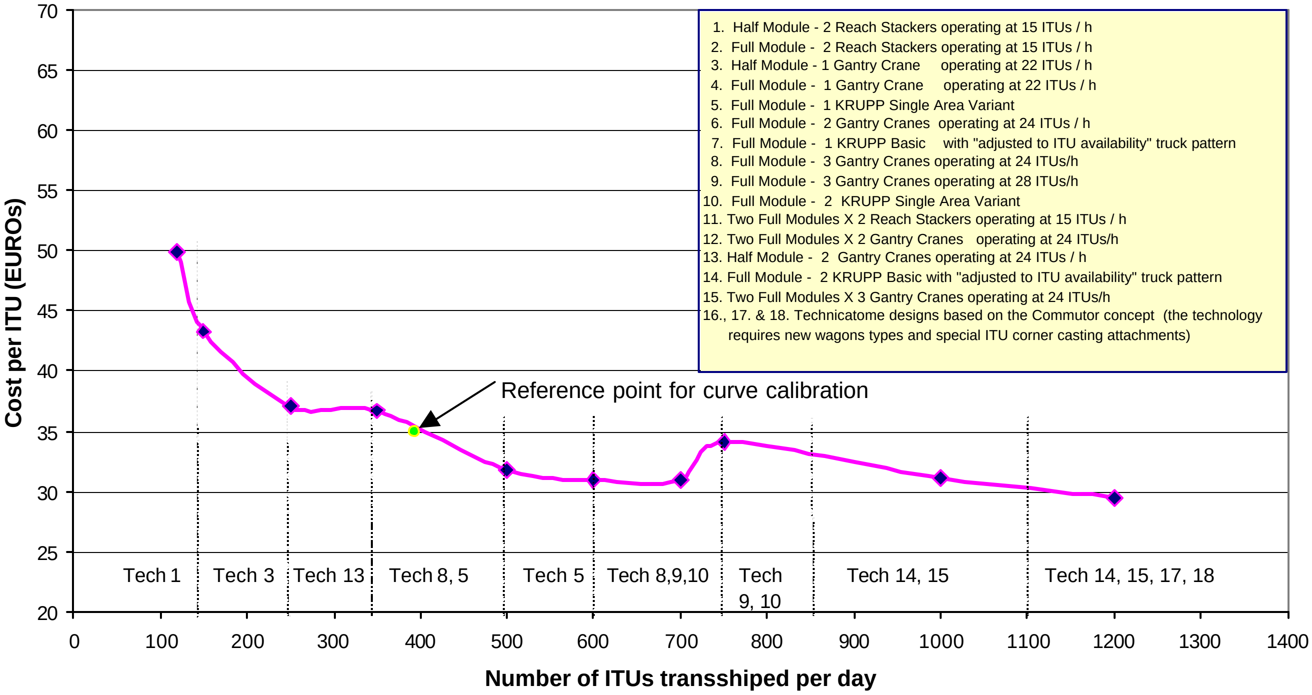


Fig. 4.13.9.1/3: Composite Cost curve for various terminal designs and optimum technologies for each range



4.13.10 The Cost-versus-volume “Composite Curve”

The composite cost curve reflects a series of optimum technologies for various terminal designs and specific volume ranges based on a given conventional rail schedule. The optimum technology is shown at each section of the curve.

The bottom part of Figure 4.13.9.1/3 shows the cost points that form the curve. It can be seen that these points do not always belong to minimum cost curves. Where a cost curve has two branches the upper one is selected since this branch was calculated using operating conditions similar to today’s terminal operating conditions. Similarly, minimum cost points that belong to advanced technologies (requiring advanced operating conditions) are abandoned in favour of the cost points belonging to conventional designs.

The general shape of the curve is what could be expected for cost vs. volume curves, i.e. relatively high costs for small volumes due to the initial infrastructure costs and then an asymptotic trend. The specific course of our curve is different because of the different technologies and part-curves that have been used. Two lows could be expected: one at about 250 ITU/day, where the half-module is fully occupied and a second at about 512 ITU/day, when the full module is occupied. Consequently there are two highs: one at about 380 ITU/day and a second at about 750 ITU/day due to the track capacity limits in conjunction with "flow operation"(9).

In those cases where the costs of different technologies are very close to each other they are all shown. Medium-sized and large terminals (more than 350 ITU/day) in particular provide more choice, whereas small terminals are dominated by conventional technologies if the performance requirements are not very demanding (conventional schedule).

The curve was drawn using specific IMPULSE-related assumptions as regards schedules, truck arrival pattern, technologies, performances and detailed costs to enable a very good internal comparison of different terminal designs and technologies. However, comparison with a "real life" situation might lead to astonishing results. For example, the handling charge or "price" accepted by the market is half of the calculated costs. A reference point has therefore been added to the curve for calibration purposes. This mirrors the variety of state aid in the rail infrastructure sector, e.g. funding of all capital investment by either credit which has to be paid back without interest, or 100% financing.

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[9] The theoretical values for the full module are 40 wagons x (1.5 ~ 1.6 ITU)/wagon x 2 (incoming/outgoing ITU) x 4 tracks x 1.5 (flow factor) ✍ about 750 ITU/day.

4.13.11 Selected Example Designs

The findings regarding the various terminal designs are presented and commented on in the following sections. The designs are grouped according to the type of basic handling equipment used. This gives five cases:

1. Reach-stacker based configurations
2. Conventional gantry-crane based configurations
3. The Krupp basic designs
4. The Krupp single-area variant designs
5. The Technicatome designs based on the Commutor concept

4.13.11.1 Reach-stacker Based Configurations

Terminal designs 1, 2 and 13 are based on a reach-stacker configuration. Design 1 is characterised by short (350 m) transhipment tracks, while designs 2 and 13 have long (750 m) transhipment tracks. Design 2 has only one rail track while in design 13 the terminal is located between the two transhipment tracks/sidings. All the above terminals are equipped with reach-stackers.

The reach-stacker is said to be low-cost, flexible equipment with a relatively low purchase price. The fact that this equipment cannot stack very densely and requires a great deal of space for manoeuvring significantly reduces its value for medium-volume and high-volume terminals. On the other hand, reach-stackers are widely used in many small/medium European terminals. The Italian combined transport network is based on reach-stackers. Moreover, reach-stackers are used in combination with gantry cranes. The RSC terminal in Rotterdam is a good example of efficient use of reach-stackers in a large terminal for truck service. The RSC terminal's practice indicates that an efficient pre-planning system (based on EDI information exchange) can increase the stacking density in the storage areas (e.g. three-lane, three-high stacking areas for ISO containers) and at the same time keep the ITU reshuffles at a relatively low level(10).

Taking into account traffic conflicts between equipment and trucks as well as an increased mean travelling distance between successive trucks to serve them (due to a low truck arrival rate that does not allow the grouping of truck services), the reach-stacker handling rate is assumed to be 15 per hour. However, the equipment productivity is not the dominant factor for terminal performance.

The terminal's capacity limit is imposed by the fact that reach-stackers can normally reach/serve only one transhipment track, namely the one which is near to the 15 m driving lane (they cannot straddle over loaded trains). Where proper infrastructure exists (embedded rail tracks), reach-stackers can also serve other tracks, but only when the intermediate tracks are not occupied by a train(s).

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[10] Information obtained for Deliverable D11 "Design and organisational aspects of combined transport terminals".

Evidently, more than one train can be served by switching the trains between the transhipment track and the waiting track(s) but many (costly and time-consuming) shunting operations are required. In addition the percentage of indirect (train-store-track and vice versa) movements is high (due to the frequent need for “clear the train” operations) and “inconvenience” and delays occur when trucks arrive to pick up ITU which are still on the trains in the waiting tracks.

This is why the total number of sidings (transhipment and waiting tracks) is kept relatively low. For example, in design 2 there is one transhipment and one waiting track. In terms of static capacity (trains arrive in the terminal in the morning and depart late afternoon) the terminal can serve two trains per day and therefore the (theoretical) terminal capacity is restricted to 2 ? 120 ITU.

The operating conditions are better when the terminal has two rail sides (see design 13) but in that case two 15 m zones should be provided for manoeuvring the equipment.

Comparison of the costs of reach-stacker based designs for small volumes reveals the importance of module length. "Half-modules" with short transhipment tracks are more economical than full modules, although the trains must be split in two.

4.13.11.2 Conventional Gantry-crane Based Configurations

Terminal designs 3, 4, 6, 9, 13 and 15 are based on a conventional gantry-crane configuration. “Conventional” means gantry cranes under manual control with a maximum theoretical handling rate of 30-35 ITU per hour, which – under real conditions – would be lower.

Design 3 is characterised by short (350 m) transhipment tracks, as opposed to the remaining designs which have long (750 m) transhipment tracks. Designs 3 and 4 have one crane operating at 22 handling operations an hour. Design 6 has two cranes operating at 24 handling operations an hour while designs 8 and 9 include 3 cranes operating at 24 and 28 ITU/hour respectively. All the terminal designs have 4 transhipment tracks, 3 storage lanes and 2 road lanes under the crane(s).

Electrically operated rail-mounted gantry cranes (RMG) are currently the dominant equipment for high-volume intermodal transport terminals. This equipment came into regular use in the early stages of intermodal transport. These cranes straddled one or more railway lines, roads or rows of stored transhipment units. They had a load-carrying capacity of 35 t and were equipped with a special arm for handling containers from top to bottom. The development and use of new types of Intermodal Transport Units (ITU) on the European market (swap bodies and semi-trailers) led to the modernisation of cranes and to their being fitted with grapple-arms to enable them to handle these new ITU from underneath. Modern types of crane have a load-carrying capacity of 41 t, can stow containers three-high and can transfer 30 units an hour (in uninterrupted operation)(11).

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[11] Information retrieved for Deliverable D11 “Design and organisational aspects of combined transport terminals”.

One-module Gantry-crane Configurations

The term “half-module” means a terminal with short (350 m) transhipment tracks. Since the gantry crane straddles 4 transhipment tracks, two long trains can be hosted, which gives a static capacity of 240 ITU/day (4 ? ½ ? 2 arriving/departing trains ? 60 ITU/train). The addition of two (short) waiting tracks gives a dynamic capacity of 360 ITU/day (240 + 2 ? ½ ? 2 arriving/departing trains ? 60 ITU/train) with the expense of the operations required to switch the train between transhipment and waiting tracks as well as the need for “clear the train” operations.

The simulations and cost calculations for the above half-module indicate that above 240 ITU/day the handling equipment is not adequate to serve the tracks at the assumed quality-of-service level (see Figure 8.1.a, curve 3).

These simulation results comply with the empirical “DB rule” which predicts 250 ITU per day as the limit for the 1 gantry crane module.

However, for low volumes the “half-module” design gives a lower cost per ITU transhipped than “full modules”, although the trains must be split in two. The saving is due to less road and storage pavement and the cranes and trucks driving in a longitudinal direction.

Design 6 consists of two gantry cranes (operating at 24 ITU/hour). The simulation reveals that the handling system performance was close to 500 ITU/day. Three cranes (design 8) extended the limit to 750 ITU/day but the handling equipment started to perform badly. These simulation results comply with the empirical "DB rule” which predicts 500 and 750 ITU per day as the limits for the 2 and 3 gantry crane configurations respectively. In contrast a 3-crane configuration handling at 28 ITU/hour performed well even when the simulation (ignoring the limit of 750 ITU/day imposed by the track) reached 850 ITU per day.

Two-Modules Conventional Gantry-crane Configurations

Terminal design 12 consists of two modules similar to design 6 (2 conventional gantry crane configurations operating at 24 handling operations per hour).

The infrastructure cost is assumed to be twice the infrastructure cost of design 6. Minor cost savings (e.g. one large in/out gate instead of two smaller gates) are ignored.

The truck cost was based on the truck dwell times of each module, and assumed to be equal to design 6, i.e. disregarding additional conflicts.

An additional cost with the two-module configuration is the internal transport of ITU between the two modules. The Busto-Arsizio II terminal reported 50 internal transports per day between its two modules. To include this cost type we had assumed a dedicated terminal truck and the associated personnel for two shifts. The associated costs (purchase cost of 120 000 Euro for the terminal truck, two shifts of drivers) were included in the terminal cost calculation.

4.13.11.3 The Krupp Basic Designs

The “Krupp basic” equipment was used in two designs (7 and 14). Both designs use the “moving train” technique. Design 7 has 6 waiting tracks for the incoming/outgoing trains plus one additional track for the transhipment operations. Design 6 was selected for compatibility with “equivalent” conventional crane designs with 6 tracks (4 transhipment plus 2 waiting tracks). The storage area is also as determined according to the “equivalent” conventional crane designs. Those designs generate a long module with a productivity of 500-600 ITU/day, which is greater than the original Krupp design (with a 200 m storage area).

This effort to “conventionalise” the advanced design comes from the “desire” for advanced designs that can operate as efficiently as the conventional designs (in today’s operating conditions) and – in addition - can operate more efficiently under “improved” operating conditions. This approach seems to be “unfair” for the comparative evaluation of advanced and conventional designs, but it does reflect the market view.

An important characteristic of the “moving train” technique is that the vast majority of ITU are transhipped through a temporary intermediate storage phase. This system favours a truck arrival pattern “adjusted to ITU availability”. Therefore only one cost curve is shown in Figure 8.1.a.

The “Krupp basic” equipment does not seem to be very effective for the medium-sized terminal with a rather conventional train schedule. The system consists of 3 parts (specialised crane for trains, cross-conveyors and specialised crane for trucks). It has a greater investment cost and its truck service capability is restricted to the productivity of one specialised crane that allows 50-70 handling operations per hour. Another disadvantage is that direct train-to-train handling operations are not possible. On the other hand it should be noted that the “serial” service of incoming trains (instead of the “parallel” service that conventional gantries offer) incorporates/imposes a fast “clear the train” operation that frees the train and allows better rolling stock utilisation (with appropriate rail operating forms).

Under today’s operating conditions, truck arrivals create a "peak" at the opening of the terminal, since ITU are available all night and wait for collection by trucks while additional ITU arrive on morning trains. This peak has to be served by one device! If all lorries have been served, the device remains idle or non-productive. It can not even "help" the rail side device, nor can the rail side device help it. This is why – for some designs - Krupp proposes installing one road lane on the rail side which is used for storage – i.e. road transhipments when no trains are in. However, it should be noted that the capacity of the road device is 50-70 ITU all day and night!

This weakness of “low utilisation” of the specialised cranes is less marked in design 14 which consists of 2 Krupp basic designs that seem to operate up to 1200 ITU/day at a cost per ITU transhipped similar to “equivalent” conventional designs. The design has the advantage of day and night operation (with almost the same productivity) but requires a convenient truck arrival pattern (“adjusted to ITU availability”).

4.13.11.4 The Krupp Single-area Variant

The single-area variant of the Krupp Fast Handling System was used in two designs (5 and 10). The single-area variant is an effective compromise between Krupp's conventional and "basic" fast handling systems. The equipment has a lower purchase price than the basic version and performs all rail, road and storage operations. It also uses the "moving train" technique and offers automatic operation on the rail side and semi-automatic on the road side.

The design has 3 transhipment tracks and 4 storage lanes plus 2 road lanes. Figure 8.1.a shows that the design performs well at a minimum cost over a range of volumes.

Similarly, the design with 2 sets of single-area equipment (for one module) also performs well. The "effort" of the modelling procedures to "conventionalise" the advanced designs (see 8.3.5) hides the advanced properties of the design.

Generally, the configurations that consist of fewer faster cranes give better results because there is no loss caused by interference with other equipment.

The difference in cost compared with other configurations is not significant enough to justify additional volume in the network model just because of reduced terminal costs and remaining conventional production. Nevertheless, advanced equipment can work at considerable cost, even for larger volumes because it offers capacity reserves due to the possibility of working 24 hours a day and 7 days a week.

4.13.11.5 The Technicatome Designs Based on the Commutor Concept

As already mentioned, the cost figures for these designs were produced by Technicatome and therefore can not be compared directly with the other results.

The company's "philosophy" for advanced handling is that a fully automatic system (mainly for the rail-rail yards) that can offer very high productivity at reasonable cost requires new wagon types, highly standardised ITU and special connectors between ITU and wagons. However, these costs are not included in the calculation since the benefits from the advanced wagons and connectors concern the whole transport chain and not only the terminal.

One interesting point about the Technicatome designs is that the design cost should be examined in relation to the "qualitative" aspects of fast handling. For example, the Commutor based design 17 is more expensive than design 18 despite the fact that both serve 1200 ITU/day. This is because design 18 can serve the trains in a shorter time and therefore enables "more" operational forms in the network (i.e. an additional capacity reserve).

4.13.12 Comparative Evaluation of Conventional and Advanced Designs

The cost-effectiveness of a terminal is determined by many design parameters. The sections below examine issues relating to the cost-effectiveness of conventional and advanced terminal designs in terms of the requirement for sidings/transhipment tracks, storage area requirements, number/length of road lanes, direct access systems, number and quality of equipment used, etc.

Sidings/transhipment track requirements in relation to handling speed

The terminal requirements for sidings/transhipment tracks are mainly determined by the number of trains that use the terminal and their timetables.

In today's "night jump" rail operation, the block/shuttle trains (which represent the vast majority of combined transport trains) arrive in the terminal in the morning and leave in the afternoon (despite the duration of the transhipment period). Therefore, the need for fast handling does not seem that essential.

The effects of fast handling are more significant for the liner trains that should stay in the terminal for a short period. Theoretically, one track can serve all liner trains if their timetables are properly synchronised.

The effects of fast handling are also essential for the shuttle-shuttle trains that operate in very short time windows. However, this operating form does not have additional track requirements since it uses sidings/transhipment tracks in the destination terminal that remain "idle" during the night.

Therefore, it seems that there is no great difference in the total number of sidings/transhipment tracks between conventional terminals (equipped with gantry cranes) and advanced terminals (e.g. equipped with Krupp fast handling systems). For example, a medium-volume terminal with long (750 m) tracks would require 4 transhipment and 2 sidings/waiting tracks (for block train service), 1 track for liner train service (partly used) and 1 free track for the shunting locomotive manoeuvres, i.e. a total of 8 tracks. The "equivalent" advanced design consists of 8 tracks for the waiting trains plus a 200 m transhipment track. It should be noted that the advanced design is more flexible since the transhipment can be separated from the waiting tracks and can be located in any "convenient" area. In practice the total track length depends on the number of wagons that are in the terminal at the same time, either due to the schedule or the inability of the handling equipment to allow their departure.

Stacking area requirements

The ITU stacking area requirements depend on the volume of ITU transhipped, the market characteristics that define the ITU dwell time in the terminal and the mean stacking height in the storage area.

The market characteristics form the truck arrival/departure patterns in relation to the train timetable. Customers usually ask for both last minute delivery and long ITU stays without charge. On the other hand, the terminal wants a "reasonable" ITU dwell time, i.e. not very short (to avoid great peaks due to train arrival/departure times that increase the need for equipment), but also not very long (since that would require larger storage areas).

ITU stacking reduces storage requirements and mean travelling distance (for mobile handling equipment) or gantry span (for gantry configurations where the storage area is located between the gantry legs). On the other hand, ITU stacking increases handling activities since it creates a number of shuffles (rearrangements required in order to provide access to the ITU that are not on top of the stacks). Currently, the mean stacking height in the majority of rail terminals is very close to 1. Containers are usually stacked one- or two-high, while (exceptionally) an empty (box-type) swap body can be placed above a loaded one. This situation can be improved. It should be noted that conventional gantry cranes have to leave a ground-to-spreader height of 9.9 m to allow a semi-trailer to pass above another semi-trailer on a pocket wagon. This minimum crane height allows a stacking height of “2+1” in the storage area (two units stacked plus a pass-through corridor one unit high).

The ITU stacking issue seems to be a “fuzzy” area in advanced handling systems. From a technical point of view, the advanced systems incorporate automatic monitoring systems and therefore can optimise the storage area. On the other hand and in order to increase the handling speed, a lot of ITU have to be placed temporarily in intermediate storage or buffer areas, which increases the area requirement.

The conclusion is that conventional and advance systems follow different approaches: conventional systems use the wagons as temporary storage (and therefore indirect handling and stacking area requirements); advanced systems free wagons as far as possible (allowing better rolling stock utilisation) and create some additional intermediate storage/buffer requirements which is to some extent offset by storage management systems.

Transhipment track length and advanced direct access systems

The transhipment phase is only one of the components that determines the train dwell time in the terminal. The terminal access time (where a diesel locomotive replaces the train’s electric locomotive), the train split (in the case of short transhipment tracks) and the required tests (proper loading of ITU, brake tests) significantly increase the dwell time and restrict the cost-effectiveness of the trains.

The cost-effectiveness of short or long transhipment tracks can be considered from different points of view. A short transhipment track (e.g. the DB half-module) costs less than the full module (with the same capacity) that allows train service without the need for a split.

It should be noted that the cost reduction is mainly determined by the cost of land (purchase and development costs as well as fencing, lighting, etc.), while the savings due to reduced track length are balanced out by the greater number of switches and signals that a half-module requires compared with a full module with the same capacity.

From the terminal point of view, the existence of long transhipment tracks reduces the operating cost of the terminal due to the elimination of personnel and there being no need for a shunting locomotive. This cost is estimated at approximately 100 Euro/train. This amount does not seem to justify the additional investment cost, at least for a small-volume terminal.

From the transport chain point of view, this “cut the train” operation and the associated brake tests increase the transport time by about one hour per terminal stop, thus reducing the number of intermediate stops that a train can make, which might mean losing customers.

Additional time savings (about half an hour per train/stop) can be achieved by using advanced direct access systems. Two systems exist:

- A slewing catenary on the loading track. Following the arrival of a train hauled by electric traction, the catenary is withdrawn to one side (over the entire length of the train), thus allowing work to be carried out above the train in complete safety.
- Allow the train to coast from the main line into position on the transhipment line. The train enters the terminal with the pantograph lowered and stops when the electric locomotive is positioned under the overhead on the far side, so that it will be able to move off.

However, not all terminals can be equipped with one of the above advanced direct access systems.

Both techniques also have a limited effect when the trains have to be cut in two in order to fit into the transhipment area, which is determined by the terminal length. Some specialists expressed doubts as to whether the rolling-in speed in the “coast with momentum” system could be achieved in all terminals. The alignment of the access track in some terminals imposes significant limitations and high winds plus wagons rolling badly could also pose problems. Another disadvantage of the “coast with momentum” system is that the system requires a terminal with separate entry and exit tracks. Otherwise (e.g. in half-modules with a dead end) the electric locomotive will be stuck in the transhipment area dead-end.

ITU loading/unloading schemes for conventional and advanced systems

In a conventional (gantry-crane based) design, ITU remain on the wagons for a long period. If a truck arrives within that period, a direct (train-to-truck) handling operation is performed. If a truck does not arrive in that period, an indirect handling operation (through storage) is needed, which means double handling from the equipment point of view (train-to-store plus store-to-truck).

On the other hand, in the advanced (Krupp fast handling based) designs, the ITU are transhipped as soon as possible to the storage area, so that they are accessible to the road-side system’s crane for truck service. This operation is performed sequentially (train by train). This system’s approach can be an advantage or a disadvantage depending on the market operating environment. If a large number of trucks is presented “simultaneously” in the terminal opening hours asking for immediate service (as more or less is the situation today) then:

- the trucks for the first train proceed according to the system, which means they will be served in a very short time, but
- there will be long delays for the remaining trucks waiting for the sequential service of their trains. Despite the fact that the total service time of all trucks is reduced, this imbalance of service time is a significant disadvantage.

The sequential train service imposes a discipline (which is not always convenient) but at the same time spreads the truck traffic, reduces the truck service time (by reducing the waiting times) and increases the service reliability in a truck service “by appointment” system.

Advantages/disadvantages of conventional and advanced handling systems

Current medium/high-volume technologies for combined transport terminals are based on rail-borne gantry cranes (pure system), combinations of gantry cranes and reach-stackers and combinations of gantry cranes, reach stackers and transport devices (e.g. the multi-trailer system).

Reach-stackers are low cost, very flexible equipment but the fact that they cannot stack very densely and require a great deal of space for significant manoeuvres reduces their value for medium-volume and high-volume terminals.

Gantry cranes on rubber tyres (RTG) are cheaper to purchase and maintain than rail-mounted gantry cranes (RMG) and are more flexible (no rail tracks). However, there are limitations on their span and they are less capable of automation. All experts/terminal operators interviewed for the purposes of this report expressed negative views on this equipment in comparison with reach-stackers and gantry cranes.

Electrically operated rail-mounted gantry cranes are currently the dominant equipment for high-volume combined transport terminals. The development and use of new types of load unit on the European market (swap bodies and semi-trailers) led to the modernisation of cranes and to their being fitted with grapple-arms to permit the handling of these new ITU from underneath.

The main advantages of the conventional (gantry-crane based) designs are:

- Direct train-to-train transhipment can be performed. This advantage is significantly reduced for terminals with short transhipment tracks where only two trains or only half of each of four trains can be handled in parallel and where longitudinal sorting is required to form destination groups.
- Direct train-to-truck transhipment can be performed among the four tracks under the crane legs and the number of trucks in the terminal “on-time”. Since four trains are present the crane(s) can pick up “at random” and serve the relevant trucks in almost(12) the order of their arrival.
- Use of the same equipment for rail and road operations. This increases equipment utilisation but reduces the overall handling productivity due to the involvement of the trucks in the procedures.

The main advantages of the advanced-handling based design are:

- The layout is relatively flexible since the transhipment module can be separated from the siding module in any nearby “convenient” location or by using existing sidings.

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[12] In order to reduce travelling times, the crane(s) do not usually follow exactly the first-in first-served discipline.

- Transhipment can be arranged in a rectangular area that is 200 m along one side. Compared with the “conventional” shape (long rectangle the same length as the transhipment lane) this layout reduces the transport distances as well as the internal road network, thus leading to area savings.
- Less handling equipment is required in relation to conventional handling systems. The IMPULSE simulation shows that a limited number of fast “servers” gives better service times than a larger number of slow “servers” (the same conclusions are indicated by the queuing theory). From the operating point of view, there are also cost savings from reducing the personnel. On the other hand, special care must be taken to ensure uninterrupted operation of the more limited amount of fast equipment since breakdown has more significant effects on service system output.
- The management of the storage area can be optimised. For example, the storage area in the Krupp system is managed automatically by a storage management program that optimises the routes taken by the operating equipment and therefore eliminates re-stacking procedures (as far as possible) by taking into account the train timetables.

The single-area variant of the Krupp fast handling system is an effective compromise between their conventional and “basic” fast handling systems. The equipment has a lower purchase price than the basic version and performs all rail, road and storage operations. It also uses the “moving train” technique and offers automatic operation on the rail side and semi-automatic on the road side.

4.13.13 Terminal Design in Improved Operating Conditions – Future Possibilities

The basic result of the previous sections is that the terminal’s capacity limitations are imposed mainly by the capacity limitations of the sidings/transhipment track sub-system rather than by the handling equipment capabilities.

This result should be considered in relation to the results of previous IMPULSE work packages which showed that the enhancement of the rail sector should be based on advanced rail forms since the technology is able to provide the required support (advanced/fast handling systems, advanced/improved rolling stock, advanced access systems, identification/location/positioning systems).

The various advanced rail operating forms are presented in Deliverable D 4 (Operating Forms for Network Modes). The document concludes that the future in the rail sector should be based in the complimentary and comprehensive use of all operating forms (direct trains, feeder systems, shuttle-shuttle forms, liner trains, hub-and-spoke systems, full-load traffic). Taking into account that direct trains are currently the most wanted form of operation but are not fully achieved in the majority of cases, it seems that the use of other operating forms should be enhanced/promoted to catch additional volume.

The (conventional and advanced) handling system performance has already been considered (see sections 8.2 to 8.4) for a conventional train schedule where all trains remain idle throughout the day.

This section considers the conventional and advanced handling system performance in a future scenario where the use of liner trains has increased and where shuttle-shuttle forms have been introduced to attract volume over short and medium distances. Both forms should result in more volume per infrastructure (e.g. track).

The relevant cost calculation should take into account the costs and benefits for the whole transport chain. The IMPULSE macro-model was used for that purpose. However, since the terminal operators focus on the economics of their specific terminal, the effects on the terminal cost must also be calculated.

The above cost calculation (for the combined transport terminals involved in the liner and shuttle-shuttle train itineraries) was based on the additional cost and additional benefits when operating these rail forms. The analysis was performed individually for liner trains and shuttle-shuttle trains and took into account the status of the terminal capacity (e.g. one case concerns terminals operating between static and dynamic capacity).

The minimum number of additional ITU required to cover the additional cost imposed by the “new” operational forms was calculated for each case (break-even points).

4.13.13.1 Increasing the Use of Liner Trains – Break-even Points

The increased use of liner trains should be examined in relation to the capacity and the expansion possibilities of the existing and advanced terminal designs. There are three basic situations:

1. Terminals operating to the limits of their dynamic capacity.
2. Terminals operating between their static and dynamic capacity.
3. Terminals operating below their static capacity.

These situations are analysed below.

Terminals operating to the limits of their dynamic capacity

Theoretically, the terminals operating to the limits of their dynamic capacity have two options:

1. To dedicate one transhipment track to the liner train service.
2. To expand the waiting transhipment track by adding one more track (if no area restriction exists) and swap (direct and liner) trains between transhipment and waiting tracks(13).

The first option (dedicate one transhipment track to the liner train service) means that the terminal must “reject” a direct train “customer” in favour of some liner train “customers”. A global calculation indicates that the “loss” of a direct train with 120 ITU (60 incoming, 60 outgoing) needs 5 liner trains for the end result to balance out.

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[13] The option of adding one transshipment track is not realistic since the span of gantry cranes cannot be increased accordingly.

This rough calculation assumes an average of 30 ITU exchanged (15 incoming, 15 outgoing) for each liner train and 60 Euro/train additional terminal costs for the train’s access and the short brake tests. If the terminal’s handling system can serve the liner train within one hour and the time for train in/out procedures and cargo checks is 0.5 hours, the transhipment track utilisation is about 50% (5 trains ? 1.5 hours/train working period in the 16 terminal operating hours). The calculation assumes that the handling system can serve the liner trains without causing long delays for the direct trains which are served in parallel.

There are two points of view on this result, one positive and one negative. The positive point of view is that 50% capacity remains to give additional “profit” to the terminal (by adding more liner trains). The negative point of view is that even 5 liner trains with synchronised timetables may be difficult to achieve. Therefore the cost-effectiveness of this option is questionable.

The second option is to expand the waiting transhipment track by adding one more track (if no area restriction exists) and swap direct and liner trains in the transhipment tracks. This generates three additional costs:

a) An investment cost for the additional track of about 200 Euro per day

b) 80 Euro cost for the liner train switches (40 Euro per switch ? 2 switches minimum)

c) An additional cost for the “clear the train” operations as well as for the associated delays in the truck service sub-system. This is estimated (based on simulation results) at close to 700 Euro/day (cost of time for truck delays). The additional cost due to more intensive equipment operation (increased power and maintenance costs) is ignored.

This gives a total additional cost of 980 Euro (200 + 80 + 700). This cost can be “balanced” by the “income” of 55 ITU (about 55 ? 18 Euro/ITU) which is the “income” of 2 liner trains. This option seems worth investigating.

Terminals operating between their static and dynamic capacity

For terminals operating between their static and dynamic capacity the cost of the additional waiting /transhipment track is not needed. The “break-even point” is (80 + 700) / 18 = 44 ITU. Assuming 20-30 ITU per (liner) train visit, the additional cost can be justified by 2 liner train visits.

The limited difference as compared to the above case is because the (remaining) operating cost for train switches and the additional cost of the “clear the train” operations as well as for the associated delays in the truck service sub-system are the “heavy” cost elements in the calculation.

Terminals operating below their static capacity

For terminals operating below their static capacity, the cost of the additional waiting/transhipment track and the cost for the train switches is not justified. The “break-even point” depends on the truck delays due to additional train traffic, but terminals that operate below their static capacity would (generally) welcome any additional traffic.

As far as the liner train service is concerned, it should be noted that the "moving train" technique can offer new possibilities for half-module terminals. The figure below shows a long train that can be served during its (slow) movement to the extension track.

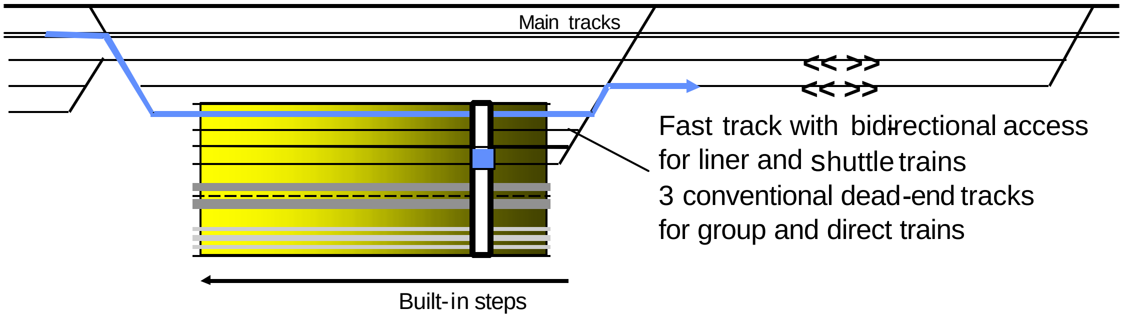

Fig. 4.13.13.1: "Fast Track" in Conjunction with Krupp Single-Area Variant

4.13.13.2 Cost Impact for the Shuttle-shuttle Trains – Break-even Points

The scepticism of the railway authorities as regards modifying their schedules and the complexity of introducing liner trains during the day gave rise to the idea of using shuttle-shuttle services. These trains are handled at night and can be seen as additional volume for the terminal attracted over short and medium distances.

Most of the terminal infrastructure can be used without additional costs at night, assuming that the neighbourhood is not disturbed by the noise produced (this can be another advantage of the advanced systems which operate more quietly than the conventional ones). What is different is the marginal operating cost (personnel, power and maintenance).

For both the Krupp basic and Krupp single-area variants the following personnel is required(14):

- 1 crane supervisor
- 1 driver for the shunting loco. Alternatively, there can be no driver and the loco is then radio-controlled. The crane supervisor can control the loco while the two persons working on pin rearrangement can also stop the loco if there is an ITU loading failure.

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[14] It is assumed that only the rail handling takes place during the night whereas the corresponding trucks are served during the conventional opening hours. However, for a "good client" the crane supervisor can also serve a limited number of trucks.

?? 2 persons for wagon-pin rearrangement. We can assume that the same personnel can connect/disconnect the train to electric and shunting locomotives (or, alternatively, that the shunting loco pushes the train with the e-loco attached).

The above two persons used for wagon-pin rearrangement can be eliminated if unloading and symmetric re-loading can be ensured or advanced wagons are used. Another approach is for these personnel to take one day off instead, which gives the same cost as above.

The conclusion is that 3 or 4 persons are required, depending on the loco control technique used (radio control or manual control respectively).

For conventional terminals the following personnel is required:

?? 1 terminal operator who also serves as ground-man to check the incoming ITU.

?? 1 crane operator per crane(15). In our calculation we assumed 2 cranes for the night shift in order to achieve a fast transhipment phase as the train should return within a limited “time window”.

?? 1 driver for the shunting loco to move the train in/out of terminal tracks. This employee can also perform wagon-pin rearrangement once the train is parked.

?? 1 (additional) person for wagon-pin rearrangement.

Therefore, a total of 5 persons are needed.

We have to assume that the above personnel will be paid for the extra time that they work with a bonus for the overnight work.

Since railways do not have experience of the costing of night work(16) we assumed in our calculations that the personnel working for a few hours on the night shift would be paid the same as the personnel working a whole morning shift (the extra payment for the night work is balanced out by fewer working hours) or that these personnel are given a day off, which has the same result as regards costs. Therefore, about 35 000/250 = 140 Euro per person per night shift can be assumed.

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[15] The benefit for the crane is its increased performance because it operates without interference with trucks. On the other hand (especially for the manually operated equipment) the night operation imposes lower productivity, which in turn decreases the benefit.

[16] Maritime terminals had experience of night shifts. Relevant information can be found In IMPULSE Deliverable D 11 “Design and organisational aspects of combined transport terminals”.

The “break-even point” is as follows for different operating conditions:

	Case/calculations (N.B.: these costs concern only the terminal side)	**Break-even point** (18 Euro/ITU profit was assumed for the terminal)
1	*Manual wagon-pin re-arrangement* Personnel cost: 3 ? 140 = 420 Euro/night shift for a radio controlled loco or 4 ? 140 = 560 Euro/night shift for manual loco control Power (handling and lighting) = 100 Euro Total: From 520 to 660 Euro/night shift	29 or 37 ITU depending on the control system for the loco (moving train technique)
2	**Unloading and symmetric re-loading can be ensured** Personnel cost: 2 ? 140 = 280 Euro/night shift Power (handling and lighting) = 100 Euro Total: 380 Euro/night shift	21 ITU
3	**Use of advanced wagons that do not require wagon-pin re-arrangement** Personnel cost: 2 ? 140 = 280 Euro/night shift (A minimum of 2 persons is assumed for safety reasons) Power (handling and lighting) = 100 Euro Use of advanced wagons instead of conventional, which are 10% more expensive. It is assumed that the additional 10% cost is only charged to the terminal side. 62 500 Euro/wagon x 10% x 6% annuity ? 1/250 days per year ? 40 wagons/train = 60 Euro. Total: 440 Euro/night shift	25 ITU Also required: 25 < 40 wagons ? 1.6 ITU/wagon = 64

Tab. 4.13.13.2/1: Break-even Points for Various Cases of Shuttle-shuttle Night Service for Terminals Equipped with Krupp Basic and Krupp Single-area Variants

The same calculation for terminals equipped with conventional gantry cranes (more cranes are needed to achieve the train service within a limited time-window) gives:

	Case/calculations (N.B.: these costs concern only the terminal side)	**Break-even point** (18 Euro/ITU profit was assumed for the terminal)
1	*Manual wagon-pin re-arrangement* Personnel cost: 5 ? 140 = 700 Euro/night shift Power (handling and lighting) = 100 Euro Total: 800 Euro/night shift	45 ITU
2	*Unloading and symmetric re-loading can be ensured* Personnel cost: 3 ? 140 = 420 Euro/night shift Power (handling and lighting) = 100 Euro Total: 520 Euro/night shift	29 ITU
3	**Use of advanced wagons that do not require wagon-pin re-arrangement** Personnel cost: 3 ? 140 = 420 Euro/night shift Power (handling and lighting) = 100 Euro Use of advanced wagons instead of conventional, which are 10% more expensive. It is assumed that the additional 10% cost is only charged to the terminal side. 62 500 Euro/wagon x 10% x 6% annuity ? 1/250 days per year ? 40 wagons/train = 60 Euro Total: 580 Euro/night shift	33 ITU Also required: 33 < 40 wagons ? 1.6 ITU/wagon = 64

Tab. 4.13.13.2/2: Break-even Points for Various Cases of Shuttle-shuttle Night Service for Terminals Equipped with Conventional Gantry Cranes

Non-transhipment shuttle-shuttle technique

In this case no handling equipment is used - the train locomotive leaves one group of 40 wagons and takes another 40. Wagon utilisation is 50% since they remain idle in the terminal for half the night. The associated costs for this technique are:

?? Personnel. Since railways normally operate at night, only 1 hour is the marginal cost for this action for 2 persons (two persons is the minimum for safety reasons). Therefore the personnel cost is (1/8) ? 2 ? 140 = 35 Euro.

?? Less wagon utilisation. Compared to the shuttle-shuttle with unloading and re-loading we assumed 40 (additional) wagons which cost 62 500 x 6% x 1/250 days per year = 15 Euro per night and wagon, or 15 ? 40 = 600 Euro per train.

?? Any costs for an additional waiting track for the 40 additional wagons during the day, which have been disregarded in our case.

The total cost is therefore 35 + 600 = 635 Euro/night shift. This cost is similar to the costs of the transhipment techniques. However, it seems more convenient to use (existing) cranes for handling instead of purchasing an additional wagon group.

The conclusion from the above analysis is that the additional costs imposed by the night operation can be absorbed by a moderate volume of “attracted” traffic. The break-even points vary from 29 (under convenient operating conditions) to 45 ITU per night shift. The results are sensitive to the number of personnel involved. Since the advanced handling systems require less personnel, they give better results than the conventional ones.

However, cost calculation using the macro-model shows that the critical factor for this service is the cost in the chain and not the cost in the terminal.

4.13.13.3 Cost-effectiveness of Advanced Rail Access Systems

Various advanced rail access techniques/systems were addressed in Deliverable D 11 (Design and organisational aspects of intermodal transport terminals). Two techniques were selected for further analysis:

1. Allowing the train to coast from the main line into position on the transhipment track. The train enters the terminal with the pantograph lowered and stops when the electric locomotive is positioned under the overhead on the far side, so that it will be able to move off. Studies and a pilot demonstration have led DB to conclude that the “coasting” technique is feasible.

   However, some specialists expressed doubts as to whether this rolling-in speed could be achieved in all terminals. The alignment of the access track in some French terminals imposes significant limitations, for instance, and high winds plus wagons rolling badly could also pose problems.

2. Using a slewing catenary on the loading track. Following the arrival of a train hauled by electric traction, the catenary withdrawal device allows work to be carried out above the train in complete safety. This is achieved by moving the overhead line to one side over the entire length of the train, by horizontally slewing the supports, thereby vacating the space above the track. This technique is not affected by “inconvenient” alignment of the access track or high winds.

Coast with momentum

There are two cost groups associated with this technique: costs to provide bi-directional access to the terminal (if only one-way access is already provided) and costs for electrification and the required additional signals(17).

The costs for bi-directional access to the terminal (excluding the land) are:

- Additional 650 m of track ? 300 DM/m = 195 000 Euro;
- 4 additional switch control units (signal + switch + protection device) = 4 ? 88 000 Euro = 352 000 Euro.

The system requires bi-directional access, otherwise the electric loco would be "caught" in the dead-end track. However, for safety reasons there should be a diesel engine available within a reasonable time to push the train under the wire.

The costs for electrification and the additional signals are:

- Electrification: 2 ? (200 + 650 m) ? 155 Euro/m = 263 500 ✍ 270 000 Euro. This cost is for the electrification system within the terminal area. There is assumed to be another 200 m to be electrified from the main line to the terminal, even though some terminals are not located near to the main line.
- 1 entry signal to the locomotive driver (route-indicating signal): 28 000 Euro x 2 directions = 56 000 Euro.
- 1 local signal at the point where the driver must lower the pantograph = 2500 Euro x 2 directions x 4 tracks = 20 000 Euro.
- 1 local signal at the point where the driver has to stop the train = 2500 Euro x 2 directions x 4 tracks = 20 000 Euro.
- 1 local signal at the point where the driver can raise the pantograph = 2500 Euro x 2 directions x 4 tracks = 20 000 Euro.

These costs total (about) 550 000 Euro for bi-directional terminal access plus (about) 400 000 Euro for the additional signals, which gives a grand total of 950 000 Euro. Assuming a 6% annuity, the cost of the system (for 250 working days per year) is about 228 Euro/day. Since 8 trains (4 incoming + 4 outgoing) (18) can use the system in one day (static terminal capacity), the end result is 29 Euro/train.

It should be noted that the above cost assumes that the “installation” is used at static terminal capacity, which means only twice a day (1 incoming + 1 outgoing train). At dynamic terminal capacity with a floating factor of 1.5 this cost is reduced to 19.4 Euro/train. This can be reduced still further with a better utilisation scheme (e.g. use of liner trains).

Where the terminal already has bi-directional access the calculation gives 12 Euro/train (400 000 ? 6% ? 1/250 ? 1/8) for static terminal capacity and 8 Euro/train for dynamic terminal capacity.

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[17] Cost information provided by DB AG.

[18] The outgoing trains also benefit from the direct access since the shunting loco time is saved.

Use of slewing catenary on the loading track

The cost elements associated with this technique are as above, plus the cost of the slewing catenary. Since this system does not need bi-directional access 400 000 Euro are assumed for electrification and signal costs. For a 700 m slewing catenary the cost is 460 000 Euro(19). Therefore, the total cost of a system comprising 4 tracks (as above) is (400 000 + 4 ? 460 000) = 2 240 000 Euro. Assuming a 6% annuity gives 134 400 Euro per year, which means 5376 Euro/day for the system (for 250 working days per year). Since 8 trains (4 incoming + 4 outgoing) can use the system in one day, the end result is 67 Euro/train.

The above calculation assumes static terminal capacity (each track is used twice a day). For dynamic terminal capacity with a floating factor of 1.5 this cost is reduced to 44.7 Euro/train. In conjunction with the “moving train” technique (a technique that is used in Krupp designs) this cost per train is reduced significantly. For example, if only one track equipped with a slewing catenary is used to serve 8 trains (using the “moving train” technique) the total system cost is:

Electrification	62 000 Euro (400 m ? 155 Euro/m)
Signals	116 000 Euro (as above)
Slewing catenary	460 000 Euro
Total	638 000 Euro

and the cost per train is 19 Euro (638 000 ? 6% ? 1/250 ? 1/8).

The conclusion is that the “coast with momentum” direct access system has a relatively low cost per train of between 8 and 29 Euro depending on the required terminal re-engineering and the track utilisation (static/dynamic capacity). The main system disadvantage is that bi-directional terminal access is a prerequisite for system implementation. Furthermore, the system requires proper alignment of the access track (in order to achieve the necessary speed) while the effects of high winds could also pose problems.

The “slewing catenary” direct access system is much more expensive but can be applied to every terminal. The system is more effective in conjunction with rail techniques that lead to high track utilisation (e.g. the moving train). In this latter case the cost per train can be 19 Euro.

4.13.13.4 Time and Cost Savings Due to Direct Access Systems and Fast Handling

The above additional costs due to the use of (rail) direct access systems must be compared with the benefits from better rolling stock utilisation. This is not an easy task.

The first element to take into account is the time saving multiplied by the cost of a train. The ETH data indicates approximately 1866 Euro/day (one way, one set of

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[19] Cost information provided by Technicatome.

wagons). The direct access systems can save 30 minutes (2 ? 15) of train time in the terminal.

For a direct train the 30-minute time saving represents approximately 6% of the train’s “running” time (8.6 running hours per day were assumed). This percentage is not significant and is probably not converted to a profit in monetary terms. It is part of the (usually long) train dwell time in the terminal.

In contrast, for a liner train that visits 3 intermediate stations the total time saving represents almost 23% of the train’s “running” time (15 minutes in the station of origin + 30 minutes ? 3 intermediate stops + 15 minutes in the destination terminal). This time saving can be converted into a train “profit” of 429 Euro/day (23% ? 1866 Euro/day). The cost saving per terminal can be assumed as 85.8 Euro per train that uses the direct access system (429 Euro/5 terminals).

Where this time saving can be “converted” into service time for one or two additional intermediate terminals, the benefits increase disproportionately since additional traffic is generated between the “old” and the “new” terminals.

The conclusion is that the direct access system has a very positive effect on liner train operation (especially when fast handling is provided in parallel). It reduces the operating cost and leads to significant time savings (which can be converted in terms of monetary cost) and/or increases the number of intermediate terminals served.

4.13.14 Conclusions

There are many different terminal designs (layout and handling equipment configurations). Each design is effective in a certain cargo volume range and is restricted by its capacity limitations. As in most complex/multiple systems, the capacity limitation of the intermodal transport terminal is defined by its weakest sub-system. In practice, there are two major sub-systems that usually affect the terminal capacity:

?? The capacity of the (rail-side) transhipment tracks,

?? The capacity of the terminal’s handling system.

In static capacity terms (trains arrive in the terminal in the morning and depart late afternoon) the terminal can serve only two trains per day and per (long) track (one coming, one going). Therefore the terminal capacity is restricted to about 120 ITU/track (60 incoming plus 60 outgoing ITU).

Besides the transhipment tracks, it is possible to include additional rail tracks for trains to wait (these are called waiting tracks). That allows a “dynamic capacity” where more than two trains per day can be served on a given transhipment track. The disadvantage of this system is that the incoming train has to be unloaded totally before it can be taken out of the transhipment area.

The capacity of the terminal’s handling system depends on the type and amount of equipment used.

Reach-stackers are flexible equipment with a relatively low purchase price. The terminal's capacity limitation is imposed by the fact that reach-stackers can normally reach/serve only one transhipment track, i.e. the one that is near the driving lane (they cannot straddle over loaded trains). Where proper infrastructure exists (embedded rail tracks), reach-stackers can also serve other tracks (but only when the intermediate tracks are not occupied by a train(s)).

Evidently, more than one train can be served by switching the trains between the transhipment track and the waiting track(s) but many (costly and time consuming) shunting operations are then required. In addition the percentage of indirect (train-store-truck and vice versa) movements is high (due to the frequent need for "clear the train" operations) and "inconvenience" and delays occur when trucks arrive to pick up ITU which are still on the trains in the waiting tracks. This is why the total number of sidings (transhipment and waiting tracks) is kept relatively low. The operating conditions are better when the terminal has two rail sides but in that case two (15 metre) zones should be provided for manoeuvring equipment.

Gantry-crane based designs are effective for a wide range of cargo volumes. The designs require a high level of investment (even for one crane) but enable progressive capacity improvements by adding more cranes in the existing infrastructure. A gantry crane enables direct train-to-truck as well as train-to-train transhipment.

The simulations showed that one crane operating at 24 ITU/hour is not adequate to serve the tracks at the assumed quality-of-service level when the terminal volume reaches 250 ITU per day. The limit for two gantry cranes (operating at 24 ITU/hour) was close to 500 ITU/day while three cranes extended the limit to 750 ITU/day but the handling equipment started to perform badly.

These simulation results comply with the empirical "DB rule" which predicts 250, 500 and 750 ITU per day as the limits for the 1, 2 and 3 gantry crane configurations respectively. In contrast, a 3-crane configuration with a handling rate of 28 ITU/hour gave a good performance even when the simulation (ignoring the limit of 750 ITU/day imposed by the track) reached 850 ITU per day.

The "**Krupp basic**" equipment was used in two designs with the "moving train" technique. The terminal characteristics were selected bearing in mind the "equivalent capacity" of conventional crane designs. Those designs create a long module with a productivity of 500-600 ITU/day, which is greater than the original Krupp design. This effort to "conventionalise" the advanced design comes from the "desire" for advanced designs that can operate as efficiently as conventional designs (in today's operating conditions) and – in addition - can operate more efficiently under "improved" operating conditions. This approach seems to be "unfair" as regards the comparative evaluation of advanced and conventional designs but it does reflect the recent market view.

The "Krupp basic" equipment does not seem to be very effective for medium-sized terminals with a rather conventional train schedule. On the other hand it should be noted that the "serial" service of incoming trains (instead of the "parallel" service that conventional gantries offer) incorporates/imposes a fast "clear the train" operation that frees the train and allows better rolling stock utilisation (with the appropriate rail operating forms). The design, which consists of 2 Krupp basic designs, seems to operate up to 1200 ITU/day at a cost per ITU transhipped similar to that of "equivalent" conventional designs. The design has the advantage of day and night operation (with almost the same productivity) but requires a convenient truck arrival pattern ("adjusted to ITU availability"). The necessary information tool is provided with the system.

The **single-area variant** of the Krupp Fast Handling System is an effective compromise between their conventional and "basic" fast handling systems. The equipment has a lower purchase price than the basic version and performs all rail, road and storage operations. It also uses the "moving train" technique and offers automatic operation on the rail side and semi-automatic on the road side. The simulation shows that the design performs well at a minimum cost over a wide range of volumes. Generally, the configurations that have fewer faster cranes give better results because there is no loss due to interference with other equipment. Again, the "effort" of the modelling procedures to "conventionalise" the advanced designs hides the advanced properties of these designs (automatic operation with Cargo Sprinter trains, capacity reserves due to the possibility of working 24 hours a day and 7 days a week, etc.).

Technicatome's (**Commutor-based**) designs follow the company's "philosophy" for advanced handling which focuses on a fully automatic system (mainly for the rail-rail yards) that can offer very high productivity at reasonable cost but which requires new wagon types, highly standardised ITU and special connectors between ITU and wagons.

The comparative evaluation of conventional and advanced designs reveals some common ground as well as some distinct differences:

- There are no great differences in the total number of sidings/transhipment tracks between conventional terminals (equipped with gantry cranes) and advanced terminals (e.g. equipped with Krupp fast handling systems). In practice the total track length depends on the number of wagons that are in the terminal at the same time, either due to the schedule or the inability of the handling equipment to allow their departure. However, it should be noted that the advanced design is more flexible since the transhipment can be separated from the waiting tracks and can be located in any "convenient" area.
- As regards ITU stacking, the advanced systems follow different approaches from the conventional ones. Conventional systems use the wagons as temporary storage points (and therefore indirect handling and stacking areas). Advanced systems free wagons as far as possible (allowing better rolling stock utilisation) and create some additional intermediate storage/buffer requirements which are partly offset by advanced storage management systems.

The main advantages of the advanced handling design are:

- The layout is relatively flexible since the transhipment module can be separated from the siding module in any nearby "convenient" location, or existing sidings can be used.
- The transhipment area can be arranged in a rectangle that is 200 m along one side. Compared with the "conventional" shape (long rectangle the same length as

the transhipment lane), this layout reduces the transport distance as well as the internal road network, thus leading to area savings.

?? Less handling equipment is required in relation to conventional handling systems. The IMPULSE simulation shows that a limited number of fast “servers” gives better service times than a larger number of slow “servers” (the same conclusions are indicated by the queuing theory). From the operating point of view, there are also cost savings from reducing the personnel. On the other hand, special care must be taken to ensure uninterrupted operation of the smaller amount of fast equipment since breakdown has more significant effects on service system output.

?? The management of the storage area can be optimised. For example, the storage area in the Krupp system is managed automatically by a storage management program which optimises the routes taken by the operating equipment and therefore eliminates re-stacking procedures as far as possible by taking into account train timetables.

The basic result of the simulations was that the terminal’s capacity limitations are imposed mainly by the capacity limitations of the sidings/transhipment track sub-system rather than by the handling equipment capabilities.

This result should be considered in relation to the results of previous IMPULSE work packages which showed that the enhancement of the rail sector should be based on advanced rail forms since the technology is available to provide the required support (advanced/fast handling systems, advanced/improved rolling stock, advanced access systems, identification/location/positioning systems).

The various advanced rail operating forms were presented in Deliverable D 4 (Operating forms for Network Modes). The document concludes that the future in the rail sector should be based in the complimentary and comprehensive use of all operating forms (direct trains, feeder systems, shuttle-shuttle forms, liner trains, hub-and-spoke systems, full-load traffic). These findings are in harmony with the findings of the present report which identified direct trains as the main reason for terminal capacity limitations. Given that direct trains are currently the most wanted form of operation but are not fully achieved in the majority of cases, it seems that the use of other operating forms should be enhanced/promoted to catch additional volume.

A future scenario where the use of liner trains has been increased and where shuttle-shuttle forms have been introduced was examined. The cost calculation was based on the additional cost and additional benefits imposed due to the operation of these rail forms. The analysis was performed individually for liner trains and shuttle-shuttle trains and took into account the status of the terminal capacity. For each case the minimum number of additional ITU required to cover the additional cost imposed by the “new” operational forms was calculated (break-even points).

The increased use of liner trains was considered in relation to the capacity and the expansion possibilities of the existing and advanced terminal designs. Three basic situations were identified:

1. Terminals operating to the limits of their dynamic capacity,
2. Terminals operating between their static and dynamic capacity,

3. Terminals operating below their static capacity.

Theoretically, the terminals operating to the limits of their dynamic capacity have two options:

- To dedicate one transhipment track for liner train service. This means in practice that the terminal must “reject” a direct train “customer” in favour of some liner train “customers”. A global calculation indicates that 5 liner trains are needed to balance one direct train “customer”. 50% of the terminal capacity remains to give additional “profit” to the terminal (by the addition of more liner trains). However, even 5 liner trains with synchronised timetables may be difficult to achieve. Therefore the cost-effectiveness of this option is questionable.
- To expand the waiting transhipment track by adding one more track (if no area restriction exists) and swap (direct and liner) trains between transhipment and waiting tracks. The calculation reveals that the additional cost (investment cost for the additional track, operating cost for train switching, additional cost for the “clear the train” operations as well as for the associated delays in the truck service sub-system) can be “balanced out” by the “income ” of 2 liner trains. This seems worth investigating.

For terminals operating between their static and dynamic capacity the additional waiting/transhipment track is not necessary. The additional cost would have to be balanced out by 2 liner train visits. The limited difference from the previous case is explained by the fact that the (remaining) operating cost for train switching and the additional cost of the “clear the train” operations as well as for the associated delays in the truck service sub-system are the “heavy” cost elements in the calculation.

For terminals operating below their static capacity, no additional waiting/transhipment track is needed and no train switching is required. The “break-even point” depends on the truck delays due to additional train traffic but terminals that operate below their static capacity would (generally) welcome any additional traffic.

As far as the liner train service is concerned, it should be noted that the “moving train” technique can offer new possibilities for the half-module terminals since long trains can be served during their (slow) movement to the extension track.

Similarly, the cost calculations for the shuttle-shuttle (overnight) services identify break-even points that can be achieved. It seems that the critical factor for this service is the cost in the chain and not the cost in the terminal.

The advantages of the fast handling systems are increased in combination with direct access systems.

The “coast with momentum” direct access system has a relatively low cost per train depending on the amount of terminal re-engineering that is required and on track utilisation (static/dynamic capacity). The main system disadvantage is that bi-directional terminal access is a prerequisite for system implementation. Furthermore, the system requires proper alignment of the access track (in order to achieve the necessary speed) while the effects of high winds could also pose problems.

The “slewing catenary” direct access system is much more expensive but can be applied to every terminal. The system is more effective in conjunction with rail techniques that lead to high track utilisation. In this latter case the cost per train can be close to the cost of the “coast with momentum” system.

The direct access system has a very positive effect on liner train operation (especially when fast handling is provided in parallel). It reduces the operating cost and leads to significant time savings (that can be converted in terms of monetary cost) and/or increases the number of intermediate terminals served.

4.13.15 Transport Chains Modelling

4.13.15.1 Introduction and Application of the Macro Model

The evaluation of the economical interest to introduce new " chains of transport " or " logistic chains " into the complex world formed by the consignors, consignees, operators and transport facilities justified the development of a specific modelling tool allowing:

?? to represent the " solutions " of transport offered to the operators,

?? to calculate the costs of the solutions according to the means of transports and the infrastructures used,

?? to represent the potentials (demand for transport) between origin and destination.

?? to simulate various behaviour of the consignors or operators vis-à-vis the differentials of costs, times or even of qualities between competitive solutions.

The activity is performed by means of a 'Macro Model' which is to be distinguished from the 'Micro Model' which looks at the terminal in detail.

The aim of the model is to evaluate the potential of competing logistic chains serving a same number of *relations*. A relation is characterised by an *origin* and a *destination* and a *transport demand*. Each model comprises a variable number of relations. The transport demand is expressed as a number of ITU to carry per unit of time. The unit of time (day, week, month, year, …) varies according to the temporal resolution adopted in the analysis. Various *alternatives* of transport (transport chains or logistic chains) can be simulated on each relation. They represent the transport offer. Each alternative is built in a detailed way by specifying :

?? the infrastructures used (transhipments terminals, roads, rail lines, inland waterways, intermediate marshalling yards, intermediate storage or consolidation areas)

?? the transport facilities (trucks, trains, boats, barges) involved on the various sections of the itinerary with the typical operating parameters (speed, waiting times, cost …) and constraints (minimal filling rate, capacities, …).

The operational cost (and delay) of an alternative is calculated as the sum of the fixed and variable costs (delays) of each component of the logistic chain. A component is a transport means or an infrastructure. The quality of the chain is defined as a composition of the quality of each element. The composition rule is implemented as a fuzzy operation between the result of the fuzzy assessment of each component of the transport chain. The model performs a choice between the various alternatives according to :

- the average cost by transported ITU,
- the average delay
- the resistance factor (behaviour of the consignors or operators)
- the operational requirements and constraints.

The solver searches the solution which minimises the costs, while offering acceptable transport delay and which approaches best a qualitative goal while respecting the operational constraints. The general model is not convex and can have several local minima. A method of research of the global minimum, derived from the simulated annealing algorithm, was developed to solve this type of problem.

The model is developed following an object oriented approach. The modelling framework provides the definition of abstract classes having properties and methods allowing calculation of :

- the costs,
- the delays
- the quality
- the checking of the operational requirements.

The modelling framework provides also the implementation of the solving algorithm.

The model building requires the implementation of user classes derived from the abstract classes of the framework. These classes are instanced as objects which are the true model elements.

The framework classes are

- Node Class
- Operational Form Class
- Path Class
- Origin Destination (OD) Class.

This model was used to test the impact of new transhipment technologies within the framework of a traditional (direct block train) and innovating (Shuttle, double Shuttle) transport chain operation.

The model is composed of couples of origin and destination, being able to be connected by various means of transport (referred as *"path"* in the model terminology) .

The full road transport is always present like a possible option. It is simply modelled like a operational form having a cost proportional to mileage covered.

The other means of transport combining rail and road transport are modelled while considering:

- an average fixed cost by ITU for the pre/end haulage (road transport).
- a fixed cost for the railway service proposed between the two transhipments terminals for a given transport capacity including the immobilisation cost of the engine and the wagons during the idle time if any.
- a variable cost for the railway service proportional to the mileage covered including mainly the wagon and engine maintenance, the energy, the personal and the slot cost.
- a constraint of minimum filling is imposed. If the number of ITU transported by the convoy does not reach this minimum threshold, the service is regarded as nonprofitable and is thus not retained as solution by the model.

The transfer costs at the terminals are entered separately, and depend on the number of transfers per year that this terminal must carry out.

A market constraint is also proposed, this constraint indicates the maximum share of market that this mode of transport is likely to attract by comparing it with the road transport solution.

This constraint is relaxed in the results presented in appendix. This makes it possible to the reader to calculate the total requirement in term of volume to attract for various rates of use of the combined solution.

Three levels of filling are proposed:

- 100%,
- - 75%,
- a rate corresponding to a balance between the cost of the road transport and the combined solution. (equilibrium case).

Further comments are available in the section devoted to the results.

4.13.15.2 Evaluation of Chain Cost Results

In order to analyse and evaluate the cost impact of several proposed measures on the integrated transport chain a number of scenarios have been calculated. The following parameters have been varied:

?? The Price Level for Road and Rail. Three basic combinations have been considered:

  ?? A medium price level for road and rail assumes "medium" level price situation in all cost centres.

  ?? An elevated road price assumes "expensive" situation for road costs and 25% increase pre- and on-carriage costs for intermodal transport.

  ?? A medium price level for road against a (State) funding of intermodal infrastructures (terminals and slots) mirrors a relatively "cheap" situation.

?? The market, to be either continental or maritime. In the continental traffic two terminals are linked and the chain composes of one pre-/on-carriage at either side whereas in the maritime market both pure road and intermodal transport have to

cope with the port handling charge before leaving to their final destination. For intermodal transport that means that only one hinterland-terminal and pre- or on-carriage is to be considered.
For the maritime terminals a base load of 700 ITU/day and the continental terminal a base load of 400 ITU/day have been assumed.

?? The utilisation of the train in two variations: 75% or 100%.

?? The distance between the terminals. Three (short and medium) distances have been examined: 200, 300 and 400 km. These distances stand for the main haulage distance terminal-to-terminal. The associated road distances are the same plus one road haulage to take into account that pure road transport is door-to-door and includes collection/distribution already

?? The operation concept as pure road or intermodal transport. For intermodal transport three operation forms have been considered: 2 conventional direct trains, one Shuttle^2-Train or two Shuttle2-Trains. The latter means that in fact 4 load directions are served by just one set of wagon per 24 hours.

Table 4.13.15.2/1 presents the cost calculation results produced by use of IMPULSE Macro Model.

Medium Price Level for Road and Rail 1)

Market	Distance 4)	200 km			300 km			400 km		
	Train Cap.Use	100%	75%	Equal 5)	100%	75%	Equal 5)	100%	75%	Equal 5)
	Operation	EURO/ITU			EURO/ITU			EURO/ITU		
Continental 7)	Pure Road	153,6	153,6	-	217,6	217,6	-	281,6	281,6	-
	2 Direct Trains	195,3	210,2	-	210,6	230,5	90%	225,8	250,9	58%
	1 Shuttle^2	188,5	201,2	-	203,8	221,5	80%	216,4	238,4	51%
	2 Shuttle^2 6)	182,0	194,0	-	194,7	210,8	68%	207,3	227,7	45%
Maritime 8)	Pure Road	153,6	153,6	-	217,6	217,6	-	281,6	281,6	-
	2 Direct Trains	119,6	134,2	56%	134,9	154,5	41%	150,1	174,9	36%
	1 Shuttle^2	111,2	123,4	47%	126,5	143,8	37%	139,1	160,7	31%
	2 Shuttle^2 6)	106,3	117,4	41%	118,9	134,3	32%	131,6	151,2	28%

Elevated Road Prices 2) - Medium Rail Prices

Market	Distance 4)	200 km			300 km			400 km		
	Train Cap.Use	100%	75%	Equal 5)	100%	75%	Equal 5)	100%	75%	Equal 5)
	Operation	EURO/ITU			EURO/ITU			EURO/ITU		
Continental 7)	Pure Road	192,0	192,0	-	272,0	272,0	-	352,0	352,0	-
	2 Direct Trains	217,3	232,2	-	232,6	252,6	61%	247,8	272,9	42%
	1 Shuttle^2	210,6	223,2	-	225,8	243,5	54%	238,5	260,4	37%
	2 Shuttle^2 6)	204,1	216,0	-	216,7	232,9	46%	229,4	249,8	33%
Maritime 8)	Pure Road	192,0	192,0	-	272,0	272,0	-	352,0	352,0	-
	2 Direct Trains	129,0	143,5	41%	144,2	163,8	32%	159,5	184,1	28%
	1 Shuttle^2	122,2	134,4	35%	137,5	154,8	28%	150,1	171,7	24%
	2 Shuttle^2 6)	117,3	128,4	30%	129,9	145,3	24%	142,6	162,2	22%

Medium Road Price - Funding for intermodal infrastructures 3)

Market	Distance 4)	200 km			300 km			400 km		
	Train Cap.Use	100%	75%	Equal 5)	100%	75%	Equal 5)	100%	75%	Equal 5)
	Operation	EURO/ITU			EURO/ITU			EURO/ITU		
Continental 7)	Pure Road	153,6	153,6	-	217,6	217,6	-	281,6	281,6	-
	2 Direct Trains	163,9	178,4	-	179,1	198,7	61%	194,4	219,1	46%
	1 Shuttle^2	157,1	169,4	-	172,3	189,7	54%	185,0	206,6	41%
	2 Shuttle^2 6)	151,9	163,2	-	164,5	180,0	46%	177,2	196,9	36%
Maritime 8)	Pure Road	153,6	153,6	-	217,6	217,6	-	281,6	281,6	-
	2 Direct Trains	103,5	117,9	46%	118,8	139,2	38%	134,0	158,5	34%
	1 Shuttle^2	95,9	108,0	39%	111,1	128,3	33%	123,8	145,2	29%
	2 Shuttle^2 6)	91,5	102,4	34%	104,1	119,2	29%	116,8	136,1	26%

1) Acc. to "medium" situation in all cost centres. 2) Acc. to “expensive” situation f. road costs +25% m. pre/oncarr..

3) Acc. to “cheap” situation for slot and handling costs 4) Terminal Distance, pre/post-haulage to be added.

5" Utilisation of train capacity at equal costs intermodal/road -) Not applicable or no equilibrium.

6) The “2 Shuttle^2 “ means, 4 trips/d per set of wagon 7) Continantal Traffic with 2 terminals and 2 pre/oncarriage

8) Maritime Traffic with 1 terminal and 1 pre-/on-carriage. Internal transport a. handling is incl. in port charge

Tab. 4.13.15.2/1: Total Cost in EURO/ITU for specific situations

Impact of price level

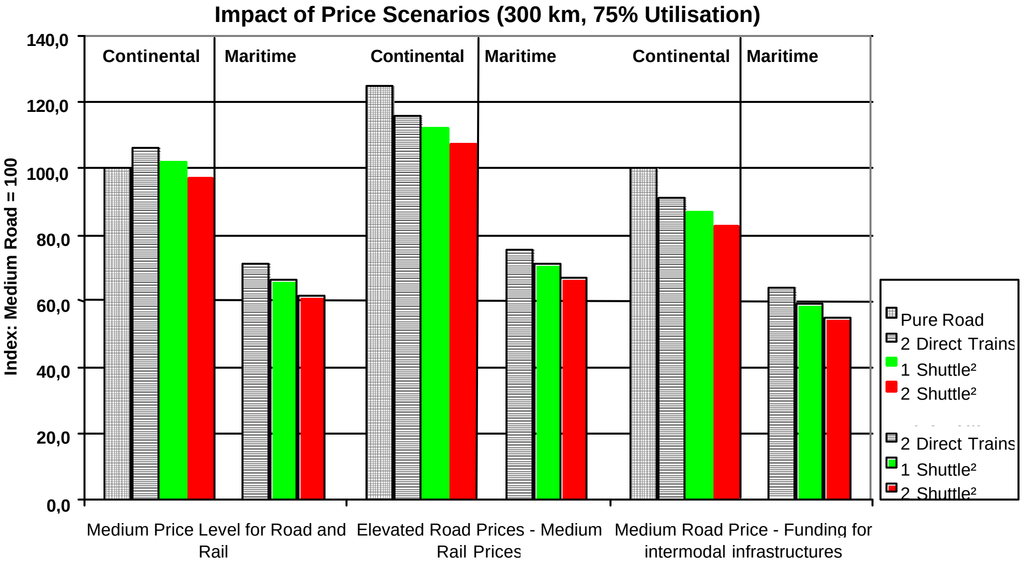


Fig. 4.13.15.2/1: Impact of Price Scenarios

It can be seen that generally the continental market is more expensive than the maritime due to the double handling in two terminals and pre- <u>and</u> on-carriage whereas in the maritime terminal a port handling charge has to be covered by all modes. Therefore in the continental case intermodal transport can hardly compete with pure road transport.

On the contrary, intermodal transport gives noticeable lower cost and therefore allows competition with the road transport in two cases:

?? in the cases of elevated road prices (although the raise intermodal terminal haulage, too)

?? in the case of funding of intermodal infrastructures (terminal and track)

Impact of Train Utilisation rate

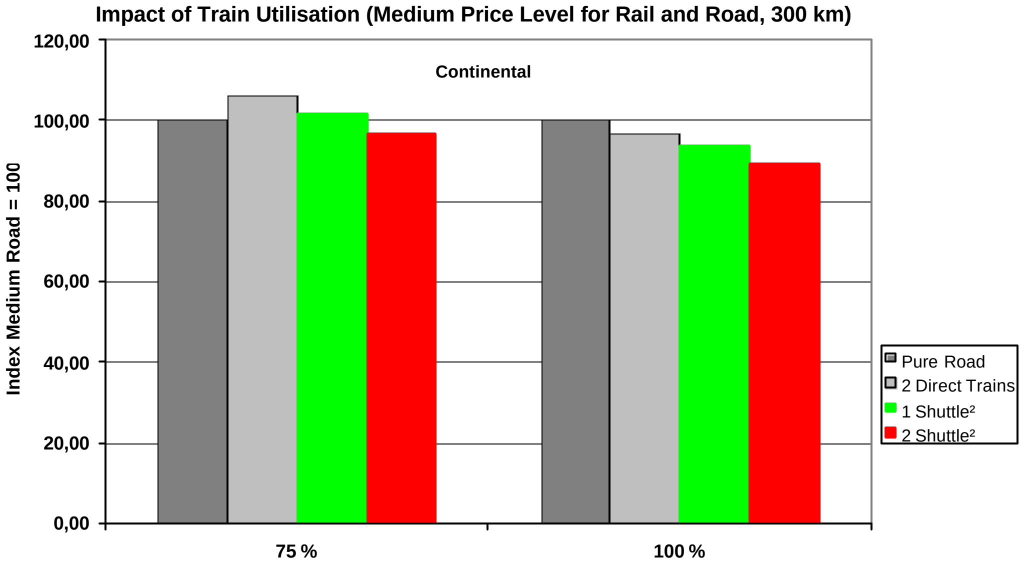


Fig. 4.13.15.2/2: Impact of Train Utilisation

More favourable for the intermodal transport results can be produced if 100% train utilisation will be considered (see relevant cost data in Table XX.1). However, an intermodal service that requests 100% train utilisation in order to be economic viable is very sensitive. Therefore, it is more appropriate to perform the analysis based on a 75% train utilisation. After all, a 25% decrease of utilisation elevates the unit price by only 9%.

In case of 75% utilisation direct and Shuttle² are not compatible any more whereas 2-Shuttle² are still less expensive.

In the following the case of 75% utilisation will be examined regarding its distance dependency.

Impact of Distance

For the most realistic scenario (medium price level for both modes and a 75% utilisation of the train) the maritime market was proved to be more economic than the continental market regardless the rail operating form. Also the difference between the three operating concepts remains valid. The new information is indeed the break-even distance, which is 310 km in the continental and 133 km in the maritime case (for Shuttle² trains). Considering a better utilisation, or higher truck rates or funding of intermodal infrastructures this distance can become even lower, e.g. 208 km for 100% utilisation, funding and a continental Shuttle².

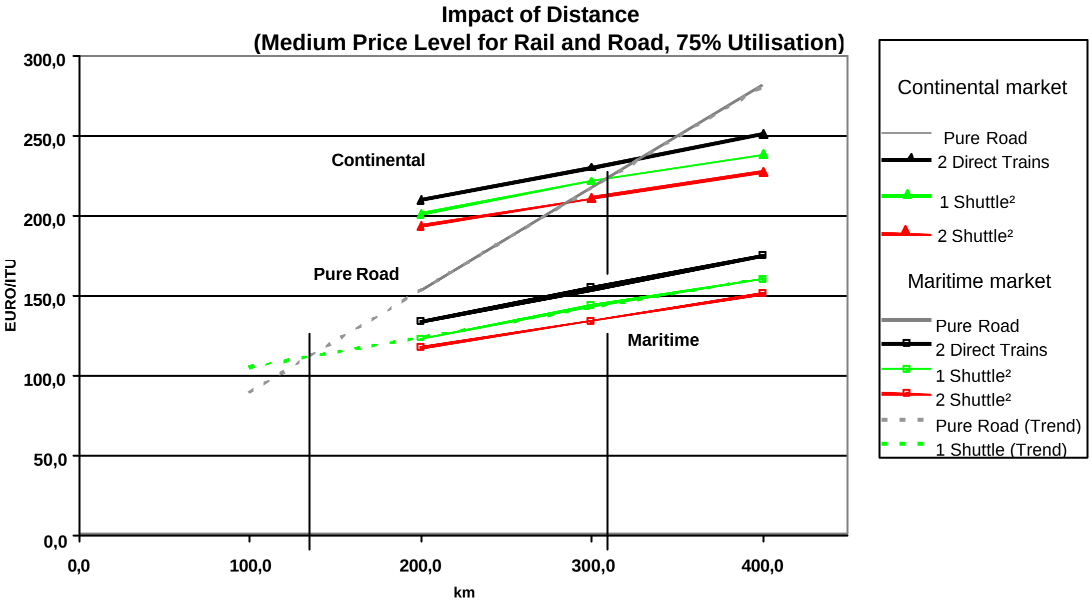


Fig. 4.13.15.2/3: Impact of Distance

Impact of Distance and Price Variations on Shuttle²

In the following figure the impact of distance and variations of prices in a continental market reaching 75% train utilisation can be seen. There is a considerable effect of price modifications also on the intermodal transport due the influence on the pre- and on-carriage. However, the impact on pure road is higher and therefore the intermodal transport can benefit from that.

Nevertheless there are also measures like running Shuttle² instead of direct or group trains and funding of rail infrastructures which allow intermodal transport against pure road transport even under continental market constraints.

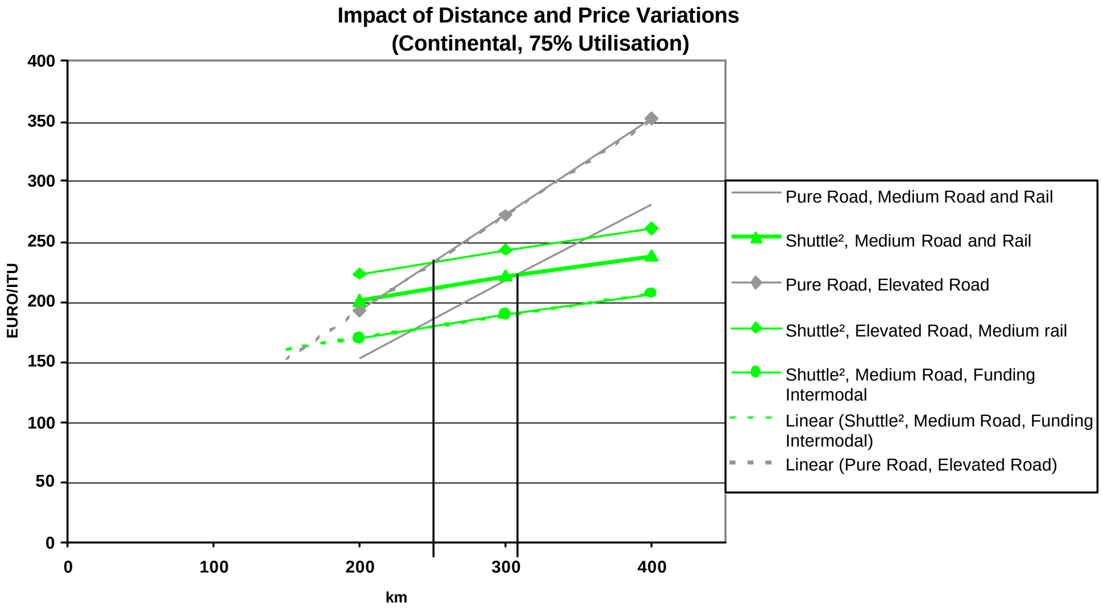


Fig. 4.13.15.2/4: Impact of Distance and Price Variations on Shuttle²

The Rail-Road cost "Equilibrium Case",

The cost of intermodal transport depends on the average filling or utilisation rate of the trains in service on a given connection. The equilibrium is defined as the utilisation rate of train capacity at which intermodal costs are equal to road costs. In other words, this value can be used as an indicator of the market penetration required to launch such a service at a cost equivalent to the road market.

By example, the equilibrium filling rate on the continental market for the Shuttle² is equal to 51%. This means that a minimum market of 128 (ITU) x 10 (tons/ITU) x 250 (traffic days per year) x 51 (utilisation rate) = 163,200 tons/year is required to make profitable the intermodal transport on a connection.

At equal (Rail – Road) price the Rail market share (up to now) is very low (e.g. 3%). Then if the market share is evaluated at 3% when the price ratio equal 1, the Shuttle² can be implemented between area where the total containerisable flows exceed 163,200 / .03 = 5,440,000 tons/years (both directions summed). This value is considerable and except if an increase in utilisation rate decreases the price and thus tends to augment appreciably the market share, the Shuttle² risk to be very difficult to make profitable on this precise case.

Same assessment could be made for price ratio (intermodal price / road price) equal to 0.9, 0.8, 0.7 (with hypothesis on the market share at these references points) in order to evaluate the total market required for each operation case.

If the equilibrium rate is equal to 20% the maximum reference market is equal to 2,130,000 tons/year and relation.

4.14 RECOMMENDATIONS FOR FUNCTIONAL LAYOUTS FOR TERMINALS (WP 4.1/WP 4.2)

The works which are summarised in the following, have technically been co-ordinated by Euretitalia (Workpackage Leader) and Krupp. ERRI, Framatome, Costamasnaga, Euretitalia, NTUA and ETH IVT have contributed.

4.14.1 Introduction

Objective of the Workpackages 4.1 and 4.2 of the IMPULSE projects is to elaborate and describe recommendation for functional layouts of advanced terminals and to contribute to the dissemination of the results related to terminals achieved in the course of the whole project.

The work was originally thought as two different Workpackages: one dealing with terminals of limited performance, the second with terminals of high performance.

Some factors have influenced the decision of aggregating together the two previously distinct Workpackages 4.1 and 4.2, among these: the similarities of organisation and contents of the original programs and the difficulties encountered in the classification and clear distinction between terminals with "limited" and "high" performance.

The problem of terminal classification is strictly related to the identification of the key parameters that influence various terminal capabilities. Section 2 deals with this subject, reviewing the main aspects emerged during the project.

Technical operation performed in terminals influence, and are influenced by, the terminal layout configuration. Section 3 outlines the main factors to be taken into account for the design of future advanced terminals.

Operations in most seaport and inland terminals are currently totally manual. According to some operators automation in the context of terminals with limited requirements is not applicable or non cost-effective.

What has often happened in many fields, however, is that automation made it possible to establish a service where it would be unfeasible to set it out with conventional techniques.

Part of the work performed was therefore devoted to investigating the limits for the employment of automation in terminals; section 4 summarizes the most important findings.

One of the main results emerged from the project is that we can achieve substantial benefits from new automated terminals only if an overall vision of the complete transport chain from origin to destination is considered. Section 5 deals with the role of different terminal typologies within the network.

The final part of the report treats aspects related to terminal design, cost effectiveness and final recommendations.

4.14.2 Elements for Terminal Evaluation

This section contains a synthesis of the main elements to be taken into account for a correct evaluation of a terminal configuration. Categorisation can be done according to:

?? Modes served, ITU types handled and volume achieved

?? Geographic position

?? Number and length of tracks

?? Storage facilities

?? Road distribution

4.14.2.1 Volume of ITU Handled

This is often the first element for the characterization of a terminal. Usually in the past there was a direct correlation between ITU volumes and spatial dimension of terminals in terms of occupied area. Considering the total number of ITUs handled per year a distinction in three categories of terminals, small, medium and large is often made, but it seems hard to agree on sharp limits, and even to define limits at all, since there are substantial differences among countries. As already pointed out in Deliverable D11, SIMET has developed a suitable classification scheme. IMPULSE has accepted this scheme and it is shown in Tables 1 and 2 below.

Type	**Modes**	**Unit type(s)**	**Current volume range [units per year]** ?? **Small terminals** ?? **Medium terminals** ?? **Large terminals**	**Future volume range [units per year]** ?? **Small terminals** ?? **Medium terminals** ?? **Large teminals**
I	Rail-Road Combiterminal	Swap bodies Semi-trailers Containers	< 20 000 20 000 - 100 000 > 150 000	< 30 000 30 000 - 150 000 > 150 000
IIa	Barge-Road Container terminal	Containers	< 30 000 30 000 - 50 000 > 50 000	< 50 000 > 50 000
IIb	Barge-Rail-Road Container terminal	Containers	< 50 000 > 50 000	< 100 000 > 100 000
IIIa	Maritime Full-Container terminal with Road and Rail connection	Containers	< 100 000 > 100 000	< 200 000 > 200 000
IIIb	Maritime Full-Container terminal with Road/R ail/Barge connection	Containers	< 200 000 200 - 500 000 > 500 000	< 300 000 300 000 - 500 000 > 500 000

Tab. 4.14.2.1/1: Existing Intermodal Transport Terminal Types

Type	Modes/description	Unit type(s)	Future volume range [units per year]
VI	Rail-Road Bimodal terminal	Bimodal units (special semi-trailers)	10 000 (small terminals)
V	Rail-Rail Transfer terminal	Swap body Semi-trailer Container	< 300 000 (small terminals) > 300 000 (large terminals)

Tab. 4.14.2.1/2: Future Intermodal Transport Terminal Types

Rail-Road terminals with dedicated "bimodal" transhipment techniques were expected to be of only limited significance – bimodal systems are not suited for large-scale operations.

These first elements are only useful for classification purposes, but we found out that it is difficult to completely agree on a rigid repartition of terminal in the three categories listed above. Moreover, the introduction of automation and advanced handling and storage techniques originate a separation between total throughput and spatial dimension. A more correct classification should take into account not only the size and capacity of a terminal, but its position within a network. Some of these issues are discussed in later chapters of this report.

For the simulation of the different system configurations of rail-road combined terminals, the following daily volumes were considered: up to 250 ITU/day for small terminals; between 250 and 500 ITU/day for medium terminals and above 500 ITU/day for large terminals (see deliverable D13/14 for details).

4.14.2.2 Geographical Position

A factor, which influences the terminal configuration and dimension, is the location of a terminal with respect to

?? industrial and commercial agglomerations;

?? configuration of the approaching railway network,

?? presence of the main road infrastructures,

?? geographical barriers (especially mountains),

?? barriers caused by legal restrictions and regular frameworks.

Regional development and location of industry and commercial sites strongly influence the determination of the optimal place and size of a terminal and the choice of the equipment.

Position within a network determines several conditioning factors that are more extensively described in section 4

The presence of laws and regulations, which restrict road circulation, can influence both the locations of a terminal and the techniques used. The permanence of an "antiquate" form of intermodalism such as the rolling-highway is linked to these barriers.

The Impulse Project focused most of its efforts in the evaluation of technological and organizational issues of intermodal transport, seeking to provide solutions that enhance its efficiency. Additional advantages derived by geographical position and regulatory framework were not taken into account, since the main effort was to prove the feasibility of innovative solution in a mode-neutral environment, where competition based on service quality is the leading force. Nevertheless, these additional factors should be taken into account when evaluating the possible impact of a new service; in most of the cases they would increase the competitiveness of intermodal transport, making convenient even sub-optimal solutions.

4.14.2.3 Number and Length of Tracks

Most of the existing terminals have short transhipment tracks (450 m to 550 m), which means long trains must be split and serviced in two parts. This could continue to be the case for the majority of small and medium terminals in the near future. The reason for this approach is that during the terminal design phase, the infrastructure cost for a long transhipment area is compared with the infrastructure cost of a shorter transhipment area plus the additional operating cost for servicing the train in two parts. It seems that for small and medium-volume terminals this calculation comes out in favour of the shorter transhipment design. For terminals served by reach stackers the simulation results showed that "half-modules" with short transhipment tracks are more economical than full modules. Although additional operating costs are supported by the latter due to the additional operations of train switching between the transhipment tracks and the waiting tracks, the overall cost saving taking into account investment cost are higher.

Longer tracks are needed for some innovative rail operation forms (see Section 5), when traditional equipment is installed in the terminal.

The Krupp Fast Handling equipment has the advantage of providing the possibility of transhipping a train without having to break it in parts, even when the length of the transhipment area of the terminal is shorter than 700 m.

The number of sidings/transhipment tracks are mainly dependent on the number of trains that use the terminal, by their composition and their timetable, i.e. by the number and size of wagon which are present in the terminal at the same time. For each train that can not be served and returned or parked outside a garage siding must be foreseen. Depending on the technology, the number of transhipment tracks can vary. The simulation model has shown that there are not apparent differences in the total number of sidings/transhipment tracks between conventional terminals (equipped with gantry cranes) and advanced terminals (e.g. equipped with Krupp fast handling systems). An example presented in deliverable D13/14 showed that a medium-volume terminal with long (750 m) tracks would require 4 transhipment and 2 sidings/waiting tracks (for block train service), 1 track for liner train service (partly used) and 1 free track for the shunting locomotive manoeuvres, i.e. a total of 8 tracks. The “equivalent” advanced design consists of 8 tracks for the waiting trains plus a 200 m transhipment track. It should be noted that the advanced design is more flexible since the transhipment can be separated from the waiting tracks and can be located in any "convenient" area.

4.14.2.4 Storage Area

This element is strictly related to the volume and the kind of ITUs predominantly handled in the terminal, the relation of train- and truck- arrival pattern and the specific demand to using the terminal as storage area in the logistic chain.

As pointed out in Deliverable D11, different kinds of ITU highly differ in storage requirements, handling capabilities and lifecycle. Very infrequently inland terminals are specialised in a kind of ITU. It sometimes happens that some terminals linked to main ports handle only containers, but it is especially true for private terminals. The situation in public accessible terminals is that almost everywhere they can cope with all different kind of standardised ITU (containers, swap bodies and semi-trailers).

For the evaluation of necessary storage area, assumptions about repartition of traffics among different kinds of ITUs is essential.

If a high percentage of containers are to be managed then usually more space for storage is required because their average dwelling time within the arrival or departure terminals lasts more than for swap bodies. Moreover often the complete cycle of container movement requires an empty return, as they are hardly used for inland movements, and thus they need to be re-positioned to a maritime port.

Containers, on the other hand, have the advantage of stackability, which reduce land consumption, but causes an increase of handling time and costs. , ITU stacking increases handling activities, since it generates a number of shuffles (rearrangements required in order to provide access to the ITUs that are not on top of the stacks). Currently, the mean stacking height in the majority of rail terminals is very near to 1. Containers are usually stacked one or two high, while (exceptionally) an empty (box-type) swap body can be placed above a loaded one.

In case of a strong relation between train arrival (departure) and truck pick-up (delivery) the buffer area on or next to the wagon is reduced. However, sometimes the terminals are used as buffer for longer time and thus the need for extensive storage places (e.g. for reefer container and dangerous cargoes) increases. On the one hand this bears the risk to "fill" and overload the terminal area, on the other hand it is a potential source of income. In this case the terminal should invoice for the staying which e.g. exceeds one day.

4.14.2.5 Characteristics of Road Distribution

Two key factors have to be considered:

?? Pattern arrival of trucks

?? Catchment area of terminals,

As far as the first aspect is concerned, in Workpackage 3.1 a set of Truck Arrival patterns was hypothesized. The arrival pattern used for carrying out some simulation reflects the common experience in most European contexts. It is to be mentioned, however, that many factors influence this arrival pattern, the most important of which being the kind of loading units prevalently handled.

The catchment area of terminals aspect is influence by factor like:

?? Total distance between origin and final destination

?? Position within the intermodal network and train service

?? Presence of other nearby terminals

?? Marketing of the terminal and commercial agreements with operators and other terminals.

4.14.3 Assessment of the Technical Operations and Procedures

Different issues related to current procedures in terminals have been discussed in previous Workpackages. We highlight here a couple of issues, which are considered relevant for their impact on costs and on safety in terminals.

4.14.3.1 Safety Inspection on the Train

A number of safety inspections are carried out in terminals: Technical control on empty container wagons before they are loaded again (Test WU 1K), test for conformity with load/gauge/vehicle specifications (Test WU 2K), test for damage caused by marshalling (Test WU 3K) and braking test. Despite the fact that some test can be performed in parallel, the total time required for safety checks related to combined traffic loading and train formation is quite long (about three hours using two people). An allowance of some minutes should be made in case an irregularity is discovered on a wagon, which a member of staff can eliminate on the wagon or in the train set. An additional allowance of some minutes should be made in case damaged wagons have to be removed from service or returned to the transhipment yard for correct loading.

If the trains only stop and are not split up and re-composed in the terminal – e.g. if automatic rail-rail transhipment is used – the vehicle test can be limited to checking the positioning of the load (providing tests on load units from the local dispatch are carried out by an inspector). It is sometimes also possible to carry out this positioning test using a camera and monitor on a stationary train (during loading) or on a train passing by slowly. Approximately 15 minutes must be allowed for this check when carried out by two people on a train 700 m long.

4.14.3.2 Transhipment Operations

The current fashion in transhipment procedures in rail-road terminals is the direct transhipment from rail to road and vice-versa, to avoid double handling of ITUs and storage in dedicated terminal areas. Practically the ITUs are buffered/stored on the wagon, which is forced to stay in the terminals for almost all day.

This fact has two main negative consequences:

?? Bad utilisation of rolling stock, with consequent technological ageing of wagon without much usage

?? Poor utilisation of terminal capacity.

As far as this second aspect is concerned, IMPULSE defines two different capacities: static and dynamic (see Deliverable D11).

“Static capacity” assumes that there are two trains per track per day (one incoming in the morning and one outgoing in the evening). If we assume an average of 20 m per wagon, we can calculate that one metre of track corresponds to 1/10 of a wagon; the daily static capacity of a terminal can thus be calculated by dividing the number of metres of loading track by 10. In reality, however, the same wagon from the incoming train stands at the terminal throughout the day.

“Dynamic capacity” assumes that there can be more than two trains per day on a given transhipment track; this is of course possible when there is enough volume to allow for further trains and requires trains to arrive and leave during the day (a floating system). In the flow system, the incoming train has to be unloaded totally before it can be taken out of the terminal. Otherwise the ITU will not be accessible for the lorries to be picked-up or require additional shunting to be made available.

The aptitude of different terminal equipment and layout configurations to improve the capacity were examined by means of cost calculation and simulations. The main recommendations deriving from this analysis are presented in section 7.

4.14.4 Definition of the Necessary Automation

In view of the desired increase of intermodal transport volume industrial companies have proposed to apply automation in intermodal terminals. This would respect the progressive development in other business sectors like production, warehousing, consolidation and groupage but also large seaport container terminals. Examples for the latter can be found at Rotterdam ECT Sealand terminal. Automation is a generic term summarising all aspects related to measuring, controlling and steering. Automation is aiming to:

?? Control difficult tasks, because human beings can not solve those tasks without support, because they are e.g. too complex, fast, inaccessible or decentralised.

?? Achieve better economical results through increase of quality and quantity of production, reduction of time, energy, material or manpower, increase of flexibility and better utilisation of means of production

?? Raise the reliability, safety and lifespan by optimisation of load capability (constant parameters without peaks), avoidance of mistakes and automated diagnosis of machines and processes

?? Improve working and living conditions by replacing lowbrow, monotonous, strenuous, dangerous works by improvement of comfort of operation.

Discontinuous processes like inside intermodal terminals have become accessible to automation to a great extent by the development of microelectronics. This may contribute to:

?? Measuring and logging of data

?? Collection of data

?? Processing of data

?? Steering and control of processes

?? Optimisation of processes

Which can be seen as complementary steps to be executed in succession. In this respect automation in terminals can vary from relative simple logging-in of data for operation and mostly commercial activities (which ITU, when, from where to where, by which mode, whom to invoice) to sensor-based (e.g. radio frequency tags or video cameras) systems which are able to provide sufficient (timely and accurate) set of information for automated movement and loading/unloading operations. More complex terminals will have fewer employees in the operation area and are supervised from the central control room.

Control room architecture requires sensors at all relevant places of the terminal and high-skilled multi-purpose employees to control all activities. Those will be fewer but more trained to execute a couple of different tasks during the day. Gate-in procedures, verification of ITU (identity, condition, location and position of gripping points), unloading strategies, creation of jobs, communication with customers, problem solving, planing of outgoing load according to booking, supervision, inspection and invoicing are typical tasks which can occur during the day.

In terms of automation the decisive factor for intermodal terminals will be the demand of the operation modes to handle an increasing amount of ITU in short time throughout a full 24-hour day and seven days a week. In addition to economical reasons differences in national culture may influence the promotion and introduction of automated intermodal terminals.

In regions with a peak demand of ITU confronted with valuable estate and expensive workers (work legislation, payment) and environmental awareness the introduction of – relative expensive - automation technologies will be easier compared to other places where less ITU are to be transhipped and industrialisation of transport processes is not so far developed.

However, in order to apply automation, the whole operation process has to be structured and devided into sub-tasks. Just by this analysis the first step into a structured and transparent operation is made. The first automation will therefore appear in the data control rather than in the physical handling. Some experts may even see a prerequisite that information is made available electronically prior to automated handling. Nevertheless some industries have developed handling systems which can be called “partly-automated” because they are guided by a control system whereas the final movement and gripping is carried out by a human being. In other cases the lack of reliable data on the transport means and ITU is compensated by appropriate terminal equipment which creates the necessary information from different sources and verification at the terminal gate ("stand-alone"). Other manufacturer and operator have selected special areas for automation; e.g. internal transport and storage whereas links to external means of transport (vessels, trains and especially lorries) are not subject to automation but still manually controlled. This is the second line of decision: internal or external automation.

A third and most sophisticated will be the man-free or man-less terminal in which the external operation staff (e.g. train driver or lorry driver) can "ask" for the ITU and it will automatically appear without manual intervention in-between.

To summarise, there can be three levels of automation:

1. manual, which means that automation is limited to data processing and providing relevant information to the operators (advice)
2. semi-automated, some data is provided automatically, the rest is maintained manually and verified manually, first, basic movements with less accuracy and dispersal (e.g. 1-m) are executed by the machines whereas fine tuning and final handling is carried out manually automation is limited to machine control (e.g. anti collision, anti sway, drive to distinct places) and not to whole system control
3. Fully automated operation in which the User – if any - is reduced to being a passive controller and the machines communicate via a central material flow unit. This degree of automation requires a maximum of sensor and control mechanism and provides the largest advantage compared to the aims of automation.

These degrees of automation also imply a time component: the higher the degree of automation the longer the time horizon for implementation in large-scale daily operation throughout Europe will take.

Large terminals with a large annual volume and a high throughput per time unit (peak load factor) have high investment cost and operational costs. On the other hand the operation cost per ITU can be reduced through the application of automation. On the other extremity are small terminals defined as less total and per time unit volume, which is to say fewer requirements. In this field automation is not obviously applicable. However, there are situations in such small terminal where one should consider automated processes.

In case that small volume has to be treated on very limited infrastructure, automated processes, e.g. for terminal operation planning and management can increase the throughput. This is particular important if peak-demand occurs occasionally.

Such small terminals have of course also less buffer space, equipment and personnel to deal with short time peak demand and opening hours exceeding e.g. one shift or in case of illness. To resume, there are also cases in which one should consider automated or partly automated processes in smaller sized terminals. A general rule for the size capacity for the threshold can not be given. It needs to examined in particular case considering:

?? the anticipated annual and peak throughput

?? the train operation form (schedule)

?? the behaviour of truck side (pick-up and delivery)

?? the steadiness and stability of the traffic flow

?? the opening hours and their time (one shift, two part shifts with break, day/night, etc.)

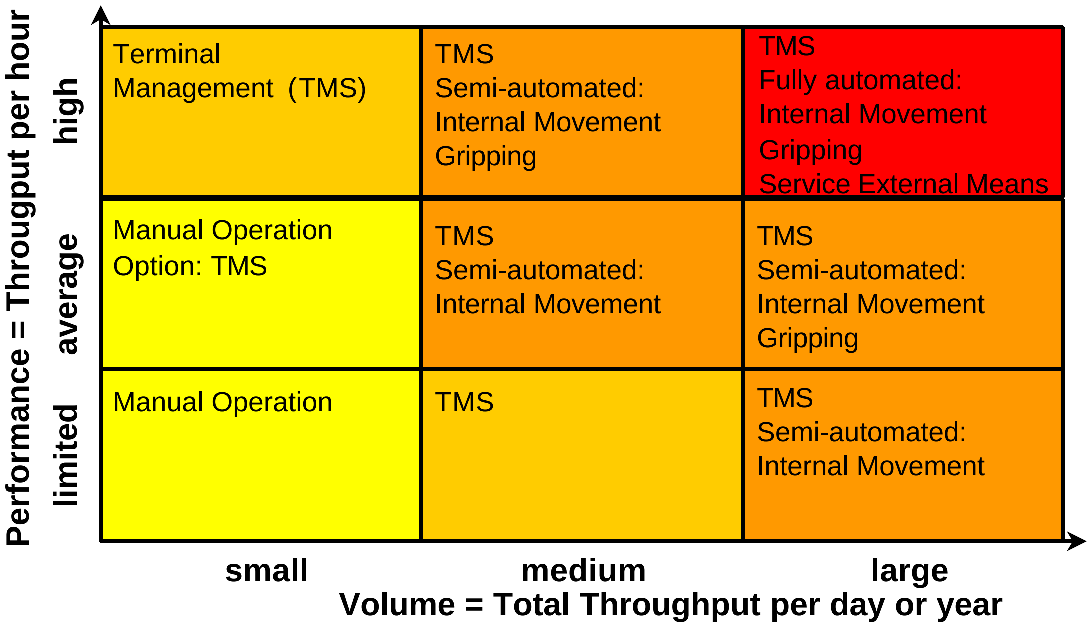
?? the availability of land and infrastructures (tracks, storage area, road lanes and gates)

?? the cost of personnel

?? the environmental factors such as limits to noise emissions and space and energy consumption

The following figure demonstrates the fields of automation compared to performance and volume of terminals.

Fields of Automation



Performance = Througput per hour	small	medium	large
high	Terminal Management (TMS)	TMS Semi-automated: Internal Movement Gripping	TMS Fully automated: Internal Movement Gripping Service External Means
average	Manual Operation Option: TMS	TMS Semi-automated: Internal Movement	TMS Semi-automated: Internal Movement Gripping
limited	Manual Operation	TMS	TMS Semi-automated: Internal Movement

Source: Krupp, 5.06.99

Fig. 4.14.4: Fields of Automation

4.14.5 Terminals and Train Operating Forms

One of the main results emerged from the project is that we can achieve substantial benefits from new automated terminals only if an overall vision of the complete transport chain from origin to destination is considered. Which is the role of different terminal typologies within the network? In the past the process of concentration of traffic over a limited number of large terminals was judged the only way of developing Intermodal Transport, although reality shows a network of small and very small terminals throughout Europe. Is there still place for small terminals? How can new operational forms on rail and automation influence the development of small terminals?

These are a few questions we have tried to answer during our work. There is no clear and complete answer to all of them, and a specific solution have to be worked out for each particular situation, taking into account regional regulations, current operations and local factors. This section provides some elements that can help developing a first answer.

The different train operation forms have different demands on the terminal-designs. It is not necessary that a terminal served by block trains has the same transhipment performance as a terminal which is served by a liner train. The position of the terminal should always be located in good accessible position in the railway network, especially the hub terminals has to be in a very central position in the network. These just exemplary described demands and correlation are shown in the following table. For the terminals served by different train operation forms the terminal design has to comply the highest demand per category.

Train form	**Terminal requirements**				
	Rail access	**Loading speed**	**Terminal size**	**Geogr. position**	**Organisation transport chain**
Shuttle trains	direct, electrified if possible	fast, depending on timetable	not significant	medium-large agglomeration	Road+Terminal in one hand
Shuttle2 train	direct, electrified if possible	very fast	not significant	large agglomeration or hubs	Road+Terminal in one hand
Hub&Spoke trains	Hub: direct, electrified if possible Others: direct access less significant	very fast	medium	medium agglomeration, central position in the network	One operator for the whole network Road+Terminal in one hand
Block trains	direct access less significant	not very fast	not significant	medium-large agglomeration	Road+Terminal in one hand
Feeder trains	direct access less significant	not very fast	small-medium	small-medium agglomeration	Road+Terminal in one hand
Pick up trains	direct access less significant	not very fast	small	small agglomeration	Road+Terminal in one hand
Liner trains	direct, electrified if possible	very fast	small	small agglomerations, incoperated in railway stations	Road+Terminal in one hand

Tab. 4.14.5: Train Operation Form and Terminal Requirement

The aspects mentioned on the table are briefly explained in the following sections.

4.14.5.1 Rail Access

All train operation forms with short terminal stopping time requirements (Shuttle, Hub&Spoke, Liner) need a direct access to terminal with main line locomotive. As most European mainlines are electrified, there is an electrified access needed. So the transhipment must be possible under catenary or the trains must be able to roll without catenary through the transhipment area.

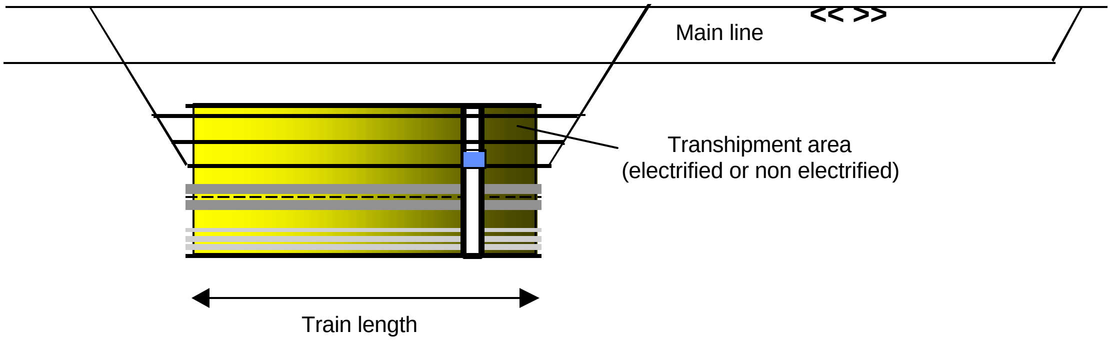


Fig. 4.14.5.1/1: Recommended Layout for Hub-and-spoke, Liner- and Shuttle-trains with Access from Both Sides

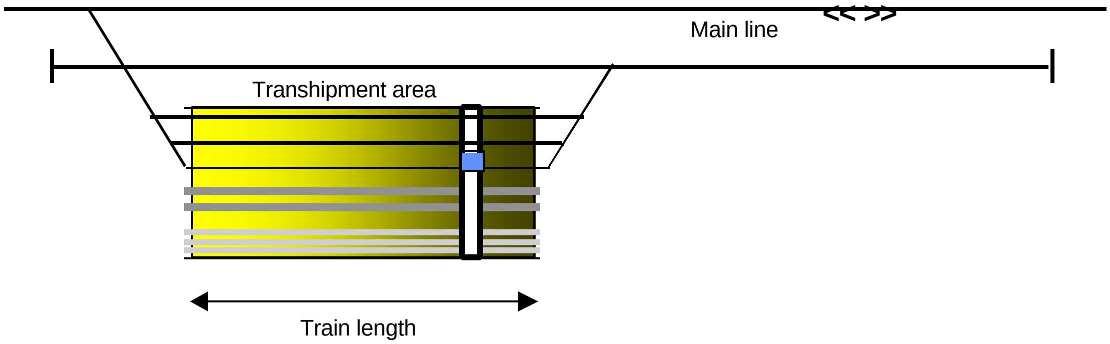


Fig. 4.14.5.1/2: Recommended Layout only Useful for Shuttle-trains with Two-sided Access

Avoidance of shunting for entrance/departure of terminals is very economic; when shunting teams have no other works to do than pull and push complete intermodal trains.

If single terminals don't allow providing an electrified entrance (transhipment technology or geographical position), the use of diesel locomotive hauled trains can be economic.

All operation forms without requirement of short transhipment time (Block-, Feeder-, Overnight Shuttle-trains) does not mandatory a direct terminal access, although an improved access can bring additional time savings.

Various advanced rail access techniques/systems were addressed in Deliverable D11. Among those, two techniques were selected for further analysis by means of simulation:

3. The "coasting technique", allowing the train to coast from the main line into position on the transhipment track.
4. Using a slewing catenary on the loading track. Following the arrival of a train hauled by electric traction, the catenary withdrawal device allows work to be carried out above the train in complete safety.

The first technique requires bi-directional access, otherwise the electric locomotive would be "caught" in the dead-end track, while the second can be efficiently used in terminals with uni-directional access.

The results of cost calculation show ed that conclusion is that the “coast with momentum” direct access system has a relatively low cost per train, with the main system disadvantage of the mandatory bi-directional terminal access.

The “slewing catenary” direct access system is much more expensive but can be applied to every terminal. The system is more effective in conjunction with rail techniques that lead to high track utilisation.

4.14.5.2 Loading Speed

The requirements to the loading speed depend on the loading time. The highest requirements have the Hub-and-Spoke-trains. When e.g. six trains with 60 ITU’s have to tranship 40% of their ITU's, there is needed a transhipment capacity of 140-150 ITU’s/hour.

A high transhipment speed is also requested for shuttle² and normal shuttle trains with short stopping time. When e.g. a shuttle train with 60 ITU’s has to be transhipped completely in 60 minutes, there are 120 ITU’s/hour to tranship (loading and unloading). This required loading speed is more or less similar to Hub-and-Spoke-trains.

The idea of Liner trains is to tranship a few ITU's in a very short time. When there are e.g. 15 ITU’s of a train with 60 ITU’s to tranship in 30 minutes, the required transhipment performance is 60 ITU’s/hour, which is less than with Hub-and-Spoke- or Shuttle trains.

4.14.5.3 Terminal Size

The terminal size for **Shuttle-trains** depends on number of shuttle-trains. When loading demand for one destination allows using a complete train, it must be a medium or large terminal. When shuttle trains must be transhipped in a short time, this loading speed allows transhipping different trains in one working shift.

Hub-and-Spoke System: The inefficient capacity use of hubs requires that hubs are also medium terminals for medium or greater agglomerations. Their rest capacity can be used between the bundles of hub&spoke-trains for other trains. With using shuttle trains as part of a Hub-and-Spoke train-system, small terminals can be served also with shuttle trains (more than one destination in one train).

Terminal size for **Block trains** is comparable to shuttle-trains.

Feeder-, Pick up- and Liner-trains are typical operation forms for small terminals. Liner trains allows offering transports to different other terminals, but only on short distances. All these train operation forms can also be used as an additional form in medium or large terminals or can be used for connections via hubs.

4.14.5.4 Geographic Position

The geographic position is usually relevant for the terminal size. But the dimension of agglomeration is only one condition for the extend of the demand. Demand for medium or large terminals can also result from specific regional economies like logistic centre for a greater region or a country (e.g. Basle). In this case it may serve as border station, own loads of the Basle region, gateway to Switzerland and nodal point to collect trans-alpine cargoes.

4.14.5.5 Organisation of the Transport Chain

In small terminals there are higher transhipment costs expected because of a non-optimal use of the installed infrastructure.

An optimal use of the daily capacity of trucks in road-distribution can reduce the distribution costs. Best solution for an optimal journey planning of trucks is that the terminal operator owns trucks or that a third party owns them, which is under contract of the terminal operator.

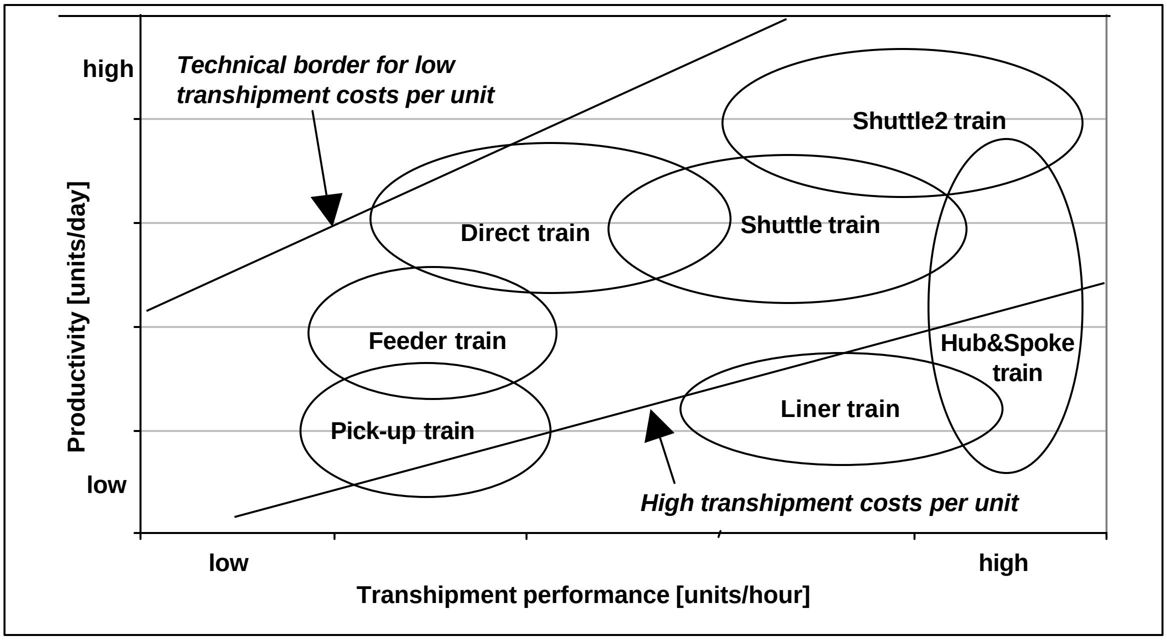


Fig. 4.14.5.5: Relation Between Terminal Requirement and Train Operation Form

It is accepted that terminals with a regular transhipment performance during the whole day cause lower transhipment costs per unit than a terminal that has only one peak load per day. This fact is shown in the diagram above; the position and size of the data-ellipses can only be interpreted qualitatively. The ordinate shows the transhipment performance per hour and the abscissa is showing the terminal productivity per day. Train operation forms in the upper-left corner causes low transhipment costs per unit, train operation forms in the lower-right corner causes high transhipment costs per unit.

Once more it has to be stressed out that it is necessary to consider all costs of the whole transport chain, with the help of just this diagram there can not be done any conclusion for the choice of the best train operating form. The high terminal costs per unit for a typical liner train terminal e.g. can be balanced by low distribution costs due to short road serving distances.

4.14.6 Evaluation of Characteristics of Different Terminal Designs

There are no definite answers to the question about the optimal size and configuration of an intermodal terminal.

The main actors of the intermodality arena have undertaken some contrasting tendencies and development policies.

The two main positions for the development of new terminals for the future are the French and the German ones.

In France, in terminals built in the coming years, the following points will be taken into consideration:

- The tracks should be 750 m long, so as to be able to receive the longest trains in one piece. (*)
- Each yard should have three such tracks
- There will be large areas dedicated to storage
- There will be no dead end. This will allow access to the terminal via two rail access points.
- There will be two sets of points, to allow two locomotives to enter and leave the terminal at the same time.
- Ideally, a number of sidings will be attached to the terminals so that idle trains (i.e. those that have already been loaded or unloaded) can be parked outside the terminal. Ideally again, these sidings will be located behind or in front of the terminal, rather than next to it, so as to limit locomotive movements.

Since many shunting yards are no longer in use, the terminals will be built on these sites. This will allow existing infrastructure to be used. Furthermore, these old

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[*] It must be noted that this selection increases the terminal investment cost but reduces the train and terminal operating cost.

shunting yards generally already have numerous long tracks. They therefore look like ideal sites for the terminals of the third and following generations.

In Germany, the basis for the planning of intermodal transport transhipment terminals at Deutsche Bahn (German Railways) is the "Standard Module" which was co-ordinated with the Eisenbahnbundesamt (EBA, Federal Railway Authority Office) and the Eisenbahnunfallkasse (EUK, Railway Insurance Office) regarding its cross-section (crane bearing distance, distances between tracks, driving and loading lanes, storage lanes) on 23 January 1998. A standard module consists of three gantry cranes with a bearing distance of 39.80 m (centre of crane rail to centre of crane rail). These gantry cranes span:

- Four transhipment tracks with a length of 700 m each
- One loading lane
- One driving lane
- Three ITU storage lanes

Outside the crane area and depending on the location, there is the driving lane for entry or exit to/from the transhipment area and the tracks for exchanges, bypasses and for stabling damaged wagons.

With a track occupation factor of 1.5, such a module has a capacity of 750 incoming and outgoing ITU per day in the flow procedure. For smaller traffic volumes, half a module is used to start with, i.e. length of the transhipment track = 350 m (dead-end track with connection at one end) and one or two gantry cranes.

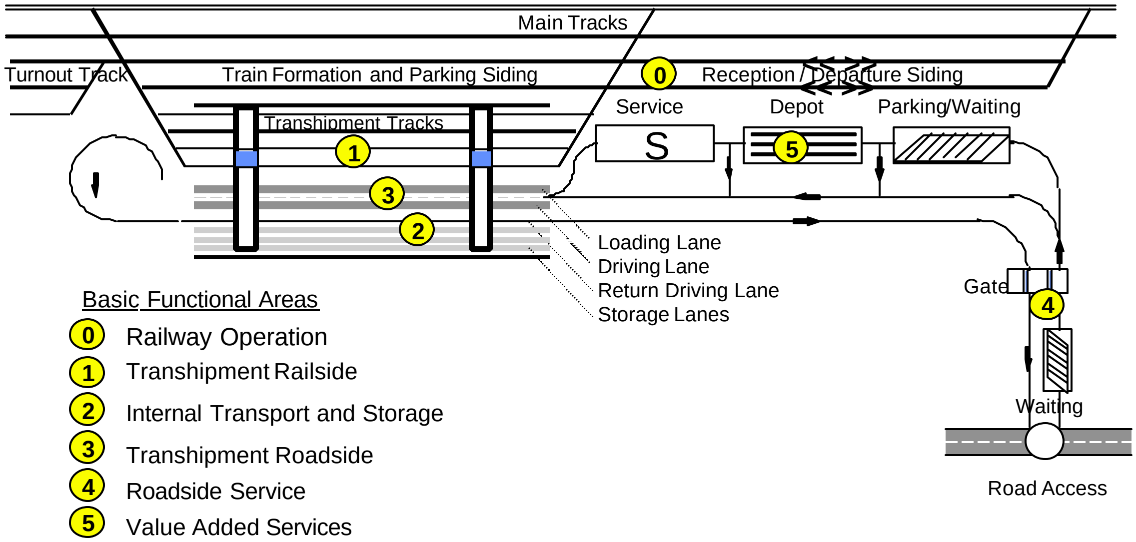
This solution offers remarkable features:

- Direct train-to-road and train-to-train transhipment (up to 4 trains can be performed effectively).
- Reasonable compromise as it matches efficiently the operational requirements for block/group train service, limited gateway and (small) hub functions.
- Good utilisation of handling equipment – used both for rail and lorry service operations.

However, the service of rail and road in same area, and with same equipment, can create conflicts (productivity losses) and increase accident risk.

Regarding installation of new technologies in intermodal rail-road terminals the following aspects may be highlighted in view of their benefits and potential to be implemented, taking the Krupp Fast Handling System as an example:

- Time
- Space/Area
- Flexibility/Adaptability to future needs



Source: WP 4.1/2 (Krupp, 1999)

Fig. 4.14.6/1: Layout of a Conventional Terminal

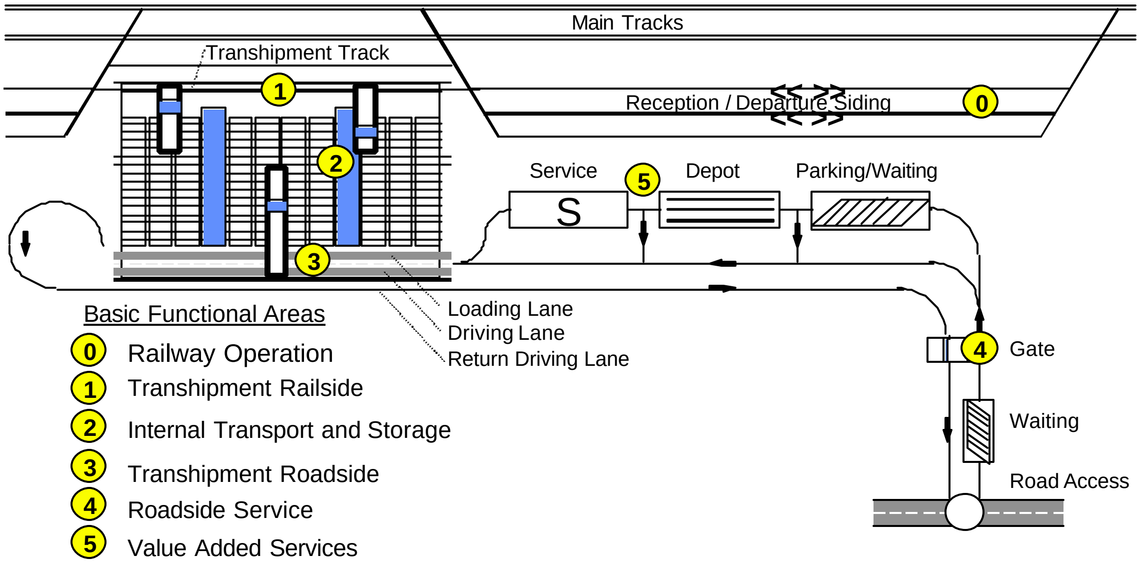


Fig. 4.14.6/2: Layout of an Advanced Terminal for Adapted for Conventional Schedule but Suitable for Innovative Schedule and Advanced Operation

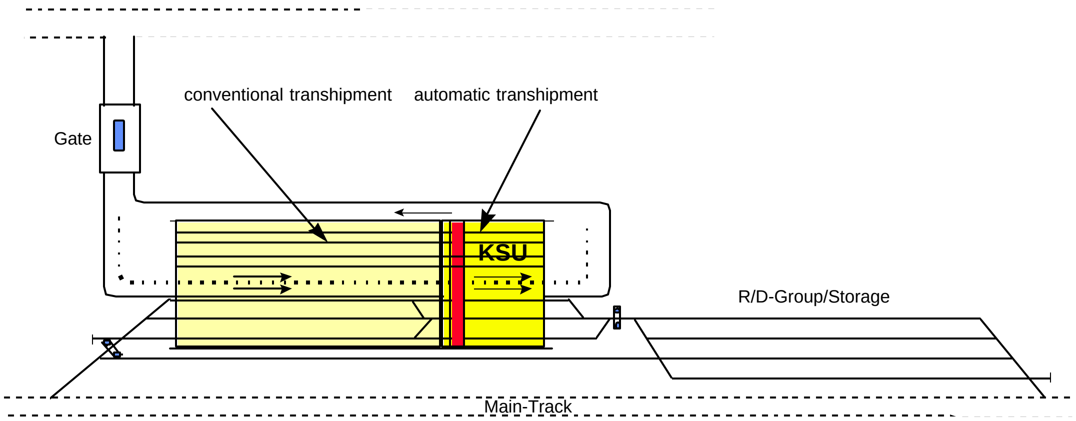


Fig. 4.14.6/3: Layout for Single Area Variant for Step-by-step Realisation

4.14.7 Final Recommendations

The work performed in the course of the Impulse project has shown that there are still margins for the improvement of the attractiveness of Combined transport. Most of the factors are related to the improvement of the quality of service; others are directly linked to cost saving connected to a better utilisation of terminal capacity.

This final chapter synthesises in some brief suggestions the project's findings related to terminal issues.

The first recommendation is, however, to consider the terminal as just one element of the complete door-to-door intermodal chain, and therefore to evaluate terminal issues, especially as far as costs are concerned, within the general framework of the complete integrated transport chain. For this reason we have always considered the external operational environment in which the terminal is situated. The connection to the railways system is extremely important because on one side it influences the terminal configuration by imposing operational constraints and on the other side it is influenced by terminal performances. More advanced concerns regarding network-related issues are presented in deliverable 17.

We have grouped the set of recommendations in three different sub-headings:

?? Recommendations for terminal operators

?? Recommendations for rail operators

?? Recommendation for road transport operators

The distinction was mainly due to the need of organise our suggestions under three homogeneous groups of issues, which have the above mentioned operators as their main actors.

4.14.7.1 Recommendations for Terminal Operators

The recommendations to terminal operators are mainly linked to terminal design.

There isn't any single optimal design, but there are many different terminal designs (layout and handling equipment configurations), each of one is effective in a certain cargo volume range and is restricted by its capacity limitations.

The capacity limitation of the intermodal transport terminal is defined by its weakest sub-system. The two major sub-systems that usually affect the terminal capacity are:

?? The capacity of the (rail-side) transhipment tracks,

?? The capacity of the terminal's handling system.

The basic result of the simulations carried out in the framework of the Impulse Project was that the terminal's capacity limitations are imposed mainly by the capacity limitations of the sidings/transhipment track sub-system rather than by the handling equipment capabilities, at least for the majority of terminal configuration with limited rail-rail transhipment.

In the present organisational context the capacity of the transhipment tracks is determined considering that the terminal can serve only two trains per day and per (long) track (one coming, one going). Therefore the terminal capacity is restricted to about 120 ITU/track (60 incoming plus 60 outgoing ITU). We defined this as "static capacity", contrasting it with "dynamic capacity", which considers the possible utilisation of transhipment tracks by more trains a day.

A more effective utilisation of siding tracks can dramatically improve the performance on the rail side, but it imposes additional costs, which varies according to different handling technology adopted. The major disadvantage of this system is that the incoming train has to be unloaded totally before it can be taken out of the transhipment area.

The suggestion arising from the evaluations and comparison of different systems is that one important issue to be considered for taking full advantage of this operational concept is the availability of an advanced terminal management system that allows an efficient monitoring of the system and an optimised pre-planning of the operations.

A truck pattern arrival linked to loading unit availability rather than train arrival could be an help. This can be achieved by an improvement of the communication between pre-/end haulage operators and the terminal

The other limiting factor, the capacity of the terminal's handling system, depends on the type and amount of equipment used.

The simulations carried out showed that each of the existing and the new proposed advanced transhipment systems has a certain volume-range over which it presents the best performance in terms of cost/ITU handled. Therefore, depending of the range of terminal's ITU throughput, both simple traditional solutions such as reach stackers and advanced equipment can have their niche of market.

The advantages of **Reach-stackers** are their flexibility and their relatively low purchase price. The main disadvantage is that they can serve only one transhipment track, i.e. the one that is near the driving lane. Where proper infrastructure exists (embedded rail tracks), reach-stackers can also serve other tracks. Therefore the only way to improve the capacity of a terminal equipped with this technology is to add new modules and new equipment. More than one train can be served by switching the trains between the transhipment track and the waiting track(s) but many (costly and time consuming) shunting operations are then required. In addition the percentage of indirect (train-store-truck and vice versa) movements is high (due to the frequent need for “clear the train” operations) and “inconvenience” and delays occur when trucks arrive to pick up ITU which are still on the trains in the waiting tracks.

Other findings achieved in the course of the project has shown that important quality factors in the terminal service, beyond cost performance, should be taken into account. We therefore suggest restricting the usage of this simple equipment to terminals with limited requirements, or to use them to complement other more advanced equipment to face peak flows and emergency situation.

Gantry-crane based designs has shown to be effective for a wide range of cargo volumes. The designs require a high level of investment (even for one crane) but enable progressive capacity improvements by adding more cranes in the existing infrastructure.

The simulations showed that one crane operating at 24 ITU/hour is not adequate to serve the tracks at the assumed quality-of-service level when the terminal volume reaches 250 ITU per day. The limit for two gantry cranes (operating at 24 ITU/hour) was close to 500 ITU/day while three cranes extended the limit to 750 ITU/day but the handling equipment started to perform badly.

The simulation also suggests that some investment should be put in an improvement of performance of the cranes for solutions equipped with 3 of them. In fact the results showed a good performance, up to 850 units/day assuming an handling rate of 28 ITU/hour.

Consequently our recommendation is to seek an increase of crane productivity deriving not only by an "hardware" improvement, but also by a "software" and organisational improvement.

The “**Krupp basic**” equipment has shown its main advantages on the side of a better utilisation of the rolling stock, but it hasn't shown many advantages for medium-sized terminals with a rather conventional train schedule. The simulation results were determined considering a long module with a productivity of 500-600 ITU/day, which is greater than the original Krupp design. This was done to take into account some market “desire” for advanced designs that can operate as efficiently as conventional designs in today’s operating conditions and – in addition - can operate more efficiently under “improved” operating conditions.

Better performance were shown considering a design comprising 2 basic modules, which is estimated to operate up to 1200 ITU/day at a cost per ITU transhipped similar to that of “equivalent” conventional designs.

Some smaller variants of the basic design were considered, and one of them was proven to be an effective compromise between their conventional and “basic” fast handling systems.

Our recommendation to terminal operators is to investigate the possibility of the utilisation of this advanced system in conjunction with the improvement of organisation of the train pattern arrival. This equipment can dramatically improve the rail -side operations, even if it presents major drawbacks in the satisfaction of high peak of demand on the road -side. This means that one can not expect much benefit for such a system if a thorough re-organisation of all the communications system on both the rail-side and the road -side is accomplished.

Other important advantages of the original Krupp systems are linked to the improved management of the storage area, which is now totally automatic. This does not have any measurable benefits in terms of cost, but have an high impact of the overall terminal efficiency and quality of the offered services.

Modifications of the system and adoption of part of its innovative concepts to meet the requirements of a more traditional general operational plan are of course possible, but the real advantages of the system are linked to a complete reorganisation of the services.

These notes applies in an even more strict way to the Technicatome's (**Commutor-based**) designs follow the company's "philosophy" for advanced handling which focuses on a fully automatic system (mainly for the rail-rail yards) that can offer very high productivity at reasonable cost but which requires new wagon types, highly standardised ITU and special connectors between ITU and wagons.

The general final remark addressed to terminal operators is to be aware that the possible benefits produced by new terminal design are more on the side of the quality of service improvement, rather than a decreasing of costs.

All the investigations and evaluation carried out seem to concord that we can not expect much improvement in the cost side deriving from a mere change of terminal equipment, leaving all the other factors (loading units and overall network organisation) unchanged.

4.14.7.2 Recommendations for Rail Operators

As already pointed out, the main benefits of an improved terminal design based on automated facilities are to be seen in the overall impact on the complete door-to-door chain. The rail operators therefore play a key role in the development of new terminals. The choice of alternative technology and terminal design are mainly linked to the chosen operational forms over the rail network.

The results of previous IMPULSE work packages showed that the enhancement of the rail sector should be based on advanced rail forms since the technology is able to provide the required support (advanced/fast handling systems, advanced/improved rolling stock, advanced access systems, identification/location/positioning systems).

In Deliverable D 4 (Operating Forms for Network Modes) various enhanced operating forms have been introduced, arguing that the future improvements of the rail sector should be based in the complimentary and comprehensive use of all operating forms (direct trains, feeder systems, shuttle-shuttle forms, liner trains, hub-and-spoke systems, full-load traffic).

In the framework of the project the simulation of a number of future scenarios where the use of liner trains has increased and where shuttle-shuttle forms have been introduced to attract volume over short and medium distances was carried out.

The impacts of these new operating forms over the network are taken into account in the specific recommendations in the Deliverable D17.

The effects on terminal costs have been calculated in the form of the minimum number of additional ITU required to cover the additional cost imposed by the “new” operational forms (break-even points).

The increase in the number of liner trains has different impact depending on the capacity and the expansion possibilities of the existing and advanced terminal designs. There are three basic situations:

1. Terminals operating to the limits of their dynamic capacity.
2. Terminals operating between their static and dynamic capacity.
3. Terminals operating below their static capacity.

For the first case, the two possible options to accommodate additional liner trains are:

1. To dedicate one transhipment track to the liner train service.
2. To expand the waiting transhipment track by adding one more track (if no area restriction exists) and swap (direct and liner) trains between transhipment and waiting tracks.

The cost-effectiveness of the first option resulted questionable, while the second option seems a suitable solution to be further investigated, since the additional costs resulted “balanced” by the “income ” of 55 ITU (about 55 ? 18 Euro/ITU) which is the “income” of 2 liner trains.

For terminals operating between their static and dynamic capacity there were no significant differences from the above case, while for terminals operating below their static capacity, no additional improvements seem justifiable.

As far as the liner train service is concerned, the suggestion is to take into account the “moving train” technique for its ability to offer new possibilities for half-module terminals.

The innovative solution of the shuttle^2 (double shuttle) train was introduced in the framework of the Impulse project as a mean of increasing the competitiveness of intermodal transport over short an medium distances. Its importance is based on the fact that it doesn't require a complete re-organisation of railways operations, like the liner train, but it operates under the present operational conditions of freight traffic, with trains handled at night.

Two alternative techniques were investigated for the accommodation of the shuttle^2 operating form:

?? The Krupp fast handling terminal, in its basic and single-area variants (see Deliverables D11 and D13/14)

- Non-transhipment shuttle-shuttle technique, the train locomotive leaves one group of 40 wagons and takes another 40. Wagon utilisation is 50% since they remain idle in the terminal for half the night.

The costs of the two alternatives resulted comparable in our simulations.

The conclusion from is that the additional costs imposed by the night operation can be absorbed by a moderate volume of “attracted” traffic. The results are sensitive to the number of personnel involved. Since the advanced handling systems require less personnel, they give better results than the conventional ones.

The real advantages of this innovative operating form are however measurable more on the side of the overall impact on the chain rather than in the impact on a single terminal.

Our suggestion and recommendation is therefore to take into consideration the opportunities offered by innovative services in areas where there are significant exchange of goods over short to medium distances. A favourable situation is the case of ports located at a distance of 200-400 km to an industrial area.

4.14.7.3 Recommendation for Road Transport Operators

The benefits deriving to road transport operator are linked to two groups of issues:

- Savings of time at the terminal gate
- Improvement of the quality of service.

The additional improvement in terminal performance will have only limited impact on time savings at the gate, since the time requirements are almost always met by present terminals, and were used as a constraint for the evaluation of all the terminal scenarios. We imposed that all different solutions had to fulfil the quality criterion "95% of arriving trucks served within 20 minutes" for truck arrivals in an “adjusted to ITU availability” arrival pattern (see Deliverable D13/14).

The main advantages are therefore linked to quality factors such as reliability of delivery time, completeness of information, wider time windows for the delivery of ITU.

The only recommendation to road transport operators is to pursue an efficient development of communication systems for the connection to terminal operators. Only in this way an optimal arrival pattern can be assured, with advantages on both the overall performance of terminal and on the individual shipment.

4.15 RECOMMENDATIONS FOR THE OPTIMISED DESIGN AND UTILISATION OF ROLLING STOCK (WP 4.3)

The works which are summarised in the following, have technically been co-ordinated by Costamasnaga (Workpackage Leader). ERRI and Technicatome have contributed.

4.15.1 Actual Situation of European Rolling Stock

Today a great number of different kinds of wagons is present in the European network, they are different for dimensions, uses and applications. For a easier analysis a simplified classification has been adopted in order to divide wagons in the following 4 large categories:

Type A) Two axles wagons

Type B) Four axles wagons with 2 bogies

Type C) Articulated double wagons with 3 bogies

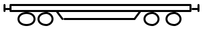
Type D) Articulated double wagons with 4 bogies

The distribution of the different kind of wagons present in Europe is summarised in the following table, in which for each main European railways companies both wagons type and number are reported.

	DB	DSB	FS	Trailstar	HUPAC	CNC	TRW	NOVATRANS	Total
Kgps			1898			2669			4567
Lgjns	5	28							33
Lgjs(s)	3								3
Lgjss *	**3**								**3**
Lgns				609					609
Lgs	200								200
									5415

* In **Bold** wagons suitable for use in "ss" traffic.

Type B)



	DB	DSB	FS	Trailstar	HUPAC	CNC	TRW	NOVATRANS	Total
Rgmms			1150						1150
Rgs(-W)	390		4937						5327
Sdgkkmss*			**900**						**900**
Sdgkms	697								697
Sdgmns	170	49							219
Sdgmnss			**400**		**55**				**455**
Sdgmss			**50**			**2514**			**2564**
Sdgns					101				101
Sdkmns					324				324
Sggnss			**800**						**800**
Sgjkkmms	1293					210			1503
Sgjmms		100							100
Sgjns	5								5
Sgjs	3018								3018
Sgmmns	61								61
Sgmnns							150		150
Sgmnnss							**50**		**50**
Sgmns	3	151							154
Sgns	500	150	2787	940	369				4746
Sgnss			**141**				**100**		**241**
Sgs	508						71		579
Sgss(-Y)	**91**						**151**		**242**
BL								**40**	**40**
BSL								**100**	**100**
CB								**198**	**198**
KC								**50**	**50**
K1 KU								**340**	**340**
K9								**49**	**49**
PB								**49**	**49**
PU								**355**	**355**
									24567

* In **Bold** wagons suitable for use in "ss" traffic.

Type C)

	DB	DSB	FS	Trailstar	HUPAC	CNC	TRW	NOVATRANS	Total
Sdggmrs	270								270
Sggmrs	1550								1550
Sggmrss*			**500**			**50**			**550**
TB								**35**	**35**
									2405

* In **Bold** wagons suitable for use in "ss" traffic.

Type D)

	DB	DSB	FS	Trailstar	HUPAC	CNC	TRW	NOVATRANS	Total
Saadggns					41				41
Sggmrrss*			**132**			**92**			**224**
									265

* In **Bold** wagons suitable for use in "ss" traffic.

Tab. 4.15.1/1: Distribution of Wagons Type and Number in Major European Railways Companies

Analysing these data It can be seen that about 75% of the total of the European wagons belong to the type B), 17% to type A), 7% to type C) and 1% to type D).

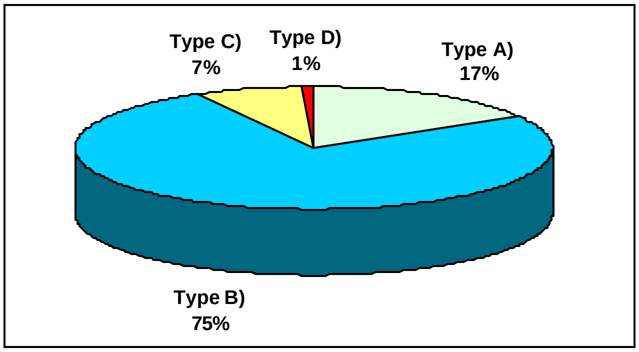


Fig. 4.15.1/1: Per Cent Distribution of Wagons Type

The average main dimensions of the wagons are respectively:

	Type A)	Type B)	Type C)	Type D)
Length over all:	17000mm	19800mm	34000mm	35600mm
Lenght loading plane:	15000mm	18400mm	32000mm	34000mm
Axles distance:	9000-10000mm			
Bogies distance		14200mm	14200mm	13300mm
Height Loading plane:	1180-1190mm	1090-1110-1140-1155-1165-1170-1175-1180-1190-1235-1240-1265-1335mm	1090-1155mm	920-940 mm
Tare:	13,5tons	20t	31t	35 t
Maximum Net Weight	28 (SC)-32 (SD) tons	60 (SC) - 70 (SD) - 65(SS)tons	92 (SC) - 98 (SD) - 99 (SS) tons	94 (SC) - 88 (SD) - 68 (SS) tons

Tab. 4.15.1/2: Average Main Dimensions of the Wagons

4.15.2 Typologies of Loading Surfaces

The main objectives consist to find out solutions to the two following problems:

- ?? made the wagon easily movable by automatic devices
- ?? made the loads lay-out on wagons easily identified by the same devices.

The first problem can be seen as to the identification of a particular point in the space, the second one can be correlated to the former and to the specific typologies of the loading surfaces.

To positioning an object in the space it needs to have an absolute known starting point and at least 6 (3 angular and 3 linear) co-ordinates that define the relative position of the object in relation to the fixed reference. A pilot solution:

An example relative to COMMUTOR is given.

- ?? The wagon defined for the automatic terminal COMMUTOR has the following particularities due to its automatic processing :
- ?? In the COMMUTOR system, the spigots are not fixed to the wagon, but put and centred in the dedicated supports fixed to the wagon. A rotating lock in this support prevents from rising the movable spigot.
- ?? A particularity of the COMMUTOR principle is that the spigot is handled in the same time as the box that it positions and maintains on the wagon.
- ?? For information, the centring lasts 5 seconds.
- ?? A particularity of the COMMUTOR wagon is that it can be positioned longitudinally by means of some stop motion device welded under its sub-frame. These stop motion device are used to receive a thrust from a jack located in the track that positions the wagon in the X axis. Except the interface spreader-wagon and wagon-positioner, the wagon doesn't present any specificity as for rigidity of its sub-frame. The deflection is about 40 mm in the wagon centre, and 30 mm at the end of the wagon.

The variations are taken into account by the interface spreader-wagon. The spreader is put for a part on the wagon and adjusts itself to level disparities resulting from the different allowances.

4.15.3 Information and Telematics Systems on Wagons

4.15.3.1 Recommended Information

As defined in WP 2.3 and adapted to the rolling stock, the basic data to be acquired during the identification process and transmitted to the user are the identity of the wagon, its direction during the journey, the place and the time at which it was identified. This frame is the basis for an identification system, but is not sufficient and can largely be extended. Indeed, the identification system must be able to display other information, displayed into :

- ?? <u>a fixed frame</u> : containing some " fixed " information concerning wagons features : wagons number, network code, wagons type, number of axles, owner code, maximal speed...
- ?? <u>a variable frame</u> : destination, next maintenance date and schedule, loaded/not loaded, loads characteristics...

This will allow to obtain particular train features such as registration, train composition, percentage of empty wagons, etc...and, more globally, operational indicators will be available, so as to improve the exploitation running (ratio loaded or not,...).

4.15.3.2 Recommended Technology

Bar code technology is not taken into account because it's too much susceptible to be dirtied by rail environment (and then implies a too frequent maintenance to wash the bar codes).

As explained in WP 3.1/3.3, it seems that the most promising technology, for the next five years, is using read and/or write radio-frequency tags, to be fixed on the wagons (more particularly, wagons' underframe), and which can be read using handheld reader systems or fixed terrestrial ones.

That kind of system can be envisaged under different scenarios :

?? scenario 1 :
a simple identification process at access interfaces between the rail network (and associated sphere of responsibility (in terms of operations,...)) and terminal area
Cost : one per wagon and two readers (in and out) and 5 handheld for terminal operations

?? scenario 2 :
at a larger scale, a squaring of the rail network by fixed readers placed across rail tracks, allowing to track wagons during the transport (it is reminded that the radio-frequency technologies are allowing " en route " lectures under speeds which can attain more than 200 km/h).
Cost : one per wagon and many readers across rail tracks
Transition period : Modular steps, which will begin with equipping the most used corridors

?? scenario 3 :
in case the unit is tagged, a reader can be envisaged on the wagon, which will read the displayed information ; an other tag, fixed that time on the wagon, would be readable through terrestrial or portable interrogators : information on goods would be directly displayed, during the transport (" en-route ") or when standing, and transmitted to the central management software.
Cost : one read/write tag and one reader per wagon and many readers across rail tracks

That technology has these advantages to possess a relatively high memory capacity (authorising several messages to be fitted in tags) and to have a high reliability and compatibility with other applications. Moreover, it is cheap and needs no power nor communication cost (except the energy consumed by the reader and associated monitoring software).

All these points are giving chances for several of these above scenario to be implemented.

The consecutive benefits are obvious :

?? Benefits to train operators :
improves service to customer by providing reliable information on wagons locations and reduces operating costs by improving asset visibility

?? Benefits to infrastructure manager :
improves quality of service to operators, improves management of train movements and allows to anticipate various control operations (pantograph monitoring, hot box sensing, weighing,...)

?? Benefits to terminal operators :
anticipation (planned movements' equipment and allocation of resources)

In consequence: operations costs' decrease and attractive to user (commercial consequences...).

4.15.4 Design Parameters

A very important aspects to reduce the wagons' costs are the design parameters related to wagons, in fact a reduction of structure's weight can carry a less use of material, a less brakes wear and a longer brakes life. On the other hand less noise wagons can be used more frequently by night.

Also the re-engineering of the structure to be automatic assembled can lead to a product more reliable and of easier construction. The main aspects to be discussed are:

Transported ITUs

Since the wagon is a component of the rail transport system the following aspects are going to be improved:

?? requirements coming from the ITU's to be transported

?? increase the ITU dimensions

This means:

?? trend to lower the loading surfaces of the wagons totally or partially in order to increase the maximum height of the ITU to be transported

?? need to use new wheels of reduced diameter and increased axle load (i.e., increase the axle load of existing small wheels)

Need to increase the ITU Load

This means:

?? reduce the tare of the wagons by optimisation of the wagon design

Need to increase the maximum Loading

This means:

?? need to study a new braking system capable to improve the braking distances of the actual trains in order to use heavier train compositions without changing the signalisation distances and systems. The braking with electronic control actually is studied.

Need to increase the Performance of the Wagons in the Marshalling Yards

This means:

- need to evaluate the possibility of automatic coupler application on the intermodal transport wagons: this matter has to be accurately evaluated according to the rail operation form. A basic issue is to be considered: the transhipment of ITU of today is substituting the marshalling of wagons for the ITU sorting. This means that the number of couplings on intermodal wagons should be limited. The application of automatic coupler may seem interesting for a rake of wagons having only the automatic coupler at each end of the rake. Possibility of conjunction with the feeder operation form.

Need to Increase the Overnight Freight Services

This means:

- need to reduce the noise generated by the wagons. The improvement of this aspect requires on one side the design of low noise wagon on the other the modifications of the existing wagons: in fact the noise level reduction is appreciable only if all the vehicles in general has low noise emission.

Need to Diagnose the Wagons Status

This means:

- need to understand what are the faults on a wagon, in order to improve the maintenance and to do in an automatic way some testings: for example, an electric braking system with a diagnose system permits to the locomotive driver of a freight wagon to know the status of the wagons (i.e. automatic braking test before to start).

4.15.5 Health and Safety at Work with Respect to Intermodal Wagon

Another precondition for fully automated transhipment is that no manual operations are required on a container wagon for loading and unloading. At the moment the fastenings still have to be put in the correct loading position manually when loading containers and swap bodies back onto container wagons.

Costamasnaga has carried out a detailed study of technical solutions where manual positioning of the fastening equipment is not required. Of the 3 different solutions tried on test wagons the most promising is the container locking mechanism with a rotating hammer head because

- this solution reduces the number of retaining bolts that are required because the containers are interlocked in place, and
- existing container wagons can be retrofitted (there is no absolute need to wait for a new generation of container wagons).

In this twistlock solution the safety heads on the retaining bolts are twisted by a bracket on the side of the wagon that can be moved along it. This sprung bracket is pushed back into the wagon by a slide rail at the side of the loading track; a gear mechanism then twists the hammer head of the locking mechanism, i.e. the container is unlocked. When the slide rail is not there, the bracket springs back out again such that the head of the lock is rotated into the locked position by the gear mechanism. In the centre of the wagon, there are lateral centring plates instead of the usual retaining bolts.

If the results of the tests are positive, then the number of retaining bolts per container can be reduced by half. This means that a container wagon for:

- one 40' long container,
- two 20' long containers or
- two 7.82 m long swap bodies

can carry these loading units without there being any need to change the position of the retaining bolts.

The studies carried out to date by Costamasnaga show that it is in principle possible, together with the MFR of an automated transhipment yard, to apply a technical solution and thereby avoid using personnel for manual positioning of fastening equipment for containers and swap bodies.

However, studies and tests are still required on the reliability of such equipment, particularly as regards its effects on operation in traditional transhipment yards.

4.15.6 Conclusions

Since the intermodal wagon is a component of the intermodal transport chain, its characteristics are coming from the systemic analysis

The major aspects to be considered in an innovative wagon are:

- the interface with transhipment systems: the applicability of the automatic handling technologies
- the interface with the rail transport system: the rail operation aspects
- the interface with workers: safety conditions

For short this means that the wagon should be a compromise among all the previous aspects , with a particular attention to the handling capacities of a wagon.

In order to have a good integration with vertical automated transhipment system, the should have the following characteristics:

- all the operation relative to the loading, unloading, positioning of the ITU should be done automatically without man intervention.
- the wagon should be able to be configured according to the ITUs to be loaded on it: the wagon enters the terminal, receives some orders and a system on it is capable of configuring the wagons pins for loading. This permits to associate a number of ITU to a certain wagon.
- the wagon should be compatible with the existing terminals and with the existing wagon operation (interoperability concept).

The wagon so should take into account all the not-rail aspects coming from the intermodal transport.

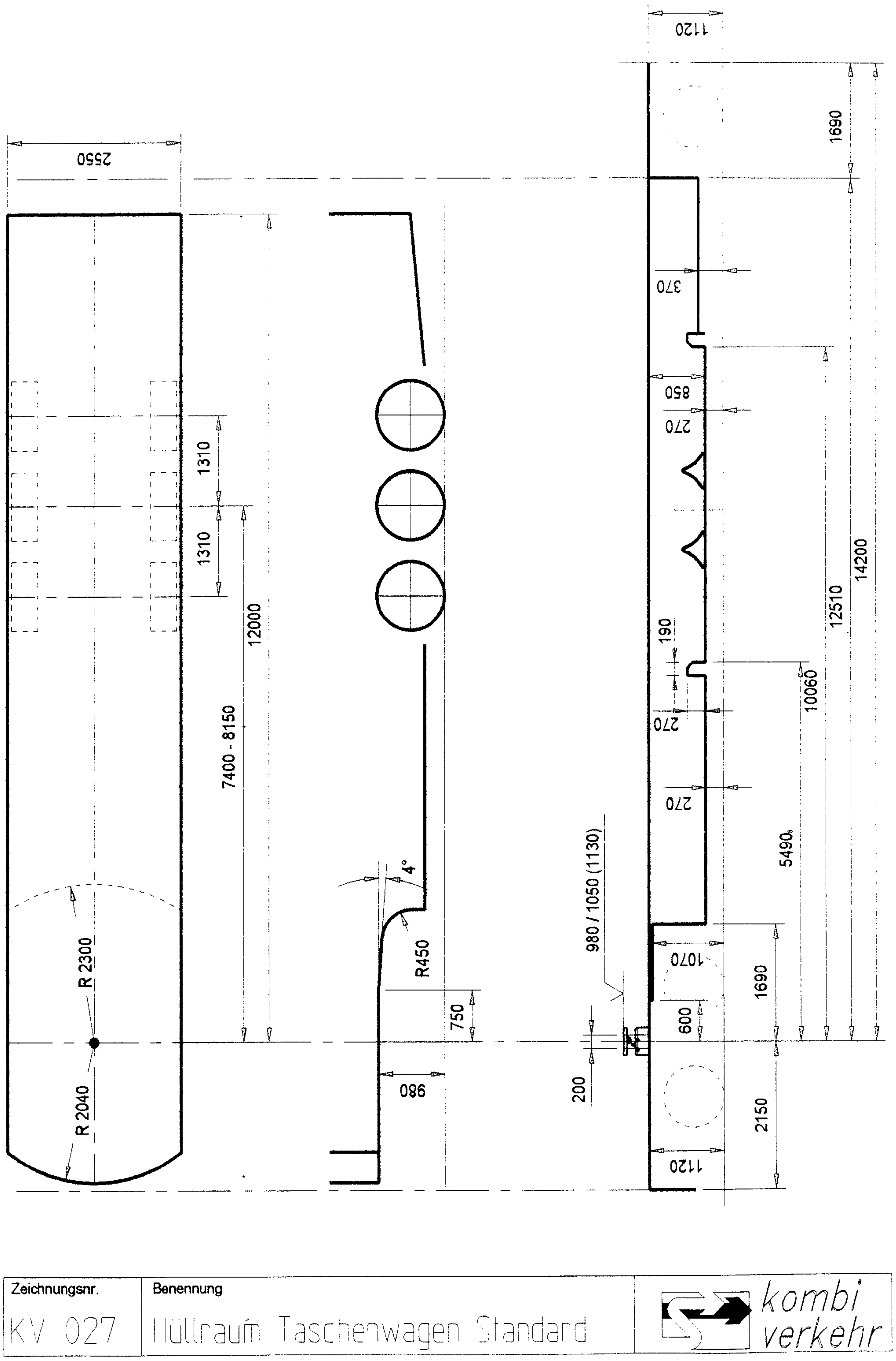


Fig. 4.15.6/1: *Dimensions of Pocket Wagon for Standard Semi-Trailers (Source Kombiverkehr)*

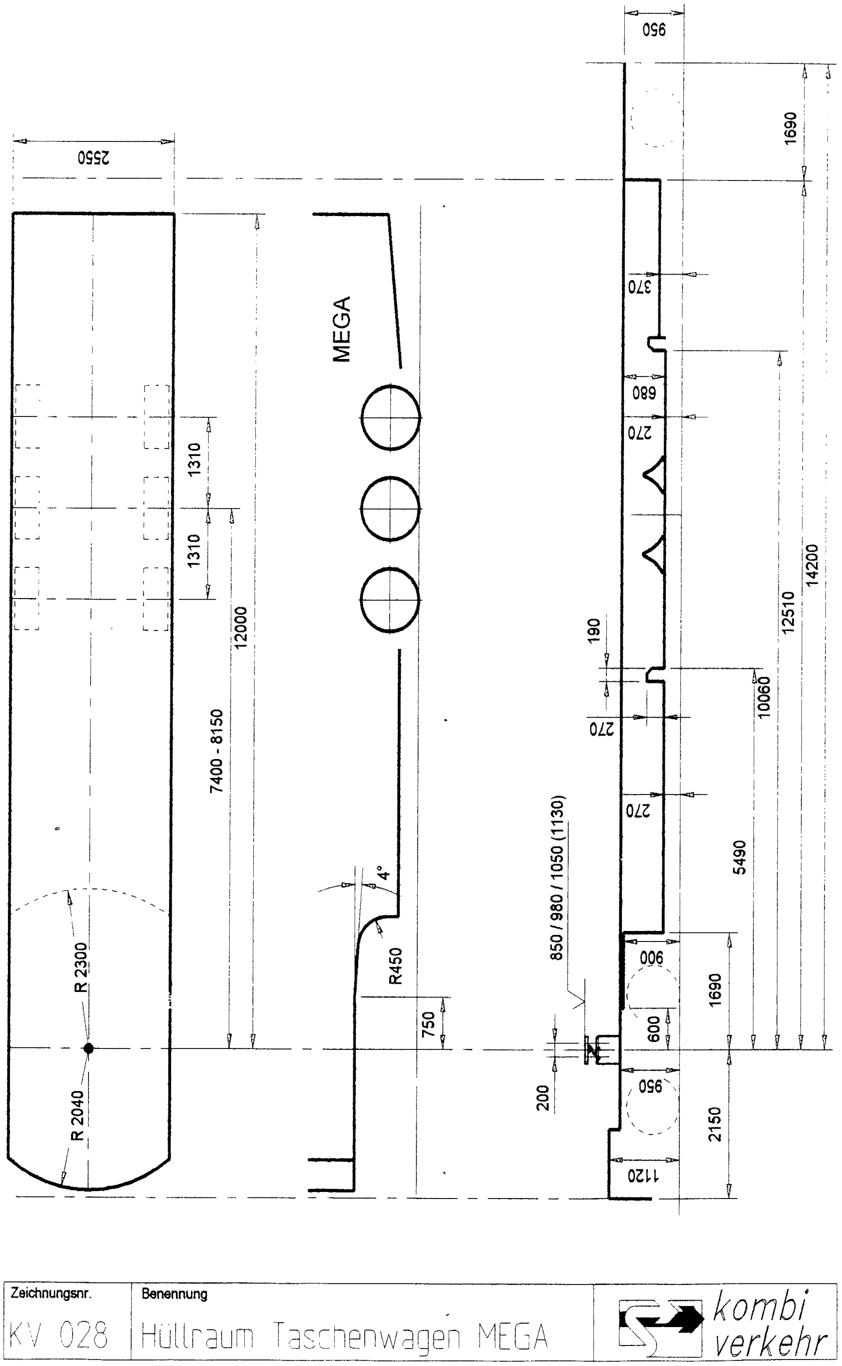


Fig. 4.15.6/2: *Dimensions of Pocket Wagon for Mega-Trailers (Source Kombiverkehr)*

4.16 RECOMMENDATIONS FOR OPERATING PROCEDURES FOR DIFFERENT TRANSPORT DISTANCES (WP 4.4)

The works which are summarised in the following, have technically been co-ordinated by ERRI (Workpackage Leader). Krupp has contributed.

The report incorporates the recommendations of previous work on terminals, rolling stock, organisation and commercial aspects, covering the entire integrated transport chain.

The recommendations have to respect the constraints imposed by existing freight flows, they will enable us, to specify the innovative technologies to use and to propose new operational procedures for short and medium-haul markets.

Innovative forms of train operation will win new market segments for rail.

In this context, creating more competitive, innovative forms of train operation mainly involves extending services to increase market share, becoming competitive over shorter distances and improving the integration of smaller traffic flows.

Future operations will not follow a unique optimum pattern. Forms of operation evolve continuously in response to changes in the technical-economic situation and the options available. In every case, a decision must be taken as to which form is the most suitable. The most effective approach is to carry out a case study for each situation.

The main elements to consider in seeking the most effective solution are:

- Transport demand
- Traffic volume
- Distance
- Network characteristics
- Economic aspects

Currently, operations fall into three main segments; international, national and a combination of both, in the form of full-load traffic.

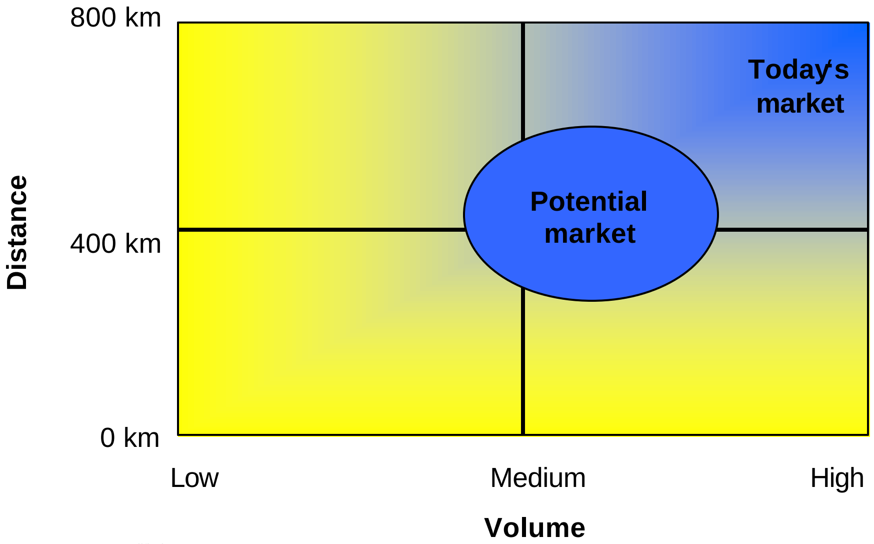
There are two primary trends – a move towards purely intermodal operation, completely separate from full-load traffic, and a tendency to extend direct train and feeder system operations.

The railways already command a considerable share of the long-haul market; attention is now turning to short/medium-haul markets – the markets with the largest freight volume.

The railways are aware that implementing new forms of operation is a key factor in the fight to win more volume for intermodal transport. The railways are also aware that improving terminals or terminal technology will not, on its own, attract additional volume; such measures will only lead to increased volume if accompanied by attractive forms of operation.

Intermodal transport over medium and short distances is the subject of long and heated discussions between railways, operators, scientists, politicians and other “experts”.

On short and medium distances, the fixed costs not related to distance therefore account for an extremely high percentage of total cost, prompting some “experts” to put the break-even point between road and intermodal transport at 600 km or even higher. However, the volume of cargo transported over such distances is small and rail has a considerable share of it already.

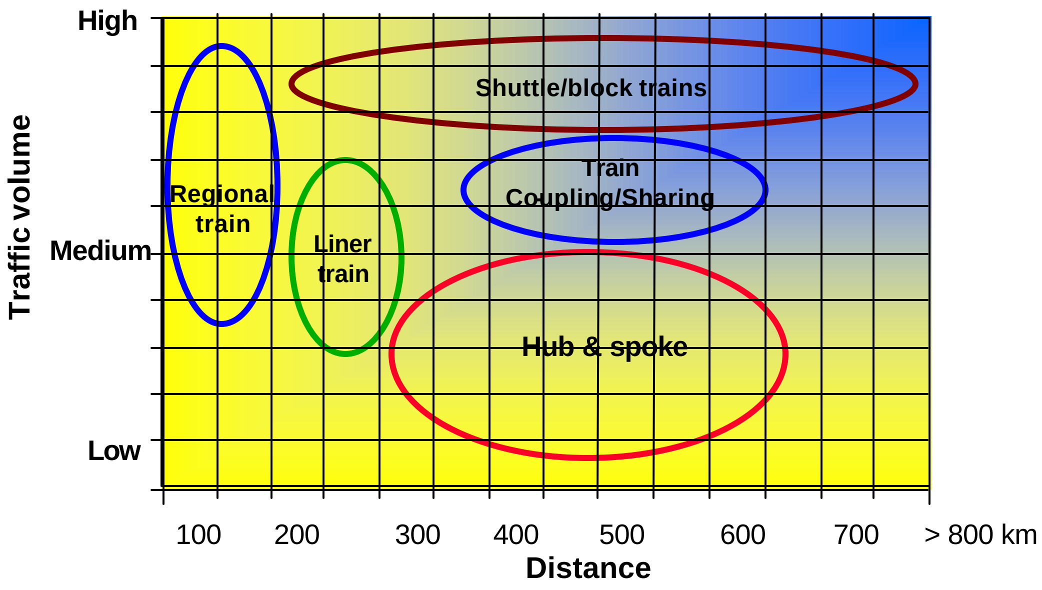


Source KV-TP 2000+, modified

Fig. 4.16/1: Intermodal Market Share in Terms of Volume and Distance

Market analysts have therefore investigated short and medium distances and attempted to develop forms of operation that allow intermodal transport to increase its share of this market, without losing sight of the traditional long-haul market.

These forms of operation have to handle low, diversified traffic flows. Their main purpose is therefore to link pairs of terminals and fill a complete train for at least the majority of the journey.



Source: KV-TP 2000+, modified

Fig. 4.16/2: Relationship Between Production Forms, Volume and Distance

Case studies within the IMPULSE project have shown that intermodal transport also has the potential to acquire an economically useful and important share of the medium-haul market (250 km to 300 km). However, this will only be possible if handling times for trains in transhipment facilities are reduced to the point where:

Either

?? A shuttle train can run twice per night with the same consist, within the time window demanded by the market, with transhipment during the night requiring less personnel

or

?? Operating liner trains becomes economically feasible, because the short transhipment time allows a stop en route to unload and load ITUs from/onto the wagons, thereby avoiding shunting of wagons or wagon groups, while still serving routes for which the volume lies below the thresholds for group and direct train operations.

A fully-automated transhipment facility, in combination with new forms of operation, renders this possible.

The case studies apply to different networks, markets and distances and were carried out for the German, Dutch and Swiss national and international networks.

The Shuttle² train is a particularly economical method of transport. This is a fixed consist train running twice a night between two terminals, thereby replacing one complete set of wagons. In addition to attracting origin-destination loads for transit between the regions of the two terminals, such trains benefit from an enlarged catchment area and transfer from other destinations – the terminals act as regional hubs. Such logistics is optimally supported by advanced (= automated and fast) handling, allowing these trains to be handled at night.

The main factors determining the use of shuttle trains for overnight services on short and medium-haul routes are cost and volume.

Advantages:

- Greater market share for intermodal transport
- Better usage of rolling stock
- Good connection possibilities for gateway systems
- Avoidance of the costs and delays inherent in marshalling
- Higher reliability

Example calculations have been carried out for three specific cases, using pure road transport door-to-door as a reference (Datum = 100). The operating costs of a “conventional” and an “innovative” form of train operation have been described.

As the cost of using the rail infrastructure is subject to scientific and political debate, three scenarios have been used. The first scenario is based on the low slot prices that seem to be achievable by “good clients” with high, regular annual volume, the second (“medium”) uses average German prices and the third was based on the Swiss system. The resulting cost lies between EUR 2.49 and EUR 9.30 per train-km.

In order to compare the form of train operation independently of terminal design and terminal cost methodologies (including or excluding “land”, “public funding”, etc.) an average “handling charge” has been used.

Finally, a “management overhead” has been added. For pure road transport, three scenarios have been defined; “cheap”, “medium” and “expensive”, varying between EUR 0.48 and EUR 0.80 per ITU-km.

The Duisburg - Rotterdam case shows that none of the intermodal transport forms can compete with road transport in terms of the achieved price level, but innovative intermodal transport in the form of Shuttle^2 trains has only minor price difference to road on this very short distance.

The calculations for Hamburg and Bremen give better results, as shown in the next two diagrams. Both conventional and innovative forms are less expensive than pure road transport on these relations. The innovative Shuttle^2 forms composes of additional savings compared to the conventional production form and is therefore the most competitive form.

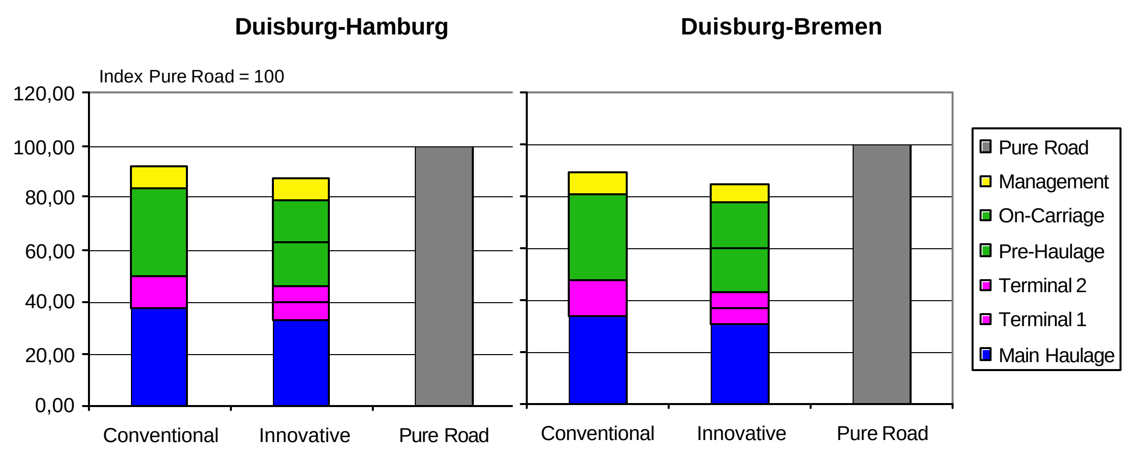


Fig. 4.16/3: Transport Costs, Duisburg – Hamburg, Duisburg – Bremen ("Medium" scenario)

However it should be noted that the relatively small difference between the intermodal operation forms was caused by the harmonisation of terminal costs to "market" prices which are the same for all calculations.

Varying the form of operation for pre- and on-carriage and in the terminal, and hence varying costs, allows us to identify the impact of such measures on the transport chain as a whole.

In all Shuttle^2 cases analysed, it was possible to find a timetable that allowed the shuttle to cover the desired distance twice per night.

The main aspects of the philosophy are as follows:

?? Main haulage distance: 200 km - 300 km

?? Commercial speed: 80 km/h

?? Short pre- and on-carriage

?? Short stop at terminal

?? Terminal operation automated

The concept covers a transport distance of 250 km - 300 km, with the Shuttle^2 vehicles travelling 400 km - 600 km per night. This form of operation can compete with road transport, as long as the required time windows are kept to.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The particular issue linked to the outcome and follow up of RTD Project IMPULSE is the bridge “from Innovation to Application”.

In the framework of IMPULSE a couple of Technical-organisational Developments have been treated and their results (“Innovations”) are related to e.g. Intermodal Transport Units (ITU), Intermodal Wagon, Shuttle train operation, Fast Handling, the Integrated Transport Chain Management and Identification/ Location equipment.

They are well thought out and described in detail by the researchers and industries mirrored against critical remarks from the operators, which have contributed. The time horizon for implementation and putting into daily practice is varying from short to long-term. Key actors involved in the realisation are shippers, intermodal operators, railways, terminal operators, industries and policy makers in specific clustering depending on the innovation.

The figure shows proposed activities in relation to innovation, time and actor.

Technical-organisational issue („Innovation“)	Time Horizon for Realisation			Key Actor							Required Actions
	short	medium	long	Shippers	Intermod. Op.	Railways	Terminal Op.	Industries	Policy	Other	
Harmonised lasting ITU		●		●					●		Fix Road Vehicle Dimensions
Innovative Wagon		●	●		●	●		●			Pre-Service validation/testing
Shuttle Train Operation	●				●	●					Feasibility Pilot Projects
Fast Handling	●				●		●				Realise Reference Terminal
Integrated Transport Chain			●		●				●		Install Control System
Identification/Location		●			●	●	●	●			Install

Source: WP 4.5 (Co-ordinator, Industrial Partners)

Fig. 5/1: From Innovation to Application

At the beginning of the IMPULSE Project Intermodal transport looked back to a 30 years history of almost steady growth. The future was described in purple colours. In Germany - for which figures are available - political desires are aiming at 120 Mio t in 2010. Together with German Railways and the operators a Masterplan called „Location Concept“ was elaborated in which the aim of 90 Mio t in 2010 was fixed.

Achieving this goal required a dramatic change in the increase rates compared to the long-term growth.

Such expected growth rates automatically awake industrial companies- especially if they are scientifically sound and financially approved - to invest in these “potential markets”. As a logical consequence of this forecasted demand a couple of engineering companies have therefore followed Krupp Fördertechnik to develop an advanced intermodal transport systems to improve terminals and operation.

However, framework conditions have changed. Key words are liberalisation of (road) freight transport market, opening of east European countries and continuous re-organisation of the railways.

Now experts are estimating a realistic volume of 30 Mio t - which is practical equal to today’s situation and does not require new investment. The proposed systems are far away from being a powerful, future oriented alternative compared to pure road transport.

There exists no “natural growth” which automatically demands more offers and formulating and working out mid- and long-term industrial strategies in such circumstances is hardly impossible.

This in particular, as the market partners are aware of the need to build a new innovation infrastructure system, which composes of basic structural and procedural blocks.

It is already common knowledge that the intermodal transport system is closely interlocked with the terminal and the handling plant - technically (interoperability) and operationally (interconnectivity).

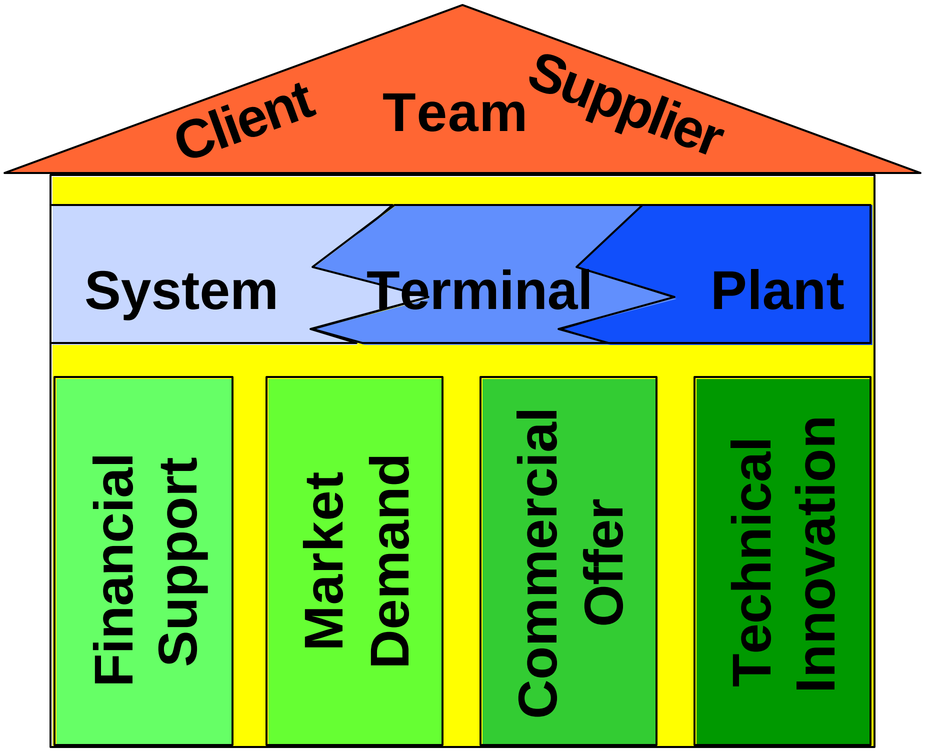


Fig. 5/2: Building Infrastructure Innovation Projects

Nevertheless, installing of such as system requires four columns, which are (without priority):

- ?? a technical innovation
- ?? an industrial company which is able to prepare a commercial offer
- ?? an operator or Investor which is able to formulate his demand and
- ?? financial resources to realise the investment.

The roof of the building, the shelter against “acid rain” from the outside as well as the glue between the - sometimes diverging - interests is a strong team of innovators and operators, which are willing to co-operate and keep to joint decisions.

It seems if this common rule is not valid in intermodal transport with its changing faces and roles, in the past, but it shall be re-considered in the future in order to manage the challenge of advanced logistics and the increasing environmental awareness.

5.2 RECOMMENDATIONS (WP 4.5)

The works which are summarised in the following, have technically been co-ordinated by Krupp (Workpackage Leader). ERRI, SGKV and DUSS have contributed.

5.2.1 Objective

On the basis of the experience developed in previous Workpackages of the Project, key partners have determined measures to facilitate implementation and define the regulatory framework. Recommendations have been formulated towards technologies and procedures regarding the various groups being engaged in Intermodal Transport as a system either as Politicians or Actors such as:

- European Commission
- Member States Level
- Railway Authorities
- Terminal and Intermodal Operators
- Industries
- Research Centres and Universities

5.2.2 Summary and Review of Previous Workpackage Results

The recommendations to be formulated are dependent on the results and conclusions of previous technical Workpackages of the Project concerning:

- infrastructural and market framework conditions
- organisation of logistic chains and operation forms with focus on main haulage
- technical improvements inside intermodal terminals and modification of rolling stock
- technico-organisational impacts on terminal and chain

They are mainly based on the outcome of the "integrating" workpackages which are dealing with the terminal, the rolling stock and the transport on short and medium distances (see previous chapters 4.1 to 4.16).

5.2.3 Recommendations

5.2.3.1 For Industries

Industries engaged in the field of combined transport are in this sense manufacturers of intermodal transport units, rolling stock, transshipment equipment, auxiliary devices and control and software systems.

In the past a couple of RTD fields such as terminal automation or improvement of rolling stock have been dealt with jointly. However, the lead customers - the railways - are in state of flux and have not yet defined their market place. This is true in their relation towards intermodal operators and forwarders but also with respect to industry. There are cases where the railways demanded turn-key realisations at first but than entered into own development, planning and building. In this environment it is hardly impossible to recommend concrete measures for RTD and implementation towards industry.

Moreover, it seems that traditional demand-orientation is still prevailing and supply siders have to have a long breath to achieve considerable success in the market. A clear "customer" can not in any case be individuated in the railway authorities, so that the present role of industry is to concentrate on concrete realisation projects rather than global RTD to provide basis for further development of intermodal transport.

Regarding the intermodal wagon the findings of the tests and conclusions for improvement should be applied on a small series of intermodal wagon (“test carrier”) to allow gaining operational experiences.

5.2.3.2 For European Railways

European railways are engaged in the field of intermodal transport as shippers, carriers, traction provider, wagon provider, integrator,.... These multiple faces make it complicated to draft recommendations.

However, a few guidelines shall be given in respect to their key business, which is rail operation between terminals. Operation of shuttle trains between large terminals over great distances is a desired operation mode in economic terms. Nevertheless, a large amount of cargoes is exchanged on short and medium distances and with certain diversity regarding time and place.

A couple of train operation forms are dedicated to meet this requirement and Case Studies have demonstrated their feasibility and economical advantages.

The Case Study results need verification by concrete operation thus intermodal operators and railways, which intend to widen their market, should apply the results and install innovative shuttle-shuttle trains. Furthermore the Case Study approach can be applied to other corridors in co-operation with potential Users.

Large railways shall be able to provide a network throughout Europe and not only on a few major links. Such links with high traffic potential are easy to be operated and bear the risk to entering into price competition with flexible regional railways, intermodal operators or even shipping lines. Whereas on the network, quality and performance are the driving factors and entering-into by small enterprises is more difficult.

5.2.3.3 For Terminal Operators

With respect to the terminals, technologies have proven their technical feasibility and need to be applied in large-scale demonstration projects in consideration of medium term infrastructure needs. In view of the past problems of realisation a joint activity of terminal operator, infrastructure provider and industry is requested.

This regards all stages of implementation from investigation of needs, planning, authorisation to building, putting into practice and operation.

Terminal operation has been a task of the railways in the past but due to recent legislation a separation of functions infrastructure provider, railway operator and finally terminal operator is requested. The effect on the terminal will be that terminals have to accept a couple of rail operators instead of only one. On the one hand this bears the risk to increase expenditure for marketing, adaptation to various needs, invoicing etc.) On the other hand it offers a chance to greater independence from monopolistic structures and accessibility to new operators. These may in total have different needs, which will allow for a more smooth operation during the day. In addition the terminal may offer value-added services for e.g. Small and Medium Enterprises (SME), which can not provide such functions themselves.

The terminal infrastructure to be realised shall therefore be able to allow:

- Multi-user acceptance
- Step-by-step realisation
- Ability to support future rail operation forms (fast handling).

5.2.3.4 For Harmonisation Process and Further Research

This task has been considered to take in eventually results of the Project regarding international harmonisation process with respect to technical standards. In the course of the Project the opinion has been changed and it can be resumed:[20] "Many experts wish standardisation to take the lead, to avoid too much variety in development, to create guidance in uncertain situations. Standardisation cannot do this. In the long run, only technologies that have been successfully approved by the market will form the basis for a successful standard."

Therefore none of the improved technologies is ready for providing input to standardisation, but the learning was, that the technologies have to respect a couple of standards set by the market, e.g. concerning the rail wagon to be accepted or Intermodal Transport Units to be handled.

A new challenge is covered in the Project UTI-Norm, which is dealing with recommendations for European intermodal transport units. It is based on the experience that ISO Containers are not accepted by the European logistics due to their limited suitability to European pallets and that a swap body cannot efficiently be carried on inland waterways and (short) sea transport due to their width and ability to be stacked.

In parallel CEN/TC 119 is working on the new design proposing the following dimensions and ratings for the new C745-S16 swap body: External length: 7450 mm, Width: 2550 mm, Height: 2900 mm and 16 t gross mass. The length corresponds to the accepted road train length, which is able to transport 2 x 7,45 m whereas a semi-trailer is 13,6 m long. The width also reflects the standard of ordered width in European road freight vehicles. The height is a compromise between the demanded 3 m interior height (which is possible for some road vehicles with low chassis heights) and the railway gauge according to UIC 596-6 to assure transportation on the main continental railway lines without hindrance.

The requirements of inland waterways are a special issue because of the width of sluices and locks and the derived maximum width of inland barges. Short sea transport demands a mixture with ISO boxes to be stowed in the same cells of the ship (width and length) and suitability to very harsh weather conditions on the sea.

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[20] Dr. C. Seidelmann speech during IMPULSE Final Conference, Brussels, 17.06.1999.

This ITU will have a top-lift application suitable for standard container spreaders, which his also appreciated by most terminal operators and ports, which have already invested in equipment (spreaders). This is also supported by the IMPULSE findings.

Generally, some aspects of the IMPULSE Project need further analysis in the framework of typical research activities:

?? Modelling transport flows on weak statistical basis and reflecting optional operation networks, e.g. intermodal transport with complex Hub-and-Spoke operation vs. direct lorry traffic

?? Unique performance model and market share estimation considering cost, time and quality

?? Cost accounting for modelling purposes and comparative analysis.

5.2.4 Dissemination of Results

Dissemination of Results in the framework of the IMPULSE Project composes of a structured set of activities:

?? Dissemination during the Project

?? Dissemination at the end of the Project

?? Exploitation after the end of the Project

Dissemination activities have already been executed **during the Project** by co-operation with other EU-Projects, presenting the IMPULSE approach and first findings during conferences and seminars and collaboration in working groups at the European Commission. A list of activities is given in Annex 4.

At the **end of the Project** a Final Conference has been organised to present and discuss the results of the Project in front of

?? European Commission services

?? intermodal operators including ports and their associations (Intercontainer, UIRR, EIA, Europlatforms, Port Authorities, Shippers, ...)

?? European Railways

?? Industries engaged in the field of intermodal transport (intermodal transport units, rolling stock, transhipment equipment, software systems, ...)

?? key decision takers

The résumé is that faster handling and automated operations provide the potential to key up additional volume for intermodal freight transport. This is of particular importance since Intermodal Transport has not fully come up the required expectations with respect to growth of volume and net coverage in the past years. Recent forecasts even reduce the importance of this favoured logistic concept under pressure of the changing marginal conditions. In contrast to this, the IMPULSE Project has investigated, developed and test technical–organisational measures to improve intermodal transport and to demonstrate their traffic impact.

“The European Commission sees a strong relation between sustainable mobility and intermodality” states J.A. Vinois, Head of Unit in DG VII, the European Union reasoning to invest in Intermodal Demonstration Projects. In order to do this, the system resistance has to be reduced. The largest potential market of such improved services is on medium and short distances in additional to the classical far distance runways. Here innovative operation concepts - and operators – are required. In order to compete with pure road transport, price and quality of service has to be matched. A future and offer oriented transport system shall be able to link large centres as well as small terminals and rail siding in an hierarchical system. Access without discrimination shall guarantee the involvement of small and medium sized enterprises. The terminals have to ease this entrance into the system. Industrial Partners Technicatome, Framatome and Costamasnaga claim that technological bricks, identification, location and positioning systems as well as advanced - which is to say fast and automated - handling technologies are available and have proven their technical feasibility during the 3 1/2 years IMPULSE Project. A powerful Expert System is able to assist in terminal planning and design as well as evaluation of technical-organisational alternatives. Case Study findings have round up the presentations: On concrete routes throughout Europe shuttle trains which drive two times a night are able to reduce the railway costs significantly and provide the “customer tailored service” as Laszlo Tordai, ERRI Project Manager, outlines.

Around 100 attendees from the European Commission, the railways and intermodal operators as well as industry and research centres have listened to the presentations of the conference with great interest and participated in lively discussion.

At the end of the Conference, Project Co-ordinator Klaus-Uwe Sondermann, expressed the need for a reference application project as a joint challenge for both industry and operator. This is necessary to bridge “from innovation to application”.

The particular issue linked to the outcome and follow up of RTD Projects is the bridge “from Innovation to Application”.

In the framework of IMPULSE a couple of Technical-organisational Developments have been treated and their results (“Innovations”) are related to e.g. Intermodal Transport Units (ITU), Intermodal Wagon, Shuttle train operation, Fast Handling, the Integrated Transport Chain Management and Identification/ Location equipment.

They are well thought out and described in detail by the researchers and industries mirrored against critical remarks from the operators, which have contributed. The time horizon for implementation and putting into daily practice is varying from short to long-term. Key actors involved in the realisation are shippers, intermodal operators, railways, terminal operators, industries and policy makers in specific clustering depending on the innovation.

Exploitation of IMPULSE Results after the end of the Project lays in the responsibility of individual Partners.

5.2.5 Conclusions

At the beginning of the IMPULSE Project in 1995 Intermodal transport looked back to a 30 years history of almost steady growth. The future was described in purple colours. In Germany - for which figures are available - political desires are aiming at 120 Mio t in 2010. Together with German Railways and the operators a Masterplan called „Location Concept“ was elaborated in which the aim of 90 Mio t in 2010 was fixed. Achieving this goal required a dramatic change in the increase rates compared to the long-term growth.

Such expected growth rates automatically awake industrial companies - especially if they are scientifically sound and financially approved - to invest in these “potential markets”. As a logical consequence of this forecasted demand a couple of engineering companies have therefore followed Krupp Fördertechnik to develop an advanced intermodal transport systems to improve terminals and operation.

However, framework conditions have changed. Key words are liberalisation of (road) freight transport market, opening of east European countries and continuous re-organisation of the railways.

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There exists no “natural growth” which automatically demands more offers and formulating and working out mid- and long-term industrial strategies in such circumstances is hardly impossible.

This in particular, as the market partners are aware of the need to build a new innovation infrastructure system, which composes of basic structural and procedural blocks.

It is already common knowledge that the intermodal transport system is closely interlocked with the terminal and the handling plant - technically (interoperability) and operationally (interconnectivity).

Nevertheless, installing of such as system requires four columns, which are (without priority):

- a technical innovation
- an industrial company which is able to prepare a commercial offer
- an operator or Investor which is able to formulate his demand and
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The roof of the building, the shelter against “acid rain” from the outside as well as the glue between the - sometimes diverging - interests is a strong team of innovators and operators, which are willing to co-operate and keep to joint decisions.

It seems if this common rule is not valid in intermodal transport with its changing faces and roles, in the past, but it shall be re-considered in the future in order to manage the challenge of advanced logistics and the increasing environmental awareness.

6 ANNEXES

6.1 PUBLICATIONS

List of Deliverables:

D0	0.3	Introduction and Approach	KRUPP
	1	**Preliminary Assessment**	
D1	1.1	Infrastructural Framework	ERRI
D2	1.2	Market and Volume	EURET
D3.1	1.3	Elements of the Integrated Transport Chain	SGKV
D3.2	1.3	Elements of the Integrated Transport Chain	SGKV
D4	1.4	Operation Forms on the Network	ETH
	2	**Modification and Adjustment**	
D5	2.1	Terminal Technical Systems	COSTA
D6	2.2	Terminal Operation Procedures	KRUPP
D7	2.3	Identification and Positioning Systems	TA
D8	2.4	Advanced Handling Systems	FRA
D9	2.5	Modified Wagon	COSTA
D10	2.6	Working Conditions	ERRI
	3	**Effects of Improved Plants and Roll. Stock**	
D11	3.1	Technical-Organisat. Effects on the Terminal	FRA
D12	3.2	Technical-Organisat. Effects on the Chain	ERRI
D13	3.3	Cost Effectiveness of the Terminal	NTUA
D14	3.4	Cost Effectiveness of the Chain	NTUA
	4	**Recommendations for Intermodal Transpor**	
D15	4.1	Terminals with High Requirements	EURET
D16	4.2	Terminals with limited Requirements	KRUPP
D17	4.3	Rolling Stock	COSTA
D18	4.4	Transport Distances	ERRI
D19	4.5	Implementation Policy	KRUPP

6.2 PRESENTATIONS AND CONFERENCES

Publication and Dissemination Activities of IMPULSE

Date	Institution/Project	Subject
01.03.96	ERRI	TechNews
27.03.96	ECP Paris et al	Les entretien de la technologie
06.05.96	VDI	Neue Umschlagsysteme Schiene
01.06.96	PTV	WELCOM Project
01.10.96	ENA Trafico	Fleet management
01.10.96	H/B	Interoperability and Intermodality
01.11.96	SGKV	Workshop: RTD requirements in combined transport
01.01.97	ENEA -AMB	HERMES (Energy and Environment)
01.01.97	STRATEC	Freight Transport
28.01.97	Innovation Relay	Innovative Control of Intermodal Transport
28.02.97	University of Bologna	Intermodal Transport, TERMINET-Project
17.03.97	EC DG VII	Clustering Activity
10.04.97	OTB Delft	TERMINET Project
11.04.97	Kombiverkehr	User Requirements in RTD Projects
18.04.97	SGKV/BIC	Innovation Schiene: Beitrag der Bahnindustrie zum KV
01.05.97	Port of Rotterdam	Rolling Stock Research
10.-14.06.97	Various	Exhibition transport '97
14.06.97	ECT Rotterdam	Visit in Rotterdam
14.07.97	DVF	Lenkungskreis Güterverkehr

Date	Institution/Project	Subject
15.07.97	Trends Europe	EUROSIL
div.	SGKV Members	IMPULSE Start and Achievements
15.08.97	Univ. Tampere	Project Information
18.09.97	Univ. Tampere	Meeting in Duisburg/Essen on 18.09.1997
11/97	ERRI	Internal Presentation on IMPULSE
25.11.97	Logistic Austria	European Dimension of Intermodal Transport
02.12.97	IVU/REFORM	Freight Platforms
27.01.98	INRETS/NEA for IQ-Project	Estimation of Potential Volume in Intermodal Transport
04.02.98	Riva Calzoni	Positioning Devices
05.02.98	Traffic '98	Innovative Solutions in Freight Transport
14.02.98	IAT/WORKFRET	Questionnaire on Safety at Work in Freight Transport
03.03.98	SOFRES Conseil	Intermodal Statistics (EUROSTAT; DG VII)
03.03.98	Riva Calzoni (Precise-IT)	Positioning Devices
03.03.98	IVU Berlin REFORM	Information on D1-D4, esp. Glossary
19.03.98	EC DG VII	Clustering Activity
01.03.98	INRETS/IQ-Project	Terminal Data
15.04.98	Coopers&Lybrand	Transport and Logistics – Questionnaire
22.04.98	Various Addresses	IMPULSE Newsletter N° 4
22.04.98	Uni Delft OTB	TERMINET Project
05.05.98	IAT/RELOOP	Participation in Workshop on Transport Chain Optimisation
12.05.98	SNCF	Review of SNCF RTD Activities
15.07.98	SBB, NS	WP 2.6 Achievements on Safety at Work

Date	Institution/Project	Subject
05.08.98	Various Addresses	IMPULSE Newsletter N° 5
10.08.98	AEA Technology	5th World Congress on IST – Seoul
15.09.98	PROTEE Project	IMPULSE Approach and Glossary
30.10.98	WORKFRET Thessaloniki	Working Places inFreight Terminlas
02.11.98	WORKFRET - IAO Stuttgart	Development in intermodal traffic
02.11.98	ERRI	Information to Member Railways and Affiliates
10.11.98	EC - Joint Research Centre	Technologies for Automatic location and tracing of freight
27.10.98	FURMIA	Presentation of new horizontal loading system and conference on "Innovation im Containerumschlag"
26.11.98	SOFRES Conseille	Booklet for EUROSTAT and DG VII
12.02.99	UIC	The Future of Rail II
17.-18.02.99	ITM/Batelle	Innovations in Intermodal Transport
25.-26.02.99	European Commission	Launch of the 5th Framework Programme in Essen
03.03.99	X-Modall	Discussion on X-Modall Approach
18.03.99	Chalmers University	Light Combi-Gateways
23.04.99	EC DG VII	Informal Council of Ministers of Transport
16.-17.06.99	IMPULSE	Final Conference
23.06.99	IMPULSE	Final Conference - Press Release
20.07.99	PTV Consult	Research Project and Freight Statistics
03.08.99	IDIOMA Project	Transport Intermodality in Metropolitan Area
20.-21.09.99	EUROSIL Project	EUROSIL 2nd Workshop

6.3 NEWSLETTERS

Newsletter N° 1:	Objective, Partners, Schedule	6/96
Newsletter N° 2:	Conditions for Successive Intermodal Transport	2/97
Newsletter N° 3:	Technical Development, Modification and Adjustment	7/97
Newsletter N° 4:	Approach and Scope, Demonstration	4/98
Newsletter N° 5:	Tests Completed Successfully	7/98
Newsletter N° 6:	IMPULSEs for Intermodal Transport	2/99
Newsletter N° 7:	Innovative Steps to Sustainable Mobility , IMPULSE Final Conference	7/99

7 REFERENCES

All references from which ideas or contributions or quotations are picked up have not been reported in the document. Any reference is given in the respective Deliverable corresponding to the Workpackage.