Concepts of new-generation terminal and terminal nodes

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TRAIL Research School

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The Directorate-General for Transport of the European Commission (DG VII) has sanctioned the Terminet Project on the issue of new concepts of networks and terminals for intermodal freight transport within the 4th Framework Programme. The project covers a period from 1 January 1997 till 1 January 2000.

The study is carried out by a Consortium of eight partners from seven different European countries.

I. Delft University of Technology, The Netherlands, project leader of the Consortium;
II. Economic & Social Institute Free University, The Netherlands;
III. Noell Stahl und Machinenbau GmbH, Germany;
IV. Tuchschmid Engineering AG, Switzerland;
V. Cranfield University Centre for Logistics and Transportation, United Kingdom;
VI. Technical Research Centre of Finland, VTT Communities and Infrastructure, Finland;
VII. Centro Ricerche Applicate All’Economia E Alle Scienze Sociali, Italy;
VIII. Facultés Universitaires Catholiques de Mons, Belgium.

Terminet comprises several studies. This publication reports an extensive investigation into new-generation terminals and terminal nodes among actors in the intermodal transport industry. We would like to thank all participating actors. Without them, this study could not have been achieved. The actors gave us detailed information about their innovative projects, showed us round their pilot plants whenever they could, and verified those sections of the report which dealt with their respective concepts.

The Terminet project has been coordinated by Fabrizio Minarini, a scientific officer of the DG VII. We would like to thank Mr. Minarini for his involvement in Terminet and his valuable comments on the draft reports.

More publications of the Terminet studies are forthcoming.
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1
THE TERMINET PROJECT

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1.1 Introduction

TERMINET is a strategic and tactic project researching new possibilities for intermod-
dal1 freight transport in Europe. It investigates innovative and new-generation bundling-, terminal- and node- concepts and analyses their technical and economical feasibility for the European transport network. Innovative concepts are involved with new ways to combine transport units or load units, new technologies and the development of new network links. New-generation terminals are highly automated and robotized, have integrated operations and have a compact lay-out. New concepts will be analysed for concrete regions, transport corridors, freight markets and terminal and node locations. The research will result in designs, simulations, animations and business plans.

1.2 Problem description

Due to the increasing pollution and congestion of road transport, intermodal transport is an issue high on the agenda of public and private actors in the transport industry. European and national governments stimulate intermodal transport in order to realise a modal shift. Shippers mention the poor cost quality ratio2 and the involvement of many actors as barriers for a modal shift. In the past many innovative plans and projects in bundling and transhipment were developed, and although the ingredients seem to be there, these plans have barely resulted in a real jump forward in the quality of intermodal transport. The best possible result nowadays seems to be the introduction of new point-to-point shuttle connections on transport links with a substantial volume. However, the point-to-point shuttle approach implicates that relations with small flows and short distances in the collection and distribution network are left over to the road sector. Other bundling concepts are needed, but they require a substantial drop in the costs, a raise in the quality or both, to make more complex bundling feasible. The

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1 In this report intermodal transport refers to "combined unimodal and combined multimodal transport".
2 The criteria of the cost quality ratio for shippers are: lead times, prices, reliability and accessibility. For transport operators these criteria are: utilisation rate of transport units and prices.
general expectation is that automated and robotized transhipment and other node operations will allow more complex bundling models, that complex bundling models need smart (robotized) operations, that in the future large volumes will allow fast large scale robotized transhipment and that small intermodal volumes will lead to innovative bundling concepts in order to reach a substantial improvement of the cost quality ratio. This brings us to the central objective of TERMINET.

1.3 Central objective

The central objective of TERMINET is to identify promising innovative developments for the bundling of networks, new-generation terminals and terminal-nodes for combined unimodal and multimodal transport within Europe.

Promising developments are those which lead to a substantial improvement of the cost quality ratio. This means an improvement of one or several of the following indicators:
- shorter lead times in the chain and thus in the nodes and terminals, too;
- higher transport frequencies;
- more destinations to be reached, also on medium and relatively short distances;
- better services for small shipments and small flows;
- higher reliability;
- more flexibility in time and location;
- a better accessibility of terminals;
- more suitable operation times for shippers and other customers at terminals;
- better results in terms of sustainability.

In this report we apply the term “innovation” for both new-generation and innovative technology. New-generation implies the use of automation and robotization, integrated operations and compact lay-out, while innovative stands for modern and intelligent technology which is based on conventional technology. We distinguish between terminal concepts and terminal-node concepts. In transport networks there are links and nodes. A node can be a solitary terminal, a spatial concentration of terminals, of a terminal together with terminal users or a combination of the two. The terminal concepts in this research have their focus on transhipment, storage facilities and operations, while the terminal-node concepts are directed towards node-internal transport systems.

In the course of the project, which means in several other publications, development and implementation paths will be discussed, and public and private measures for supporting and encouraging new-generation operations will be formulated. Its findings intend to support the recommendation of certain terminal and terminal-node concepts for certain types of nodes in certain bundling concepts or alternatively to specify bundling networks with node types and locations suited to certain terminal concepts. TERMINET

3 In the following parts of this report “combined unimodal and multimodal transport” is called “intermodal transport”.

2
should also be able to describe the circumstances of a feasible course of development and implementation. The conclusions will have to be of special interest to actors in the field (such as transport operators or producers of transport equipment and infrastructure) in the medium and long term.

1.4 Structure of the project

Specific for the TERMINET project is the integrated approach of innovative bundling, terminal- and node concepts. This means that the analyses of terminal and node concepts are focussed on their function in the bundling network and that the analyses of the bundling networks are directed towards terminal implications. The identification process is a step by step process of investigating, ordering, making comparable, comparing, evaluating, integrating and modelling of bundling, terminal and node concepts. The project consists of several workpackages, which is shown in the figure below. In each workpackage certain steps of the identification process take place. This report covers workpackage 2. The project covers a period from 1 January 1997 till 1 January 2000.
WP 1 Inventory innovative bundling concepts in Europe

WP 2 Inventory NG-terminal and node concepts in Europe

WP 3 Analysis of innovative bundling concepts by modeling with GIS

WP 4 Analysis of NG-terminal and nodes concepts

WP 5 Indicators and criteria for innovative bundling and NG-terminals and nodes

WP 6 Standardisation and compatibility in NG-operations

Integrative analysis of innovative bundling and NG-terminal and node concepts

Choice of (terminal) nodes for case studies in WP 7

WP 7 Analysing performance effects of terminal designs in five cases by design and simulation

WP 8 Business plans and analyses of the feasibility of terminal designs (five cases)

WP 9 Integral identification of probable, worthwhile and missing innovation directions. Recommendations of public and private measures to encourage and support the development and implementation of NG-terminals, -nodes and -bundling networks
The basis for the identification process in the TERMINET project is formed by this report presenting the results of an investigation into innovative and new-generation terminal and terminal-node concepts and a parallel report\(^1\) presenting the results of the investigation into innovative bundling networks. In this report we are taking the first steps towards identifying promising developments by investigating, describing and making comparable and comparing innovative terminal concepts.

For the investigation interviews were held with actors and literature has been studied. The selection process of concepts is described in chapter 2. The selected concepts are described in chapter 3. We intend to present typical innovative ideas for terminals and nodes for intermodal transport through Europe. The concepts focus on the function of the terminals and terminal-nodes in bundling networks and are described from the actors' point of view on innovations in the intermodal transport field. These actors are shippers, goods and equipment manufacturers, transport companies, railway companies, terminal operators, (semi-)governmental authorities, consultants and research institutes. In a later stage of the project (WP 4) the concepts will be compared, evaluated and integrated, but then from a researchers' point of view\(^2\).

The concept descriptions deal with the type of bundling\(^3\) network for which a concept is designed or suitable, how the bundling and transhipment take place, the capacity, performances and costs, and investments. The texts are supported with pictures and drawings. As far as possible advantage has been taken from the results of the SIMET\(^4\) project. One of the steps in the identification process is the comparison of concepts.

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\(^1\) This is named “Innovative bundling network concepts in Europe” (1999).

\(^2\) The following two forthcoming publications will cover this: 1.

\(^3\) The four basic bundling concepts distinguished are Line, Point-Point, Hub-Spoke and Trunk network with Collection-Distribution.

\(^4\) SIMET stands for Smart Intermodal European Transfer. This project has been part of an earlier Research Programme of the European Union DG VII. The main aim of the SIMET study has been the improvement of transfer in terminals, particularly focusing on transhipment technologies, conventional or highly advanced automatic (European Commission, 1997). TERMINET studies
In chapter 4 the concepts are made comparable for several indicators and criteria, such as network function, performance, cost quality ratio indicators and capacity, which are presented in matrices. In chapter 5 the results of the investigation are interpreted. The concept descriptions, the matrices and information on the European countries presented in a parallel report are used for this purpose.

these highly advanced automatic terminals in relation to innovative bundling networks in order to identify directions towards an improvement of the cost quality ratio of intermodal transport.

The name of this forthcoming publication is “Quality Jump in Intermodal Transport: Theory and Practice” and consists of country papers and the theoretical aspects of the quality jump needed (Konings and Kreutzberger et al., 1999).
3
METHODOLOGY

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3.1 Introduction

The identification of promising, missing and probable innovation strategies is a process, that has different levels and takes place in several steps. One of the first steps is to get to know the present state of the innovation projects and plans. A following step is to compare the projects and to evaluate them. An important aim of the comparison and evaluation is to get an impression of the comparative advantages and disadvantages of concepts. Such conclusions, of course, require a reference framework, a programme of required performances and costs. The programme contains the contributions of terminals and nodes to the integral network performances and costs. But such programme is not available, because the existing ones do not take account of the characteristics of new-generation operations, nor of the combination of new-generation terminals and nodes in more complex bundling models.

As indicated, there is no reference framework available yet. Certainly, there are general ideas about the future transport quality and presently some research is executed on this area. The forthcoming parallel report "Quality Jump in Intermodal Transport: Theory and Practice" deals with the performances and costs of future intermodal networks. The central statement is, that combined transport is in need of a quality jump, in other words that a substantial improvement of the cost quality ratio needs to be achieved. The most important entities of the quality jump are listed and described. The entities refer to the final performances and costs (such as lead times or maximal costs), and also to the strategies/measures to achieve these results (such as the speed of transport and transhipment, and the frequency of services respective scale of operations and utilisation rates of load and transport units). But the entities are not operational enough to compare the innovative projects, neither on the demand side (networks), nor on the supply side (terminal and node concepts): neither values, nor certain final or intermediate performances are known. A reference framework has to be constructed. The investigation of the innovative projects is an important first step in the construction of such a framework. The formulation of a set of indicators an important second step.
This report documents three parts of the first stage of the identification process:

- the investigation of single projects;
- the classification and comparison of the projects (including the choice of variables, which are used to classify and compare the projects);
- the drawing of descriptive conclusions. This is more or less a classification of the terminal and node concepts, based on the actors' point of view.

3.2 Method of investigation

Aim
The aim of the investigation was to obtain detailed descriptions of new-generation terminals and nodes as proposed by actors in countries of the European Union, Switzerland and Norway. Leading questions for the investigation have been:

- What is the function of the concept within bundling networks?
- What are the aims and what is the underlying logic?
- What are the expected or realised advantages and/or performances?
- What are the target freight markets and target bundling concepts?
- What are the physical features involved (general design and operations of terminals and node-internal transport, concrete technical, and processing and spatial arrangements of terminals and terminal-nodes)?
- What are the technical and process characteristics (including the capacity, the rate of automation and robotization) and special characteristics concerning interoperability, standardisation and at the level of nodes concerning interconnectivity?
- What are the investment and exploitation costs?
- Which actors are involved?
- What are conceptual, institutional and political barriers?
- What is the time schedule for implementation?

Geographic spreading
The activities included in the investigation have been divided into five geographic sections and have been executed by several research institutes participating in the Terminet project. The sections and the involved partners are mentioned below:

- The Netherlands and Germany by OTB Research Institute in The Netherlands;
- Belgium, Luxembourg, France, Spain and Portugal by Fucam in Belgium;
- Italy, Switzerland, Austria and Greece by Cerias in Italy;
- United Kingdom and Ireland by Cranfield University in the United Kingdom;
- Norway, Sweden, Finland and Denmark by VTT in Finland.

There are three reasons for the division into the sections mentioned: the number of expected concepts per section, location of the research institute involved and language and cultural background of the researchers. The idea was to select five to ten concepts per section for interviews. In practice it became clear this number could not be reached for all geographical sections. It appeared that the Scandinavian section and the German and Dutch section have a relatively high number of new concepts.
Interviews

The investigation started with the preparation of an overview of relevant concepts per geographic section. Concepts have been marked relevant if one of the two following criteria could be met:
- the presence of automation or robotization of transhipment or internal transport;
- the expectation of the necessity for automation or robotization in the future.

Transport newspapers and magazines of the last 4 to 6 years, existing literature, conference papers and company brochures have been used.

In total 99 concepts have been marked as possible interesting for Terminet. 31 concepts are described in this report. 68 concepts have not been described for several reasons:
- no interest in participation (7x);
- concepts are rather well known (3x);
- not enough information could be obtained (19x);
- the researcher became aware of a relevant concept in a too late stage of the investigation process (3x);
- during the interview concepts appeared not to be not relevant for TERMINET because no NG-technology is applied (22x);
- no involvement in intermodal transport (4x);
- no response (6x);
- low priority for further investigation (4x).

The not described concepts are mentioned in Appendix I.

The transport newspapers and magazines of the last 4 to 6 years, recent literature, conference papers and company brochures also have been used for the concept descriptions. For most concepts additional information was acquired by means of interviews. The interviews focused on the function in the network, the relation of the network dynamics and the terminal operational, handling volumes, performances, costs, phase of implementation and barriers. In order to improve the similarity of the gathered data and the comparability of the concept descriptions, guidelines have been used in the form of detailed questionnaires for the researchers. These guidelines (for internal use only) have been attached in Appendix II.

Concept descriptions

The collected data has been combined into concept descriptions. These descriptions reflect the actors’ point of view. In a later stage of the Terminet project the researchers’ point of view will be included. Here a separation of these two points of view is chosen, because we intend to give an overview of best practise nowadays. The concept descriptions are rather detailed, because they also have to provide data for other workpackages. The concepts presented will be used in following stages of the project in which the researchers’ point of view will be added, indicators and criteria will be formulated,

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1 Other publications about innovative terminal concepts are: Woxenius (1998); Cargo Systems (1996) and venemans (1994).
integral analyses of bundling- and terminal concepts and analyses on harmonisation will take place and modelling of network and simulation of terminal will be conducted.

3.3 Comparative approach

One of the objectives of this part of the research is to make concepts comparable. One step towards comparison is classification. For this reason the concept descriptions are categorised by operation. We distinguish between rail terminals, barge and sea terminals, rail and barge Ro-Ro terminals and node transport systems. The next step in making concepts comparable is to define indicators which will support the comparability of concepts.

The choice of indicators deserve special attention. The terminals and nodes have to meet the performance and cost demands of the integral network. The networks on their turn have to respond to different kinds of demands. First of all there are the demands of shippers. Then there are the needs of different kinds of actors in the transport sector, such as network operators and terminal operators. They do not simply want to meet the customers demands, but also want to do this efficiently. Finally; there is also the society that wants a sustainable development of the transport sector. Generally spoken, indicators and criteria for the terminal and node concepts should be derived from the networks. First the required quality would be made operational on the network level. Then the performances and costs would be assigned to links and nodes, hereby taking alternative bundling concepts into account. As a consequence indicators and criteria are known and could be used:

- to compare terminal and node concepts on performances and costs;
- to evaluate performances and costs of terminal and node concepts in relation to demand.

Since there is no suitable framework the following method is applied: the general entities of the quality jump are confronted to the concrete information on the project level. The confrontation is repeated, increasingly shifting from the micro to a macro level, thus looking towards the ensemble of projects instead of the single projects. For the first stage of the project (WP 1 and 2) the conclusions appear sufficient to point out which (sub)variables are relevant for describing and comparing the concepts. In a later stage (WP 3, 4 and 5) this puzzle-like approach will form the basis for formulating criteria and evaluating the innovative concepts on promising directions.

In this stage of the research indicators are formulated from the supply side. WP 1 will provide indicators based on the demand side. WP 3 and WP 4 will also provide indicators both from the demand and the supply side, which are based on the researchers' point of view. In task 2 of WP 4 finally the demand side and supply side will be integrated.
For the distillation of indicators from the concepts two restrictions have been taken into account. The indicators must be useful for:
- the identification of directions which lead to a substantial improvement of the cost quality ratio;
- the integration of the concepts in bundling networks.
In chapter 5 the indicators selected are explained. In order to structure the evaluation of the concepts on the indicators, tables are used for each category of operation. The indicators are stated in the columns, the concepts in the rows.
4

DESCRIPTION OF CONCEPTS

4.1 Introduction

The collected data have been transformed into concept descriptions, which are presented in this chapter. These descriptions reflect the actors' point of view. With the selected concepts we intend to give an overview of best practice nowadays. The concept descriptions are rather detailed, because they also have to provide data for other workpackages. The concepts presented will be used in following stages of the project in which the researchers' point of view will be added, indicators and criteria will be formulated, integral analyses of bundling and terminal concepts will be made, analyses of harmonisation will be made and modelling and simulation will be carried out. The concepts have been categorised by operations. We distinguish rail terminal concepts, barge terminal concepts, Ro-Ro rail and barge terminal concepts, sea terminal concepts and node transport systems.

Each of these categories will be covered in the following sections. All descriptions have a similar structure and are divided into six parts. In the first part with the heading "Baseline of the concept" a short explanation is given what the concept is about and why it is relevant for Terminet. In the second part "General features" it is explained what happens in the terminal in relation to transhipment and bundling by means of text and pictures and/or drawings. The section "Performances and costs" contains information about design criteria, time characteristics, capacity and volumes and costs and investments. In the section titled "Networks and locations" the relation between the terminal concept and the network is described. The fifth part, "Implementation phase, actors and barriers" consists of information about the stage of the project, actors involved in the development and potential users of the concept and barriers which the concepts have to face. The last section "Promising, missing and probable developments (actors' point of view) finally presents the opinion of the interviewees of the future of their own concept and of other innovative concepts.
4.2 Rail Terminal Concepts

4.2.1 Mega hub of Noell

ir. E. Kreutzberger

Baseline of the project

In the mega-hub of NOELL containers, swap bodies and trailers can be transhipped between trains and between train and truck. The concept is developed for terminal location Lehrte (near Hannover) and thus for two major bundling concept:
- the future hub and spoke network for Germany, in which simultaneous exchange of load units between trains is the central operation. The mega-hub can handle 6 trains simultaneously;
- the (existing) network with direct trains, in which sequential transhipment between trains and parallel or sequential exchange of load units between trains and between trains and trucks are the central operations.

The train-to-train-transhipments and internal operations (including the sorting and terminal internal transport) can be carried out by (semi-)automated gantry cranes. Trucks are (un)loaded manually. The terminal is designed for a final transhipment volume of half a million load units (= prepaid visits in the final stage) a year. The mega-hub is a substitute for shunting yards for combined transport.

General features

The mega-hub for Lehrte consists of an area of 730 x 80 m and the following parallel running infrastructure.

From left to right (Figure 4.1): 2 lanes for trucks, one lane for short term storage, 3 tracks for trains, 4 lanes for internal transport with shuttle cars with linear motor transport technology, 3 tracks for trains and two lanes for short term storage. Besides the lanes for short term storage there is also a long term storage for at the end of the terminal, which is connected by the internal transport system. The whole area is

Figure 4.1 Side view Megahub of Noell

Source: Noell.
covered by 7 gantry cranes (10 in the final phase) which move parallel to the tracks and lanes. The internal transport system consists of transport pallets that run on steel wheels in the rails. The direction of the movements (forwards, backwards, or - on a junction - in the x- or the y-direction) is influenced by a system of electromagnetic fields.

The hub and spoke operations at Lehrte take place during the night, between 21.00 and 4.00 hours. Between 5.00 and 21.00 hours o'clock the terminal is visited by direct trains and used for train truck-transhipments. This time assignment meets rail operational and market (of shippers and truck companies) requirements. It also contributes to an equal utilisation rate of the terminal round the clock. Night time operations are fully automated. Daytime operations are (partly) manual in order to facilitate efficient truck (un)loading.

Hub and spoke operations are split into batches. A batch has 6 trains (= shuttles) which exchange load units. Overnight 4 batches are handled. The handling of a batch lasts less than 90 minutes. The typical time schedule of a batch is that of 6 trains moving into a terminal at 6 minute intervals. Between the arrival of the last train and the departure of the first train, there are 12 minutes. The first-in-first-out-principle is applied (Figure 4.3). Consequently a train will stay at the hub terminal for about 3/4 of an hour at the most. Electrically powered trains move into the terminal by speed, decelerate and stop at a position where the locomotive can be charged again.
A load unit which is lifted from a train, can be moved directly to a truck or another train by the gantry crane, or it can first be placed in the storage area. In this case it is set on a pallet, which is part of the internal transport system and storage area. The pallet can stay at the original position or move to another crane sector or wagon/truck which is more conveniently located for later loading activities. The longitudinal moves of load units are meant to be primarily carried out by the pallet system, so that the cranes can be used exclusively for the latitudinal moves. In order to avoid disturbance of longitudinal movements, load units do not cross the longitudinal lanes during peak hours. Instead, a pallet changing positions will follow the one way traffic and round-about circulation on the central lanes.

**Performance and costs**

A transhipment (= move) cycle takes about 60-70 seconds. Thus the terminal can meet the extremely high night time capacity requirement of 10 transhipments (= moves) per minute. The relation between visits and moves is globally 2:1. This means that the hub capacity is about 300,000 load units a year in the initial phase and 450,000 in the final phase. The trains that are handled during the night, are 20 to 35 wagons long. The storage area has a storage capacity of about 270 places. Investment and exploitation figures have not (yet) been published. But the general impression is that reduction of transhipment costs by about one half, is an aim for operations such as Lehrte (Fabel, 1997).
Networks and locations

The mega-hub is supposed to substitute shunting activities. Yet it can only handle 6 trains at a time, whereas on a shunting yard load units are exchanged between e.g. 30 trains a night. The answer to this 'contradiction' lies in the bundling concept developed by DB. There is no all-round exchange of load units between all trains, but only between relevant trains (= batches). Also, the total exchange area of all batches doesn't cover the entire country. Lehrte terminal is meant to be an exchange between Northwest and Northeast Germany (Figure 4.4).

The shuttles running through the terminal partly are direct trains between the terminals in the region of origin and the region of destination, with the hub as only intermediate terminal. Thus, by adding 45 minutes to the lead time of the train, the number of destinations to be served becomes six times that number. Another part of the shuttles also has other intermediate terminals, line stations. These shuttles operate in a mixture of line- and hub and spoke-networks (Figure 4.5).
Phase of implementation
In the final development phase of the regional hub and spoke networks DB asked several German manufacturers of transhipment equipment to present a terminal concept (and their performances and investments) for a hub terminal at Lehrte. That was in 1995. In the same year DB chose NOELL’s mega-hub concept. Since then:
- NOELL has extended the operations and investigated the performances on a more detailed level (now on the basis of a simulation);
- NOELL has built a pilot installation for the internal transport system at sea container terminal Eurokai in Hamburg to test the technology and performances;
- financing of the Lehrte terminal is being prepared.
It was expected that DB would sign a contract with the federal government in autumn 1997 to finance and build the terminal. However, due to the liberalisation process of the railways implementation has become uncertain.
Promising, missing and probable developments (actors' point of view)

Lehrte terminal substitutes shunting yards, as far as combined transport is concerned. Conventional freight of volumes requiring active bundling, will continue to require shunting yards. Alternatively, also in this transport market the shunting will replaced by new production forms (such as TCS; Fabel, 1997). In this case the relation between the combined terminal network and new (terminal) networks for conventional freight needs to be extended. Generally, the multiple use of terminals by different production systems (in Lehrte the hub and spoke- and the line-operations) reduce the transhipment costs of combined transport.

4.2.2 COMMUTOR

prof. dr. M. Beuthe, dr. B. Jourquin and L. Demilie

Baseline of the project

The French "COMMUTOR" project is based on the idea that a nodal point in a hub network could consist of a “quick transfer yard” of loading units using automatic handling devices, instead of an efficient shunting yard for wagons. As operations must proceed very rapidly, the COMMUTOR quick transfer yard requires automatic handling of intermodal units. The COMMUTOR automatic “quick transfer yard” enables:

- up to 60 trains to be handled during one night;
- prevention of trains from being kept in the yard over periods exceeding 1,5 hours;
- the cost of transhipment operations to be claimed particularly low.

As will be explained below, important aspects of the COMMUTOR concept are the robotised operations, transhipment techniques lifting all loading units from down below, the slewing of catenaries to handle the loading units from above and the automatic devices which are used for positioning the trains in the terminal.

General features

The COMMUTOR Mega-Hub transhipment yard planned by the SNCF includes a train area composed of 9 to 12 parallel tracks. In principle, there is one track per train plus one additional track in order to increase the flexibility of operations and the catenary cable is held by rotating supports, connected by a stretched steel cable. It can be slewed away when the steel cable is pulled by an actuator. Thus, the electricity powered trains can move into the terminal without a change of locomotive being required.


COMMUTOR 2 is a general term that regroups the COMMUTOR 1 and COMMUTOR 2 sub-projects. COMMUTOR 1 is intended to handle small amounts of containers; COMMUTOR 2 is a high-capacity transfer yard. As COMMUTOR 1 combines classical handling techniques with COMMUTOR 2 techniques, this report will focus on COMMUTOR 2.
All the trains of a batch must arrive into the COMMUTOR quick transfer yard within minutes, one after another, since the exchange of load units should as far as possible be undertaken between the trains of a same batch. Shortly before a train arrives, the catenary cable of the track where the train will be received is slewed above the track, and connected to the high-voltage electrical supply network. As soon as the train stops, it is automatically positioned on its tracks. At this moment, the overhead cranes start picking up and laying down units onto and from the wagons and the storage frames. Whenever a change of span, i.e. a longitudinal movement, is needed for a particular unit:

- the overhead crane of the span in which this unit is placed picks it up;
- simultaneously, one shuttle moves to that span;
- the overhead crane lays down the unit onto the shuttle;
- the shuttle moves along the train tracks to the destination span;
- simultaneously, the overhead crane of the destination span moves over the shuttle tracks;
- once the shuttle is positioned in the appropriate span, the overhead crane picks up the unit from the shuttle;
- the overhead crane then moves the unit to the required track or storage frame, and lays it down.

As soon as a train stops in the yard:

- some of its units will be unloaded into the storage area;
- some units will be loaded from the storage area;
- most units will be unloaded from this train and loaded onto another one, or loaded from another train onto this one (“swapping”).

Due to the transhipment system selected for the yard, the handling of the units between trains and between trains and the storage area can be completed much more
quickly if the units are loaded onto trains in a pre-defined order. Thus, a loading plan of the units for each train is to be sent to the forwarding terminals a few hours before departure time. Those loading plans will result from a data processing system which takes into account the loading of the trains which will be in the yard at the same time.

Automatic handling requires accurate positioning of each wagon in relation to the cranes. Five special devices are placed between the rails of each track to complete this positioning. Each positioning device consists of 2 trolleys moved by hydraulic actuators. The trolleys can push one wagon, and the whole train moves on until all the wagons are correctly located. Calculations and tests showed that one device for every 5 wagons was enough to ensure sufficient positioning accuracy for all the wagons of a train. This automatic and simultaneous positioning of the trains of a "batch" is faster, more accurate and less labour-consuming than positioning by the locomotive itself.

The temporary storage area consists of 30 rows of 10 steel frames each. The frames are equipped with accessories enabling automatic laying-down and picking-up of the intermodal load units. Thirty automatic mono-directional overhead cranes, i.e. as many cranes as there are wagons in one train, can move units laterally over the trains tracks. Two additional rail tracks are located between the train tracks and the storage area; they have been especially equipped to transmit orders to approximately 10 self-propelled and remote-controlled wagons called "shuttles". These shuttles permit the movement of transport units along the train tracks before being picked up by an adequately positioned crane. Obviously, these moves take more time. This explains why the units should preferably be loaded in a pre-defined order in the forwarding terminal.

All the equipment of the COMMUTOR quick transfer yard will be automatic. Its elements will receive their orders from a central "fault tolerant" computer. This computer will plan in advance all the movements of units that will have to be completed for each train of each pulse, and will send the "real-time" corresponding missions to the equipment. Specific software has been developed in order to:
- optimise the moves of the equipment, especially the simultaneous movements of the shuttles on their respective tracks;
- take account of unexpected problems occurring in the process, such as delayed trains or equipment failures.

Automatic handling of both containers and swap bodies (of all existing and reasonably foreseeable types) requires specially designed wagons. The COMMUTOR wagons are "skeleton" bogie-equipped, 20.1 m long flat wagons. They will be very similar to the present intermodal wagons. The difference is found in the special equipment: housings for intermediate elements and guides for the gripping frames, which are carried on their sides. To avoid manual positioning of pins on the rail wagons in the COMMUTOR terminal, rail wagons are equipped with special intermediate elements. Once the spreader of the overhead crane (guided mechanically by the wagon itself) places the container or swap body onto the rail wagon, the pins pop up automatically.
and are locked at the same time. In the destination yard, load units can be unloaded with classical handling equipment, and the intermediate elements can be either removed or placed, both manually.

The maximum speed of the trains will be 140 km/h. Each wagon could be loaded with:

- one 20' to 60' container or swap body;
- two containers or swap bodies (2 * 20', 2 * 30', 20' + 30', 20' + 40');
- three 20' containers or swap bodies.

All the COMMUTOR wagons will be of the same length. This will improve rolling stock management, and reduce construction and maintenance costs. Moreover, it will no longer be required to select a specific wagon for a given intermodal unit.

*Performance and costs*

The trains converge into the yard in groups of 8 to 11, which are called “batches”. The total capacity of the COMMUTOR yard is 60 trains (35 wagons per train) per night. Depending on the number of units to be moved as well as the arrival time of the connecting trains, the loading and unloading operations of one train should vary
between 10 to about 45 minutes. The whole processing of a batch between the arrival of the first train and the departure of the last train could therefore be restricted to about one hour only. A time slot of one hour and a half for each “batch” could be sufficient in order to take into account possible delays suffered by some trains. The building of a COMMUTOR terminal has been estimated at 850 millions FF. in 1993 (wagons not included). In 1993, the cost of a wagon has been estimated at 500,000 FF. The capacity of the designed terminal would be about 7 million tons (or +/- 500,000 moves per year), compared to the 1.5 million handled by Villeneuve-Saint-Georges in 1993.

Network and locations
The COMMUTOR terminal concept can be considered as a solution for an important hub at a high traffic volume. Considering the fact that the project did not rise beyond the status of pilot experiment, no final decision has yet been taken as to its localisation. Two sites in the Paris area have been considered. Figure 4.7 represents a possible hub-and-spoke network centred around Paris. Localisation in Dijon or in Lyon however was also contemplated. If the project is implemented, the most likely site would be Noisy in the Paris area. The COMMUTOR “quick transfer yard” could be connected onto other terminal or nodal point types such as for instance the one in Villeneuve-Saint-Georges in the Parisian region, which can be considered as an efficient shunting yard. The COMMUTOR terminal can only accept COMMUTOR wagons, however.

Implementation phase, actors and barriers
The COMMUTOR project was suspended in 1995. According to SNCF (Société National des Chemins de Fer), which promoted COMMUTOR in France, the main reason of this suspension is the requirement to build a new fleet of wagons. At the present time, the operators do not wish to invest in new wagons since they are satisfied by the service they obtain from their already amortised wagons. A second reason for the suspension of the COMMUTOR project was the development in 1994 of an “automatic shunting” system by a competitor, enabling the automatic coupling of wagons. Moreover, COMMUTOR appeared to be too expensive. The estimated social rate of return is 20%, but a sufficient financial rate of return could not be reached if the State were not to supply half the investment cost. As a consequence, according to the Compagnie Nouvelle de Conteneurs (CNC), which would have been the main operator of COMMUTOR, without a substantial support by the State, the feasible tariffs would have to be too high. Another important reason which was mentioned was the lack of sufficient traffic at the present time to justify such a system. It should be realised also that the size of the project, with its successive co-ordinated pulses of trains, and the traffic volume needed to make it profitable implies a very

3 For more details about the nodal point of Villeneuve-Saint-Georges see the specific report on Villeneuve-Saint-Georges.
4 It is also important to note that the “automatic shunting” project was not implemented either, mainly for the same reason as COMMUTOR: operators that do not want to invest in new wagons.
high degree of organisation of freight transportation by rail. This is not without rais-
ing delicate problems concerning the role of the different operators in freight trans-
ports. In the context of the present policy of deregulation of transports, it is not clear
how such a project should be implemented and organised. The COMMUTOR project
has been developed by the group TECHNICA-TOME with the co-operation of SNCF.
The group is composed of several engineering firms working on the development of
public or semi-public equipments of high technology.

Promising, missing, and probable developments (actors' point of view)
Although the COMMUTOR project has been suspended, some of its concepts are still
in development. These are:
- the automatic handling of containers or swap bodies with the existing gantry crane;
- optimizing of train composition (multi-stage wagons with low loading plans).
Another concept of Fast Handling Devices and Cross Conveyors has been proposed
by KRUPP to fulfill the rail-rail hub function or node for feeder trains. According to
the SIMET report, this concept implies the unloading of all trains on cross conveyors
according to the destination of the loading units. These trains are then parked on a set
of tracks in a marshalling yard, while waiting to be re-put through the terminal to pick
up the gathered loading units which must be transported to the destination of the train.
Naturally, train schedules must be organised in such a way that they come at regular
intervals into the terminal to be (partly) unloaded one by one. It is therefore a
Sequential Hub. The handling of a train by robotised devices would take about 15
minutes. This concept does not require as much investment as a COMMUTOR type of
terminal, but it is slower. This KRUPP terminal is described in the following section.

4.2.3 Krupp Fast Handling System
ir. E. Kreutzberger

Baseline of the project
Krupp has developed a fully automated and robotized modular terminal concept. All
equipment is capable of handling containers, swap bodies and semi-trailers. Quick
transhipment handling is a central issue, as the design of the transhipment equipment
shows: the trains can be (un)loaded while the train is (slowly) moving. Dependent on
the combination of units and the layout, the concept can be implemented for terminals
at small and big volumes. However, only one train can be handled at a time. But
Krupp claims that its terminal concept meets the transhipment requirements in net-
works with direct trains/shuttles, with line trains and in railway hub-and-spoke net-
works. All terminal designs with Krupp equipment are compact and will lower spatial
demand.

The ability to meet the transhipment and storage demand of nodes in different types of
networks is partly due to the modular character of the concept. There are different
types of storage units, different combinations of storage and transhipment units and
different sizes of all units.
General features
Krupps fast handling terminal consists of the following units:
- **fast transhipment units** ('Schnellumschlaganlage') on the rail-side and the road-side of the terminal. Each unit has one or more transhipment devices;
- a **buffer unit**. In most terminal arrangements, one or more cross conveyors run through the unit;
- a **storage unit**. On both road- and rail-side storage positions are situated under the crane facilities.

The **key equipment** of the terminal concept are:
- the **transhipment devices** which enables at the large scaled terminal the unloading or loading of a train at 600 metres length in 15 minutes (average of 55 load units per train). The device consists of a spreader which is moved up and down by a telescopic arm. This is attached to a (semi-)gantry-overhead-crane, which moves back and forth while (un)loading a train that is slowly moving through the terminal. Two transhipment devices can simultaneously (un)load a train wagon or cross conveyor pallet, if they are both moving small load units (like 20’ containers). The robotized movements do not allow bumping. This transhipment system will be part of each Krupp terminal;
- a **cross conveyor**, which runs along a right angle to the train or truck lanes and consists of pallets which move on rails and in two levels. The upper level is used to move the load units. The lower level is used to bring the pallets to the requested areas (road transhipment unit, rail transhipment unit, storage unit) and moves the load units swiftly from and to the transhipment unit, The conveyor is necessary in all Krupp terminals except for some small ones and a new type of hub-and-spoke terminal. It is the only connection all the way between the rail and the road transhipment unit. It also supports the moves from, to and inside the storage area. The cross conveyor can be preloaded before the arrival of a train, and supply the transhipment devices of load units quickly.

When moving load units between a train or truck and the cross conveyor, they hardly have to be lifted. Consequently, energy consumption is relatively low and the transhipment cycles are very short. The key equipment and terminal units have a modular structure. Capacity and transhipment speed can be increased by adding transhipment devices and cross conveyors. The general layout of Krupp terminals depends on size of traffic flows and the function of the terminal in the network. Standard terminals are shown in Figure 4.8. The small terminal has no cross conveyor. The big one has six, four of have no direct connection to the storage area. They are for quick storage and loading of load units, which are being exchanged between trains.

All terminal arrangements will include a storage unit, but this may have very different layouts and sizes, all depending on the network and locational requirements. The storage unit can have the shape of a:
- **high-rack storage** (see Figure 4.9). The cross conveyors run through these. A rail-mounted mobile elevator, which moves above the cross conveyor, can pick up load units from a pallet and lift it to a shelf of the high-rack storage v.v. The storage is a steel construction with 4 to 5 stories and 10 to 16 compartments per
story. Each compartment has space for one big load unit (e.g. a 40’ container, trailer, big swap body), two small load units (e.g. 20’ containers, small swap bodies). Trailers are stored in the compartments on the ground floor. Containers and swap bodies are stored in the compartments on the higher stories.

The high rack storage in the medium size terminal consists of two halves, each one with its own cross conveyor and lift. The load units can be moved from one half to the other through the compartments. The transhipment and storage area can be covered by roof and surrounded by walls which support the operating circumstances and avoid noise pollution within terminal vicinity;

- compact storage. Load units in the compact storage are moved by cross conveyors and - in contrast with high-rack storage - also by the semi-gantry-overhead cranes of the transhipment units. The layout for a medium-sized terminal with compact storage is presented in Figure 4.10. The storage area is split into a smaller rail side and a larger road side, both connected to each other by two cross conveyors. This difference in sizes reflects the fact that the cranes on the rail side are extremely important for the quality of the terminal transhipment and may not be occupied too much by storage activities (Sondermann and Zimek, 1997). The semi-gantry-overhead-crane on the road side also cover the road lanes. The layout for the Ulm terminal at the first stage of extension is half the one in Figure 4.10. It has one cross conveyor.

The layout characteristics of a Krupp terminal permit the introduction of a node internal transport system into the terminal lot (Sondermann and Zimek, 1997), e.g. on the second road lane or in a part of the storage area.

Below, the typical operations with regard to a terminal concept at compact storage are outlined. An electrically powered train approaches the terminal which does not have a catenary for electricity. Thus a diesel robot train pushes the electric one (incl. locomotive) slowly through the terminal. While slowly moving, it is (un)loaded by the first transhipment device. This one places the load units on the cross conveyor (for all transhipments) or directly into the storage area (for train-train-transhipments only). The cross conveyor moves the load units to the road side of the terminal where the transhipment device can either move them into the storage area or directly onto a truck. All operations are fully automated, except the (un)loading of the truck. This is done manually to avoid forcing the driver to get out of the truck while (un)loading.

**Performances and costs**

The performances of a medium-sized terminal are stated by Krupp (1993):

- on the rail side of the terminal:
  - max. 3 trains per hour (no locking of load units);
  - max. 20 trains per day (20 different ones or 10 trains twice);
  - ca. 700 load units throughput per day.

- on the road side of the terminal:
  - max. 160 trucks per hour;
  - max. ca. 1,000 trucks per day;
  - ca. 700 load units throughput per day.
The storage capacity depends on the layout. The one in Figure 4.10 has 126 lots for 126 to 252 load units plus about 15 to 32 buffer lots on the two cross conveyors. The terminal itself covers 3 ha, not including the area for supporting track areas for waiting trains.
The investments are about 120% of a conventional terminal at comparable capacity. The operational costs are on the same level as those of a conventional terminal (Sondermann and Zimek, 1997). So, when does such a terminal concept pay off? When utilizing its qualities on the system level. In Krupp's view there are several interesting options, such as:

Excluding historical research and development costs, which have been depreciated by Krupp.
cutting out a train on a certain transport relation without changing its transport capacity, thus reducing the operational costs. The quick transhipment at Krupp terminals can decrease the lead time of a transport service, which may allow an additional transport cycle inside a certain time and with the same amount of trains. In this sense the Krupp-concept could increase the efficiency of commuting shuttles;
- allowing the actual possibility of having regional liner trains (such as on the Rhein Ruhr ring train) stop for a very short time for (un)loading;
- doing this in a very restricted area. The later is because of the fact that the train can be (un)loaded while moving. Thus, terminal foundations and paving will not be necessary along the whole train, which would be the fact if either a conventional terminal with portal or mobile cranes were chosen.

The SIMET project (European Commission, 1995) gives an indication of cost differences between conventional and new-generation terminals such as the Krupp or the Technicatome concept, at least as far as rail-road transhipments are concerned (Table 4.1). The compact character and robotized operations implicate (relatively) lower ground, infrastructure and manpower costs. But the financial costs of equipment and maintenance costs are relatively high.

Networks and locations
In the SIMET project a larger range of terminal types, in which Krupp or Technicatome technology is applied, has been analyzed. Not only standard terminal concepts are taken into account. Instead, a great variety of terminal arrangements (layouts) is presented and their (dis)advantages are discussed. One chapter is devoted to rail-rail-operations of a hub terminal. The exchange of load units between nine trains is investigated, assuming that the exchange of load units should take no longer than 1.5 hours and that trains will enter the terminal at 5-minute intervals. Simultaneous and sequential rail-rail-transhipments are distinguished. As far as the first group is concerned, Krupp remains outside the analysis, because its terminals only have one track. Simultaneous exchange of load units between trains is not possible, because Krupp terminals generally have only one track. If the height of the transhipment devices is increased more tracks can be added.

Table 4.1 Comparison of cost structure for conventional and automated rail-road terminals

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Automated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground and infrastructure</td>
<td>15 - 20%</td>
<td>7 - 20%</td>
</tr>
<tr>
<td>Manpower</td>
<td>26 - 32%</td>
<td>19 - 26%</td>
</tr>
<tr>
<td>Equipment</td>
<td>25 - 29%</td>
<td>23 - 35%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>23 - 24%</td>
<td>23 - 27%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

In addition, terminals for the sequential exchange of load units between trains are evaluated. Krupp developed a special layout for this purpose (Figure 4.11) with two tracks and consequently a higher positioning of the transhipment devices (load units can be moved above those on a train). The buffer entirely consists of cross conveyors, which can be preloaded according to destinations. Every train to be loaded is served by two cross conveyors. The first of the nine trains is waiting at the emplacement next to the terminal until the last of the nine trains has unloaded its load units. Then it enters the terminal again for loading. Two cross conveyors contain the load units for one train to be loaded (thus 18 cross conveyors are needed). In total, nine trains are handled in twice 45 minutes. An overall performance of 1.5 hours can just be achieved. As Krupp does not provide a concept for simultaneous exchange, the SIMET project concludes, that the Krupp technology 'is rather limited, with long processing times' (European Commission, 1995, p. 202), and therefore not suitable for a large mega hub function, yet well-suitable for all other types of terminal functions.

Figure 4.11 Functional layout of a rail-rail-terminal with a sequential exchange of load units, and applying Krupp-technology

In the meantime Krupp has designed an additional concept for a mega-hub solution with only direct transhipment between trains, still using the “Rendez-vous”-technique (Zimmerman and Zimek, 1997).

Phase of implementation, actors and barriers
Krupp started to develop its terminal concept in 1990. Simulations and animations were carried out in order to examine the performances. In December 1994 a pilot-terminal was built in Duisburg Rheinhausen to investigate the performance of the transhipment unit and the cross conveyor in practice and to elaborate the technical solutions concerning the positioning and recognition of train wagons etc. The pilot was financially supported by the state of Northrhine Westfalia. Further research and development is undertaken inside the European projects SIMET and IMPULSE. The central objective of IMPULSE is the determination, introduction and recommendation of technical and logistical 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 customers’ needs (European Commission, 1997). In SIMET the functioning of the Krupp-concept in different kinds of nodes was compared with Technicatomes COMMUTOR-concept.

In the meantime the preparation of the Ulm terminal is taking place and efforts are made to sell the concept to different terminal operators in Europe. In contrast to earlier publications, in which high-rack storage was presented as terminal part by which Krupp-terminals could be easily recognized, the new terminal arrangements contain a so-called compact storage. The reason is, according to Krupp, that at most locations high-rack storage should not necessarily be considered as an efficient construction by potential buyers in times with small revenues in the transport sector. A serious barrier against a smooth introduction of the new-generation concepts is the national policy towards trucking costs. These are not rising, on the contrary. Another problem is formed by changing railway policy. The costs of a Krupp terminal could decrease, if railways ordered a larger number of them, instead of only one at present. Generally, but certainly in the introduction phase, the system advantages of new-generation operations have to be taken into account in order to compete with conventional terminal concepts. But the (dis)advantages are distributed between different actors. Cross-subsidizing, such as from money-saving train operators to money-spending terminal operators, will be necessary in order to equalize the (dis)advantages.

Promising, missing and probable developments (actors point of view)
Krupp is of opinion that new-generation operations have a positive future lying ahead of them in the (inter)national and regional transport market, with regard to all kinds of bundling concepts. However, previous initiatives indicate that innovation-mindedness is necessary in order to determine all optimization opportunities (e.g. no

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* Actors are - amongst others - the French producer of new-generation handling equipment Technicatome/Framatome and the European railway companies SNCF, DB, SNCB and FS, represented by ERRI (European Rail Research Institute). Krupp is the project coordinator.
unnecessarily heavy constructions) and system advantages. A higher transport volume will support innovative concepts. Economies of scale render new-generation terminals cheaper. Innovation of intermodal transport is in danger if the costs of road transport decrease or remain stable.

4.2.4 TRANSMANN Handling Machine
ir. E. Kreutzberger

Baseline of the project
The TRANSMANN handling machine is developed for the fast and cheaper transhipment of containers and swap bodies (no trailers) between train and truck or between trains. It can be operated on conventional pavements for storage functions and trucks, with different arrangements of tracks and/or with a lane for terminal or node internal transport. For internal transport Mannesmann obviously advises the Mannesmann AGV system, which is already being used at the ECT SeaLand terminal in Rotterdam. The TRANSMANN handling machine can be built in different sizes (e.g. for more or fewer tracks). Capacity can be increased by using more than one machine per handling zone. The TRANSMANN machine is designed in such a way that it allows electrical trains to move through the terminal by their own power (no train stop or removal of the catenary). The TRANSMANN handling machine is developed to handle line trains, but Mannesmann also suggest that the concept is suitable for other bundling models.

General features
The TRANSMANN handling machine is an overhead crane, which slightly resembles a steel table running on rails. In the centre of the table there is a ‘rotary device’, which rotates a telescopic arm with spreader (Figure 4.12). The arm can move the load units between a train, the storage area and a truck, in a right angle to the tracks and without touching the fixed power line. The machine can handle 20’ to 45’ containers, swap bodies and trailers with a weight of up to 41 tonnes. Figure 4.13 shows a typical terminal layout: the handling machine runs between the railway (one track) and the truck road (two lanes). Beneath the machine is the storage area consisting of two lanes (more outside the area of the truck lanes). The terminal can be built in different lengths, depending on the train lengths to be expected. The length of the truck lane does not have to be as long as the track. But this depends on the design of operations, e.g. how much time there is for the handling machine to relocate load units to the proper positions. In a larger terminal a bigger machine can be installed, handling load units on up to three (possibly four) tracks (Dihlmann, 1997). The information published does not mention this option. An electrically powered train arrives and moves into the terminal. No change of locomotives, pushing by other locomotives/robots, or removal from the power line is necessary (Müller, 1996). The handling machine moves to the positions where (un)loading will take place. The exchange of load units takes place. An unloaded load unit will often be moved to the location of loading, if not, it is loaded immediately onto a truck (Dihlmann, 1997). This is to avoid double handlings. After the handled
Figure 4.12 TRANSMANN Handling Machine

Figure 4.13 Terminal for line rail road transhipment

train has left the terminal, the handling machine can reposition load units and/or (un)load trucks. All operations can be done in a semi-automatic or fully automatic mode. This description of operations applies to smaller freight volumes. When more load units are exchanged, support of the machine movements by an internal transport system parallel to the track becomes advisable (Dihlmann, 1997). In a terminal with two or three tracks the parallel exchange of load units between two or three trains is
possible, but the published information or the interview (Dihlmann, 1997) do not give further details about the operations.

**Locations and networks**
The TRANSMANN handling machine is developed to handle line trains (Deutsche Bahn, 1995), but is also suitable for the efficient handling of direct trains at medium sized terminals (Dihlmann, 1997). According to the company the terminals can also fulfil a function as hub in hub and spoke networks. But in this case only part of the transhipments between trains can be carried out in a parallel way. Another part need to be sequentially transhipped. Büdenbender and Lublow (1996) suggest this terminal concept for the function as a border terminal, where change of rail gauges requires transhipment of load units.

**Phase of implementation, actors and barriers**
The TRANSMANN handling machine is developed for the growing market of combined transport, partly anticipating transhipment needs in the upcoming line networks and the need for improved cost-quality ratios of terminals. A pilot installation was built in Wetter (Ruhrgebied). In the autumn of 1998 the pilot crane has been moved over to the part of Düsseldorf for operational use. Mannesmann hopes to be involved in the building of new terminals in Erfurt (Cargo Systems, 1996) and possibly on the line Dresden-Ulm (Dihlmann, 1997). The development of new-generation equipment was temporarily centred at a Mannesmann subsidiary, called TRANSMODAL. After a reorganisation, the work is continued by Mannesmann DEMAG Fördertechnik.

**Performance and costs**
The Mannesmann handling machine can handle (a throughput of) 40 load units per hour. This capacity can be used on the rail or the road side or both. The performance of 40 load units per hour includes longitudinal movements of the machine. More detailed performance and general cost specifications will be available in the second semester of 1997 after experiments with the pilot machine have been finished. A line train will on average stay about 30 to 60 minutes.

**Promising, missing and probable developments (actors' point of view)**
The Mannesmann handling machine is designed to handle containers swap bodies and trailers. Trailer handling would make the machine heavier and more expensive, whereas the potential of huckepack transport can only be applied at a very restricted number of terminals. In these cases it is better to adjust a concept (Dihlmann, 1997). The conclusion may be that the combined transport development benefits more from reducing costs by minimizing the construction than to increase flexibility, which in this case means the applicability of a machine or terminal concept for all kinds of load units.
4.2.5 Noell Fast Transhipment Terminal (SUT)
ir. E. Kreutzberger

Baseline of the project
Noell’s ‘Fast Transhipment Terminal’ (SUT, Figure 4.14) has been designed for fully and semi-automated and robotised rail-rail and rail-road-transhipment of containers, swap bodies, and semi-trailers. The development of the concept is closely connected with the plans for a network of regular train services. This liner train should serve as a block train and collect according to schedule load units that cannot be transported by direct train services because of their size. This means that the liner train will stop to load/unload load units at several terminals (Noell, 1995) on its route from the departure to the arrival terminal. It is assumed that these delays do not take too much time (a maximum of approx. 30 minutes; Noell, 1995). For other production methods such as a network with point-to-point-connections, shorter terminal stops are required as well. Noell emphasises that SUT is suitable for liner, hub, spoke and other networks and for jump-on, hub and final-destination terminals (Franke and Häffner, 1996).

- SUT meets the demand for faster transhipment and solves the problem of the expected hausse of intermodal transportation. Short delays of the trains are made possible by: creating buffer areas next to each wagon. The buffer area (preferably) is as long as the train;
- creating direct access to each buffer area by placing the load units in buffer sections instead of stacks;
- disposing of transhipment equipment for fast transhipment of load units from the train/truck to the buffer.

Phase of implementation
During discussions with Noell in the early nineties the DB (Deutsche Bundesbahn) expressed its desire to develop a concept for the fast transhipment of load units. This led to the 1992 SUT design which is based on the following:
- the requirements (transport flows, capacity and quality of the transhipment and warehousing), set out in detail for the new Herne terminal in the Ruhr in 1991;
- well-tested components from Noell high-bay-warehouses and cranes.
Later on, the technology centre of the DB compared the performances with the requirements set for liner services and found that SUT meets these standards (Noell, 1995). Until today the SUT has not yet been tested in pilot plants and does not form part of any real terminal planning.

General features
The concept consists of two main units:
- a highbay storage for containers, swap bodies and semi-trailers. This is 670 m long and has three layers, the top layer of which is suitable for all load units, including large ones (i.e. 40' containers, large swap bodies, semi-trailers). The

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7 This is documented in the confidential report ‘Hochleistungs-Umschlaganlagen für den LKV’ of the BZA, which compares the concepts of different manufacturers (such as SUT).
middle and lower layer can only be used for the storage of small load units (i.e. 20" containers and small swap bodies). This means that the capacity ratio for large and small units in the platform is 1:4;

- the storage and retrieval machines (S/R machines; Figure 4.15). These move on separate rails above trains/trucks and between the highbay storage construction. The load units can be deposited in storage in three layers (ground floor and two upper stories). An S/R machine lifts a load unit from a train/truck. The spreader is hung up to hauling cables. Then a telescopic lever moves the load unit sideways to the high bay storage. During transhipment the load units can be turned 180 degrees, which is particularly important for semi-trailers. Load units are turned above the platform top. Like the highbay storage, the transhipment tracks also are 670 m long. Each track has two or three S/R machines.

The main units of the concept have a modular structure. The capacity of the system can easily be increased by adding a highbay storage and track for rail and/or road, and by adding transhipment equipment to each track. However, 4 transhipment lanes is a maximum for terminals in which rail-road transhipment is important. The height and length of the buffer is also variable. The advantage of a modular structure is that the terminal can easily be expanded. Figures 4.14 and 4.15 give an impression of the main units of SUT. Figure 4.16 shows how these can be combined to small, medium-sized, and large standard terminals (SUT 400, 800, 1,200 respectively). The SUT 400 has 1 highbay storage constructions located between 1 transhipment track for trucks and 1 for trains. The SUT 800 has 3 highbay storage constructions located between 4 transhipment lanes, two of which are used for trains and two for trucks. Each transhipment lane has 2 S/R machines. The SUT 1200 has the same structure as the SUT 800, but it has 3 S/R machines per transhipment lane (Figure 4.16). Of course the concept can be adjusted according to local conditions. The terminal concept does not include special power lines for electrical trains.

An arriving, electrically powered train moves through the terminal without powering and decelerating, to a position where the locomotive can be supplied with electricity again. The S/R machine moves to the predetermined position next to the train, lifts the load unit form the train and deposits it in the most proper shelf of the high bay storage. Unlocking of the load units is not necessary, if the trains do not exceed a speed of 120km/hour. If this load is transferred to another train, it can be fetched by a S/R machine in the same lane or by one in the lane on the other side of the highbay storage construction. If the journey of the load unit is continued by truck instead of train, it will always be taken away by a S/R machine in the parallel lane. Transhipment between lanes has a certain impedance. The terminal operates most efficiently in case of sequential transhipments of the same lane or between two adjacent lanes.

Performances and costs
The transhipment cycle per S/R machine is over 2.5 minutes. The ratio between moves and visits of load units is 2, in principle.
The performances/characteristics of the standard terminals are:

SUT 400: transhipment capacity (visits) of 38 load units per hour, buffer capacity of 108 load units, room taken 24 x 700 metres.

SUT 800: transhipment capacity (visits) of 76 load units per hour, buffer capacity of 324 load units, room taken 52 x 700 metres.

SUT 1200: transhipment capacity (visits) of 111 load units per hour, buffer capacity of 324 load units, room taken 52 x 700 metres.

Of course the standard terminals can be adjusted according to local needs. Example: the transhipment capacity of a small terminal with only 1 platform can be increased by adding one-third of a S/R machine.

SUT only requires staff for the handling of the S/R machines to load/unload the trucks and staff for the control rooms.

Figure 4.14 Noell Fast Transhipment Terminal

Source: Noell, 1995a.
Figure 4.15  S/R machines and highbay storage

Source: Noell, 1995a.
Figure 4.16 SUT 400, Sut, 800 and SUT 1200

![Diagram showing SUT 400, Sut, 800 and SUT 1200](image)

Source: Franke; 1993, p. 97.

4.2.6 CCT Plus

*Dipl. Ing. J. Gröhn*

**Baseline of the concept**

The project concerns the horizontal movements of loading units between two transport units (trains or trucks) or a transport unit and a terminal. The objectives of the system are: capability of handling loading units under overhead wires and minimising the cost of quick transfer. The CCT Plus concept originates in CarConTrain, which used to be a part of the Lättkombi terminal project of SJ, the Swedish Railways. CarConTrain was eliminated from the Lättkombi project because its development turned out to be too expensive. The aim of Lättkombi is to enable fast transfer of loading units to and from trains in cheap terminals forming a dense network. Trains would run fixed routes at fixed timetables and transfers could be undertaken from one train to another in shared terminals. The purpose is to create a shift in goods traffic from road to rail by introducing a fast, cheap and reliable service. The major advantages of CCT Plus compared with the present system are horizontal handling under the overhead wires, no coupling of wagons, high utilisation rate of operating units, little or no personnel, and terminal operations requiring only little space.

**General features**

The CCT Plus transferring unit - which operates in a terminal - is a kind of wagon with a telescopic boom forming a bridge on which a sled transfers the loading unit. All transport units connected to this system (transferring unit, railway wagons and trucks), need to be equipped with hydraulics. That is because they need to lift loading units for sleds to be placed under these loading units before transfer can take place.
1. The train arrives at the terminal. The loading unit is lifted to a transferring position by the wagon’s hydraulic pistons fastened to the corner fittings of the loading unit. The transferring unit adjusts itself in a longitudinal direction and in height for actual transferring.

2. A telescopic transferring boom stretches out over the railway wagon and places itself on a steel plate in the middle of the wagon. The transferring sled moves to the railway wagon and stops under the loading unit. Air bags on the sled are filled to even out possible unevenness of the loading unit bottom. The hydraulic pistons are lowered and the loading unit settles on the sled. The sled is pulled by wires to the transferring unit.

3. The loading unit is moved to a rack serving as an intermediate depot. The loading and unloading of the rack are similar to the loading and unloading of trains and trucks. It is possible to leave one loading unit on the transferring unit.
4. The loading unit is positioned over the container corner fittings of the transferring unit when the truck arrives.

5. The truck stops beside the transferring unit, which adjusts itself in height and longitudinal direction. The transferring boom stretches out over the truck and places itself on a steel plate in the middle of the truck. The pistons of the transferring unit lower and the loading unit descends to the sled, which moves to the truck. The hydraulic pistons of the truck raise its container corner locks, which fasten to the corner fittings of the loading unit.

6. The transferring sled and the boom return to the transferring unit and the pistons of the truck lower onto driving position, after which the loading unit is locked automatically. The truck is ready to run off.

The system can be applied to different kinds of terminals considering their capacity, level of automation, location, etc. The system is composed of modules allowing incremental building. For instance: in a small rural terminal the transferring unit could be mobile; in a simple terminal the transferring unit or units could be railbound; railbound units could well be semi-automated, while in a fully-automated terminal disposing of a sufficient number of transferring units the system allows the unloading and loading of a whole train in less than six minutes.

The system is highly flexible, also in connection with decreasing volumes. Transferring units could be shifted to other terminals according to need. Capacity of container racks can furthermore be adjusted.

The system requires a control centre receiving information on loading units and instructing engine drivers. In a semi-automated terminal the transferring unit is programmed by the engine driver. A fully-automated one can be operated by the remote-control centre.

**Performance and costs**

A transferring unit consists of two devices, which can work separately (2 x 10ft loading units) or together (1 x 20ft unit). At two devices maximum weight is 25 tons. Two transferring units combined can handle 50 tons (40ft container). The system is designed to function under extreme conditions, varying from -40°C to +80°C.
One container move is estimated to take about 3 minutes, unloading constituting one move and loading the other. Each step - transferring the container from the train to the transferring unit, moving to the rack, transferring the container from the transferring unit to the rack, taking another container from the rack, moving back to the wagon and transferring the container to the wagon - takes about one minute. In larger terminals, moving time to the rack is shorter. The capacity of each terminal can be adapted by adding and reducing the number of the transferring units. Automated systems can operate unmanned for 24 hours per day.

**Figure 4.18 Small CCT Plus Terminal**

![Small CCT Plus Terminal](image)

- Transferring unit that handles the loading units between wagon - rack - delivery truck
- Track for the transferring unit. A simple track that lies parallel with the side track
- Rack, that serves as an intermediate depot for the loading units
- Main track where trains can go undisturbed during the terminal operations
- Side track where the loading units are loaded to and unloaded from the train


**Figure 4.19 Medium CCT Plus Terminal**

![Medium CCT Plus Terminal](image)

- Terminal areas for delivery trucks to leave and pick up loading units
- Rack for the loading units

The capacity of a CCT Plus terminal can be roughly estimated in TEUs by the formula:

\[ C = \frac{t_s}{t_m} \times n_{tu} \times n_{tr} \times d \]

where

- \( t_s \) is the time of the stop of a train,
- \( t_m \) is the time of one move by the transferring unit,
- \( n_{tu} \) is the number of transferring units,
- \( n_{tr} \) is the number of trains per working day, and
- \( d \) is the number of working days per year.

Assumptions on rough estimates of TEUs are: trains stop for 20 minutes; they are employed during 250 working days per year.

Estimation for small terminal:

The train stops for 20 minutes, allowing time for 6 moves per each transferring unit. There is only 1 transfer unit, for instance moving 3 containers from, and 3 containers onto the train. There are 4 equivalent trains per day on 250 days per year. Under these assumptions, handled volume would be about 6,000 TEU per year.

Estimation for medium terminal:

On 250 days 20 trains stop for 12 minutes and there are 2 transferring units. Handles volume is 40,000 TEU.

Estimation for large terminal:

On 350 days 30 trains stop for 12 minutes and there are 5 transferring units. Handled volume is 210,000 TEU.

The cost of an automated transferring unit is estimated at around 250,000 ECU. Hydraulic equipment of a rail wagon costs 8,000 - 28,000 ECU, depending on the number of wagons connected onto the same hydraulic motor. The additional cost to a truck would be the same as for swap body equipment, amounting to 7,000 - 10,000
ECU. Trucks would be able to handle swap bodies as well. The costs of a simple, open terminal with a track for the transferring unit, one transferring unit, a rack for 12 TEU as well as a computer system, are estimated to be around 0.6 million ECU. The operating costs of such a terminal are not available; however they must be very reasonable: the bigger the terminal, the higher the savings in labour costs.

Networks and locations
All terminals should be located alongside the main track to allow easy and immediate connection to the main network. The suitable distance between terminals would be around 150 km. The trains would be shuttles, preferably in a line network.

Phase of implementation, actors and barriers
The concept is approaching its pilot phase. A transferring mechanism prototype has been tested for over 400 moves. Next step is to arrive at a decision (August 1997 at the latest) as to whether or not to build a full-scale prototype of the transferring unit in a real terminal. The prototype will be ready within a year after that decision has been made. CCT Plus is now being developed by CCT AB who is negotiating with SJ (Swedish Railways). CCT AB is owned by three companies, Provehco (Mr. Lövgren, inventor), Botnia Produktion and Novare Kapital. According to Mr. Lövgren there are no technical barriers. The mechanism has proved to work well. The only limitation is that the transfer technique does not suit tank containers. CCT equipment in wagons and trucks will not cause any problems to the existing transfer systems; therefore the new and the old systems can work side by side. Some obstacles could be found in the conservative attitude of the railway organisation. Economic barriers, too, can arise in the form of old investments. Mr. Sjödén from SJ described the concept as promising, but far from ready.

Promising, missing and probable developments
The concept would allow fast, cheap and reliable intermodal transport service. It looks very promising according to Mr. Sjödén from SJ. However, he also stated that it is far from complete. Mr. Sjödén worked with CCT when it still formed part of the Lättkombi project.

4.2.7 RoadRailer
prof. dr. A. Reggiani, M. Janic and T. Spiciarelli

Baseline of the concept
RoadRailer is a system which applies a bi-modal semi-trailer transport technique. The bi-modal unit is a road semi-trailer which can also be used as a railway wagon. The semi-trailer can simply be transferred between two modes, road and rail in the horizontal plane, because of the coupling of special boogies. With this system, the rather complex operations of vertical transhipment of loading unit is avoided. The RoadRailer concept requires a much smaller (limited) surface compared to current sur-

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* Source: BTZ Company brochure.
faces of conventional intermodal terminals. RoadRailer is a concept which applies an innovative technology enabling fast, reliable and overall low cost door-to-door services of load units.

**General features**

At the terminal a number of road bi-modal semi-trailers are coupled with rail boogies forming a block train. A truck with bi-modal semi-trailer approaches the track in reverse, the back part of the semi-trailer is coupled to a special rail boogie, the trailer is put on its props, the wheels are lifted and the truck is ready to leave. The next boogies are coupled to the trailer, the props are folded in and the next trailer can be coupled. The front part of the semi-trailer is put onto a rail boogie upon which the back part of another unit will be placed in order to fix the composition of the train coupling the bi-modal semi-trailers in a sequential way. When all semi-trailers are connected, a locomotive drives the train towards the railway network. The train, which consists of boogies and trailers has the same characteristics as a train consisting of single, long wagons with buffers at the front and rear of the train. For that reason, at least in theory, a composition could be formed with another type of train. Only specially designed trailers can be transported in the RoadRailer system.

**Performances and costs**

The maximum weight of each RoadRailer trailer is 28 tonnes. The train could consist of a maximum of 38 semi-trailers. The maximum weight of a train is 1,200 tonnes. On average, one train is composed of 31-32 units each with a capacity of 33 standard size Euro-pallets. On average, six trailers can be coupled in one hour (waiting time for one truck is 10 minutes). One train is shuffled in 5 hours (discharging is faster than loading). Bi-modal equipment costs around 30% more than swap-bodies. Generally, the system is expected to reduce the inventory level and storage time of the actual shipments thanks to faster transport cycles. It will be gradually implemented, encouraged by the still-continuing trend to switch freight from road to rail. This promises to be a success, thanks to the employment of terminals using less space, requiring lower costs and being more flexible in comparison to conventional terminals. They can be located nearby main cargo handling centres and switched from one location to the another to conform to changing patterns of industrial demand.

**Network and locations**

Currently, the RoadRailer trains leave from Verona every day (from Monday to Friday) at 8.43 p.m. and arrive in Munich at about 4.30 a.m. Since the rail distance between Verona and Munich is 428 km, average commercial train speed is around 55 km/h. After arriving at Munich a composition of wagons is uncoupled and the others are coupled onto the remaining original composition heading for Cologne and Hamburg. On the reverse track the train leaves Munich at 8.30 - 9.00 p.m. and arrives at Verona at 4 a.m. The train is available for unloading at 6.00 a.m.
Phase of implementation, actors and barriers

The system started to operate in May 1995 on a busy freight corridor connecting northern Italy (Verona) and southern Germany (Munich). Currently, direct intermodal block-trains from Verona to Munich (and further from Munich to Cologne and Hamburg) are operated as shuttle services by the General Warehouses of Verona in collaboration with BTZ (Bayerische Trailer Zug). The service between Munich and Cologne - Hamburg has been offered since September 1996. Since last year, progress has been made by implementing direct block trains, at a frequency of 3 times per week per destination (Munich, Cologne, Hamburg). It could be expanded by including the national corridors into the actual international network. Verona General Warehouses has been planning to extend the RoadRailer services to the Italian Adriatic North-South axis and Bari, as well as to establish these kind of services on the corridor Verona-Roma-Napoli, even if the cost of the last transhipment is still considered too high to make such services profitable. The system cannot carry dangerous and noxious loads.

Promising, missing and possible developments

The system has appeared to be suitable primarily for high-density routes where predictable flows of freight are expected to move in both directions, from A to B, and back. Thus it will be a highly specialised niche alternative to intermodal containers and swap-body services.

4.2.8 Compact Terminal Tuchschmid
prof. dr. A. Reggiani, M. Janic, T. Spiciarelli and ir. E. Kreutzberger

Baseline of the concept

Viability and competitiveness of inter-modal freight transport have appeared to be significantly dependent on efficient transhipment operations at the terminals. Therefore any technical and/or organisational improvement to be implemented at a terminal must realise an overall rise of efficiency of the terminal as well as of the integrated logistic chain. Such an approach will lead to better adaptation of inter-modal transport to the customers' and public (social) needs, manifested by requests for higher quality, lower prices, reliable and punctual services and low ecological impact. Terminal operators should also try to participate in and benefit from value-adding intermodal services.

Such participation could contribute to a relatively positive overall cost-quality ratio. In order to be able to follow such market requests Tuchschmid has developed the COMPACT TERMINAL, which is a new-generation concept. It is developed for efficient rail-rail and road-rail transhipments. The concept intends to offer new transhipment opportunities for intermodal transport.

General features
The complete COMPACT TERMINAL concept consists of four modules: a transhipment module, an intermediate storage module, a road module and a distribution or forwarding module. The transhipment module can be built in different sizes and is part of all COMPACT TERMINAL variants. The other modules are optional.

Transhipment module
Consists of four units/components: a crane, a unit for automatic and dynamic identification of trains, wagons and load units, a loading and unloading area and a buffer area. The crane unit consists of one or two overhead crane(s), which run(s) on a steel frame above the transport unit and - in case of the larger COMPACT TERMINALS - above one lane of the buffer area. The crane is operated automatically, semi-automatically or manually. The spreader of the crane can handle all today’s containers, swap-
The identification unit comprises two identification points for the trains moving through the terminal. The first one identifies the arriving train. The other one records the train after its reloading in the terminal. The identification unit automatically registers and records the relevant data about the train and load units in question. The data relate to the locomotive, wagons and load units. Then the identification unit sends the data to the terminal management system which plans the crane and other terminal operations. These data can also be used to optimise the utilisation of the containers and available rolling stock. Whenever a new train is prepared for departure the unit sends the data to the data base. Depending on the size of the module, the transhipment area consists of up to three tracks allowing direct transfer of load units between trains. A road unloading/loading lane is located alongside the rail tracks, permitting quick and simple, timely transfer(s) (with only one lift) of load units between road and rail and vice versa. The buffer area consists of one (two tracks module) or two (three tracks module) buffer lanes along the tracks. These buffer lanes provide short-term storage capacity.

**Intermediate storage module**
This is designed to provide space for load units waiting to be picked up either by truck or by train. The module is necessary at larger terminal locations facing larger differences in flow rhythms on both the rail and road side. The load units are transferred from the unloading/loading locations (area) to the storage area by Automatic Guided Vehicles (AGV). It implies single-level storage but, on users’ requests, multi-level storage can be organised.

**Road module**
Enables transhipment of load units between the intermediate storage module and trucks. (Un)loading is done by two overhead cranes similar to the ones on the rail side. The crane lane covers one lane of the storage module.

**Distribution or forwarding module**
In this module freight can be consolidated to load units. One lane of this module is covered by the overhead crane of the road module.

There are four sizes of COMPACT TERMINALS:

**CT 1/20.** With a transhipment module with one rail track and one road lane. The transhipment module has one overhead crane.

**CT 2/100.** With a transhipment module of two rail tracks, one road lane and two buffer lanes. The transhipment module has two cranes.

**CT 3/350/600** The transhipment module has three rail tracks and two buffer lanes. It also covers one lane of the storage module. At the other side of the storage module there is a road module with an overhead crane which also covers one lane of the storage module.

**CT 4/1000** With the same lay-out as the CT 3/350/600 but with forwarding sub-module.
The train enters the terminal. Electrically powered trains have a power line (catenary) at their disposal. No change of locomotives is necessary. When the train arrives, it is identified automatically by the dynamic identification station recording its number, contents (wagons and load units), and information needed for manipulation with the particular loading units. After entering, the catenary is moved to the side to allow the (un)loading of the wagons by the overhead cranes. A single crane (either automatic, semi-automatic or manual) is now starting the processing of the train. It moves to the initial location, picks up the first loading unit, lifts it, moves to the next train standing alongside (on the other track), the road vehicle standing alongside, the buffer zone between the tracks (short-term storage) or the location for transferring to the storage module (medium- to long-term storage) and drops of the loading unit. Then the crane moves to the other loading unit waiting for departure, takes it, lifts it and loads it onto the train.

These two activities are repeated until processing of the section of the train under the roof has been finished. Then, the train is shifted ahead and its next section comes up for processing. The train is assumed to be processed when all perceived loading/unloading operations have been carried out. Since the loading of the train(s) standing on the parallel tracks can be simultaneously undertaken, the crane operating as central service unit can simultaneously process one to three trains and several trucks. The truck is assumed to be processed when the exchange of the loading unit is finished. The loading unit is assumed to be processed when, after initial pick-up by the crane, it has been placed in one of the locations quoted above. If there is no urgent
need to move ahead the unit just unloaded from the train, this will be stored in the fully-automated intermediate storage module and waited for in order to be picked up either by truck or any other train. Once a newly loaded train is ready to depart it is again automatically recorded by the dynamic identification system and its data are stored for the purpose of advanced planning of its identification in the next COMPACT TERMINAL and/or any other conventional terminal.

Performances and costs
The Tuchschmid COMPACT TERMINAL is a rail-rail and rail-road intermodal freight terminal. The main criteria for its design can be summarized as follows:
- **Flexibility of installation** enabled by modular construction allowing ease, simple and fast upgrade of the terminal capacity depending on local conditions and traffic volumes.
- **High level of automation** allowing minimized labour force and human errors and maximized throughput (capacity) by fast direct and indirect transhipment and handling of loading units by the use of the automated identification of both the rail-wagons and loading units, and automated transhipment and storage of the loading units.
- **Reduction of cost** of the transhipment operation (e.g., cost per lift).
- **High level of reliability and availability** of services thanks to the use of the well-proved and tested highly reliable, standardised components and parts, also enabling efficient system maintenance.
- **Reduction (and even complete elimination) of damage** to the loading units during handling, thanks to the use of vertical transfer instead of conventional rail shunting.
- **Reduction of the negative impacts on the environment** thanks to a reduced surface of land needed to instal the facility and reduction of noise levels, achieved by weatherproof operations.

The performances of the standard COMPACT TERMINALS are described in Table 4.2. ‘Minimum throughput time’ is the time required to move the load unit from rail to truck through the storage area, e.g. the minimum time for a load unit entering by rail and leaving by truck passing through the terminal. Average operating costs per lift are given for the fixed conditions defined by the average rate of terminal utilisation (in this example typical utilisation rate is assumed to be 55%). If this rate increases, average operating costs per lift will diminish, and vice versa. This indicates that economies of scale may exist during operations of the terminal. The typical investment costs relate to the expenses incurred in order to establish particular configuration of the terminal, consisting of different modules. As can be noticed, these expenses will be higher if the complexity of terminal configuration increases, as it has been expected.

Typical operating regimes of the terminal also dictate its daily output expressed by load units handled. It should be noted that according to company documents the terminals CT 3/350 and CT/600 are planned (preferred) to operate 16 hours per day. The CT 3/1000 is planned (preferred) to operate 24 hours/day.
Table 4.2 Main performance and costs of the various COMPACT TERMINAL modules

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Type of the module</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CT 1</td>
</tr>
<tr>
<td>1. Number of cranes per module:</td>
<td></td>
</tr>
<tr>
<td>Rail-road</td>
<td>1</td>
</tr>
<tr>
<td>Road</td>
<td>1</td>
</tr>
<tr>
<td>2. Number of rail tracks:</td>
<td>1</td>
</tr>
<tr>
<td>3. Max. theoretical terminal throughput (lifts/day):</td>
<td>~20</td>
</tr>
<tr>
<td>4. Terminal operations (load units handled during operating time)</td>
<td>640²</td>
</tr>
<tr>
<td>5. Total storage capacity (TEU):</td>
<td>150</td>
</tr>
<tr>
<td>- storage module</td>
<td>90</td>
</tr>
<tr>
<td>- buffer area</td>
<td>60</td>
</tr>
<tr>
<td>6. Total land use⁴ requirements (m²)</td>
<td>8300</td>
</tr>
<tr>
<td>- Transhipment module</td>
<td>3100</td>
</tr>
<tr>
<td>- Storage module</td>
<td>3000</td>
</tr>
<tr>
<td>- Road module</td>
<td>2200</td>
</tr>
<tr>
<td>7. Processing of the loading unit:</td>
<td>64</td>
</tr>
<tr>
<td>- minimum transfer time (rail-road) (sec.):</td>
<td></td>
</tr>
<tr>
<td>- loading time (sec):</td>
<td>60-90</td>
</tr>
<tr>
<td>- rail-rail</td>
<td>60-90</td>
</tr>
<tr>
<td>- road-rail</td>
<td>8-10</td>
</tr>
<tr>
<td>- throughput time (rail-storage-road) (min)</td>
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</tr>
<tr>
<td>8. Costs</td>
<td></td>
</tr>
<tr>
<td>- operating cost (ECU/lift)³</td>
<td>20.00</td>
</tr>
<tr>
<td>- investments (MECU)</td>
<td>3</td>
</tr>
</tbody>
</table>

¹ With two shifts operating AVE 16 hours.
² With three shifts operating AVE 24 hours.
³ ACR - According to the customers requirements.
⁴ All excluding the surface for tracks which are occupied by parts of the handled trains, which are waiting outside the terminal.
⁵ Under utilisation rate of 55%.

Networks and locations
As mentioned before, the choice as to which COMPACT TERMINAL is appropriate depends on the function of the terminal in the rail network, traffic volumes and the local situation. On the rail side any COMPACT TERMINAL can function as terminal in networks with direct connections, line networks and hub-and-spoke networks. The maximum number of trains that can be handled simultaneously is three. This allows the simultaneous exchange of load units among a limited number of trains. Otherwise the exchange between line trains or hub-and-spoke trains will take place...
sequentially. The size of the traffic flows will determine the amount of overhead cranes required. For train operations only, automated handling is characteristic. On the road side the main differences are the size of flows, and the question whether a forwarding module is required.

**Phase of implementation, actors and barriers**
Currently, there are around 6 projects of these terminals which are in the final stage just before implementation. Any pilot model of this CT concept has been excluded. Free access is allowed to particular actors (operators and users) dealing with the particular services in the CT terminals. The services in the terminal can be provided by the railways themselves or by a terminal operator. Users will be rail operators, independent companies dealing with sorting, consolidation and distribution of freight or those dealing with logistics activities in a scope of particular industries, forwarders (there may be small, medium, large domestic and international forwarders depending on the size of the terminal) and road trucking companies.

There are significant barriers to the implementation of the CT concept. According to their importance (weight) they are ranked as follows: political, psychological and environmental, economic and financial, and technological and operational. The internal transport system of the intermediate storage area is still to be elaborated.

**Promising, missing and possible developments**
The concept is highly flexible and adaptable to users’ needs. The concept is modular, allowing gradual implementation, depending on the needs and situation (volume of expected traffic and location). Modularity enables implementation and operation either as a minimal installation at a relatively small throughput or as the complex freight distribution centre providing significant throughput and high-service performances to its customers. The concept is a relatively simple one, consisting of a limited (small) number of moving mechanical parts and well-proved components, both inherently and ‘a priori’ guaranteeing ease and cheap maintenance, low risk of failure and relatively high reliability and availability.

The Tuchschmid COMPACT TERMINAL concept can increase overall efficiency of the operators and provide gains on behalf of users dealing with the intermodal transportation (shippers and forwarders). Rail operators will be enabled to make better use of their infrastructure (tracks) and mobile equipment (trains-wagons and locomotives). By shortening the trains’ processing time while in the terminal, their commercial speed will be increased and the trains’ cycling time will be shortened thus requesting the smaller number of trains to be engaged in carrying out the same transport activities. Truck operators will benefit thanks to improved utilisation of their trucks (vehicles). This can be achieved by reducing the unloading/loading and waiting time for a load while in the terminal. Owners of the loading units will profit, thanks to the increase in the average speed of their containers thanks to such a new-generation bundling network. The new CT concept is expected to be superior to the conventional rail terminal for around 3 times with regard to land use/terminal output, for 9 times
with regard to the ratio of crane area/terminal output, for 2 times with regard to the ratio of investment/terminal output; then for around 3 times with regard to the ratio of crane weight/max. loading rating, for 1.8 times with regard to the ratio of energy use/daily output and slightly under four times with regard to trains’ waiting times in the terminal.

4.2.9 Gateway Terminal HUPAC®
prof. dr. A. Reggiani, M. Janic and T. Spiciarelli

Baseline of the concept
Gateway Terminal Busto Arsizio is located north-west of Milan. More precisely it is situated along the corridor Milan - central and north-east Europe, passing through Switzerland via the Alpine valleys of Luino and Domodossola. The development of intermodal freight transport between Italy and the rest of Europe is influenced by: 1. the metropolitan area of Milan and the Lombard industrial area, and 2. the consolidation of national continental and maritime freight flows (coming or going from/to ports of the Northern Tirrean coastal arc, like La Spezia, Genova, Genova-Voltri, Savona) headed for crossing the Alps. In the light of the actual Transalpine freight traffic operating scenario towards Switzerland, Hupac, a firm managing Busto II, estimated the volume of freight in 1996 to be 2.2 million tonnes, transported by road, and 3.0 million tonnes by intermodal transport. Around 13.8 million tonnes of freight have avoided Switzerland and crossed the Alpine Chain through neighbouring countries such as France and Austria, by conventional road. Thus, around 16.0 million tonnes of Transalpine freight traffic, actually going by road, can be considered to be a potential market to be served by intermodal services offered by Hupac. Such a growth requires a more efficient and rational use of already existing assets and new investments in the intermodal infrastructure and equipment. In order to properly meet such requirements Hupac has developed and implemented the concept of the Gateway Terminal in Busto Arsizio, titled Busto II. Its role is that of a main hub-terminal for simultaneous and/or sequential loading and unloading of containers, swap-bodies and semi-trailers: road-rail and rail-rail. To fulfil market demands such as increase of throughput, shortening of transhipment time, improvement of reliability and regularity of transport services, a new infrastructure has been built, consisting of semi-mobile and mobile service equipment.

General features
Trucks arrive at the terminal, after which drivers carry out the identification procedures at the road gate. Just before the vehicles enter the terminal area, the conditions of the load units have been checked. Then the truck proceeds to the crane area, following the road lane next to the appropriate track bundle, which is equipped with one crane. By use of the rail-mounted gantry crane the load units are taken from the trucks and the crane is led by remote control towards the position where the (un)-
loading will take place. One operator remains in the cabin of the crane and another follows the ongoing transhipment operation, standing below the crane. Then, load units are put in the storage area located close to each crane area, waiting for the successive transhipment handling (loading onto the train). Trains of compact composition are loaded by parallel transhipment of different load units. ‘Compactness’ here
means that there is no shunting of any train. Thanks to their composition of different types of wagons, a mixture of swap bodies, semi-trailers and containers can always be loaded onto these trains. To eventually support overall flexibility of operations and benefit from economies of scale, Hupac introduced a "new" type of flat bed wagon, called "Mega", which is characterised by a lower loading height. After completing the loading, the trains are delivered to the railway operator by use of an electric diesel locomotive operating within the terminal. Then, the rail operator hauls them over the rail network to their final destination.

**Performance and costs**

Concentration of freight flows has allowed more efficient use of the shuttle trains, thus the effects of economies of scale have been enhanced at the rail side of the terminal operations. The "static" capacity of the infrastructure installed in Gateway terminal Busto II can be summarized as follows: the total area of the terminal is 94,000 sqm. It has been subdivided into an area of 17,000 sqm for rail operations, an area of 76,000 sqm for road operations, and 1,200 sqm for logistic services and buildings. Semi-mobile transhipment equipment consists of four rail-mounted movable cranes with a loading capacity of 40 tonnes, a lifting height of 10.5 ms. and a span of 30 ms. They cover five rail tracks and four road lanes. There are two truck lanes within each module. The total length of the five tracks is around 2,800 ms. The crane storage lanes occupy an area at a length of 3,100 ms. The capacity of the terminal is estimated to be 20 shuttle trains per 24 hours, which is equivalent to 1,000 loading units/day. On average each train is composed of 20-22 wagons. After unloading, the various loading units remain in the stacking area for an average of 12-36 hours before being piled up. Gateway Terminal Busto II handled 3,700 tonnes of freight in 1996. Around 5 to 10% of total transhipments has simultaneously been rail-rail. By the year 2000 the volume of traffic handled by the terminal is expected to rise up to 4,000 tonnes, and up to 4,200 tonnes by 2005.

**Networks and locations**

The main traffic relation actually interested in rail-rail transhipment is Pomezia - Busto-Mannheim in both directions. The main daily services provided by international trains are those between Busto and Auran, Cologne, Duisburg and Mannheim. The main function of Gateway Terminal is a begin/end terminal in a point-to-point network. However, its new function as hub terminal enables the interconnection of a greater number of regional industrial and socio-economic poles at a European level. Which means that additional freight can be attracted to the rail network. The gateway connects the main traffic corridors by shuttle trains providing higher frequencies, better quality and more efficient services, at local and general levels of whole links (the basins which have been connected by shuttle trains are northern Italy, central and southern Italy, Greece, Spain, Austria, Hungary, Baden-Wurttemberg, Reno-Main, Reno-Ruhr, northern Germany, the Benelux, Scandinavia, Great Britain).

Recently five tracks have been laid out at the Gallarate FS rail station in order to provide a direct link from Busto II to Transalpine traffic through the valleys of Sempione on one side, and Gottardo on the other. Collaboration with Cemat (the Italian UIRR
partner) has additionally affirmed the 'gateway' concept. Most recently, Hupac - in close co-operation with Cemat - has planned to improve the efficiency and competitiveness of combined transport throughout Italy by extending shuttle train services towards the south of Italy (Bari, Napoli and Lamezia). These trains will be operated, making use of a terminal gateway organisation (rail-rail simultaneous transhipment) at Busto, Novara and Bologna Interport. The main characteristics of the network of shuttle services from/to Busto II terminal are represented in Table 4.3. Shuttle trains have also been scheduled between the Busto II ‘Gateway’ and Italian terminals (places) like Pomezia, Bari, Brindisi, Bicocca (Catania), Falconara and Marcianise (Hupac, S.A., 1996).

Phase of implementation, actors and barriers
By summarizing the development of Transalpine freight transport until now and the scenario of its future development outlined by Hupac it has been noticed that Transalpine freight transport (road and rail) grew from 18 million tonnes in 1965 up to 65 million tonnes in 1992; during the same period, rail freight transport grew from 16 up to 30 million tonnes; however, rail market share declined from 89% to 46%; and road transport grew from 2 to 35 million tonnes, reaching a market share of 54%.

According to the Hupac scenario, the reasons for such a development are: the improvement of road infrastructure, the change in freight typology through an increase in the quota of value-added goods, a trend towards bulky and light goods, the progressive replacement of fixed depots with just-in-time logistic concepts.

The above facts considered, the critical issue concerning future development of the Hupac’s Busto II Gateway Terminal is to develop it as a logistic pole (main hub) in order to serve traffic flows moving between central, northern and southern Europe by shuttle train services through the Alps. However, a few preconditions have to be met for the successful realisation of such a strategy, such as: preservation of the 28-ton limit imposed by the Swiss government on trucks crossing Switzerland, preservation of the 40-ton limit imposed by the European Union on overall road traffic (an increase of this limit up to 44 tons would weaken the economic attractiveness of combined transport in Europe) and more market-oriented price policies adopted by national railway enterprises.

Table 4.3  International shuttle services from and to Busto II

<table>
<thead>
<tr>
<th>Relation</th>
<th>Shuttles per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Busto II - Aarau - Busto II</td>
<td>12</td>
</tr>
<tr>
<td>Busto II - Duisburg - Busto II</td>
<td>5</td>
</tr>
<tr>
<td>Busto II - Cologne - Busto II</td>
<td>16</td>
</tr>
<tr>
<td>Busto II - Mannheim - Busto II</td>
<td>14</td>
</tr>
<tr>
<td>Busto II - Hamburg - Busto II</td>
<td>5</td>
</tr>
<tr>
<td>Busto II - Hanover - Busto II</td>
<td>5</td>
</tr>
</tbody>
</table>

*No. of shuttle trains in single directions*
Promising, missing and probable developments

In 1996, public and private intermodal terminals operating in this area, such as the network of Interporti—private inland terminals and publicly managed rail shunting yards—handled 10.6 million tonnes of freight. Freight volumes are expected to rise up to 17.1 million tonnes by 2000 and 23.5 million by 2005. The Gateway terminal concept, allowing fast, reliable and cost-effective rail-rail and road-rail simultaneous transshipment of loading units such as containers, swap-bodies and semi-trailers, thus increasing competitiveness of certain main rail corridors, is expected to be developed elsewhere in Italy and in Europe if a network of main-hub terminal locations emerges in an integrated hub-and-spoke European railway network.

4.2.10 Lättkombi Terminal

Dipl. Ing. J. Gröhn

Baseline of the concept

The Lättkombi (small-scale combined transport) concept is meant for containers and swap bodies which are transferred from road to rail or vice versa in simple terminals. The aim of Lättkombi is to enable fast and cheap transfer of loading units to and from trains in inexpensive terminals, which form a dense network. The trains would be running fixed routes according to fixed timetables and there could be transfers from one train to another in shared terminals. The purpose is to create a shift in goods traffic from road to rail by introducing a new fast, cheap and reliable service.

By applying this concept it is possible to:
- reduce the costs of a terminal;
- increase the number of terminals which are suitable for combined transport;
- load and unload under overhead wires;
- avoid shunting;
- shorten the viable distance of combined transport.

The trains network might appear as follows. Trains at approximately 20 wagons would run scheduled fixed routes (line networks), along which terminals are located at 150 - 300 km intervals.

General features

There are no buildings or employees in the Lättkombi terminal area; nor is there transfer equipment. The terminal area is a paved, level terrain which has been fenced in and is surveyed by cameras. Road vehicles enter the area using key cards to unload and load containers or swap bodies. The loading units are unloaded from and loaded onto the train employing a special side loader running along with the train and driven by the engine driver. Handling takes place under the overhead wires. The concept requires an information centre with on-line connection to the trains. The information centre receives data on the loading units to be transported, and, before the train

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arrives a terminal, instructs the engine driver as to which units to be unloaded and loaded.
A truck enters the terminal area after being identified at the gate. The driver unloads the loading unit(s), container or swap body, from the road vehicle, and deposits it on the floor. In case there is a loading unit from a previous train due for the back haul, he loads the unit and leaves the terminal; otherwise the truck leaves the terminal unloaded. Trucks need to be equipped with either hydraulics for swap bodies or a lifting device for containers. A visit to the terminal takes 5-15 minutes.
A train set of about 20 wagons arrives at the terminal. The engine driver walks to a special wagon in the middle of the train, where the side loader is positioned. He drives the loader from the train and then unloads the loading units which are headed for this terminal, before loading the units which have been waiting for the train. One move - either the unloading or loading of a loading unit - takes about 3 minutes. At least 10 loading units can be transferred - either to or from the train - during a 40-minute stop. When unloading and loading are completed, the engine driver drives the loader back to its wagon. The train departs roughly 40 minutes after arrival.

Terminals must dispose of a side track, unless the line is very quiet. Beside the track there is a plain, paved terrain about 40 m wide. The train consists of an electric engine and about 20 standard wagons, added by one special wagon for the handling equipment; a kind of side loader. This train can carry about 40 loading units. The side loader can handle all standard loading units. The overhead wire is positioned at a 5.5 metres height above the track. At a 1 metre security margin the highest allowable working height is 4.5 metres. The wagon floor is 1.2 metres above the track, allowing 3 metres high units to be handled.

Performance and costs
The viable service area of a Lättkombi terminal is calculated to be 50 kilometres. The length of the route would be such that it could be run by one train twice a day. In the

Figure 4.25 Lättkombi Terminal lay-out

Source: Sjödén, 1997.
beginning there would be only one train at a capacity of 30 TEU. This capacity can be increased by adding wagons to the train or by adding another train, provided the frequency, too, is improved. The lead time of the loading units at a terminal depends on the timing of the road vehicle. It would be at least half an hour. In a succeeding phase the expected lead time would also depend on train schedules if loading units are to be transferred to other trains. A move of a single loading unit takes about three minutes, regardless of whether it is performed by the side loader of the train or by a truck equipped with its own handling system.

The cost of setting up a Lättkombi terminal is low. Operating costs of the terminal would be extremely low. The prices of the side loader and its wagon would be approximately the same as the prices of corresponding standard equipment (together around 0.5 MECU). The additional costs on behalf of road vehicles because of the required handling equipment would be around 10 kECU; however there are already plenty of trucks in use provided with such equipment.

Networks and locations
Terminals should be located on cheap grounds outside cities; yet close enough to industrial areas. The railroad network will require suitable crossings for fluent transfers, so that services can cover large areas.

Phase of implementation, actors and barriers
A pilot of this concept is planned to be started in autumn 1997. In the beginning it will consist of one train at 10 - 15 wagons and 5 - 6 terminals. The route is planned in southern Sweden. The project lies entirely in the hands of SJ (the Swedish Railways). The concept has been under development for years. In order to prevent it from being buried under the existing conservative railway organisation, an independent project group with certain resources was set up. The project leader is Mr. Jan-Ola Wede who works in Malmö. There are some companies committed to its piloting who expect reliable deliveries at competitive costs. According to calculations, distances as short as 150 km should be profitable. According to Mr. Sten Lövgren, the inventor of CCT Plus, there might be technical problems related to the capacity utilisation of the wagons. One wagon allows space for three 20ft loading units; however, due to handling techniques only two 20ft units can be loaded. Stability when lifting 40ft units from the side could furthermore form a problem. Last but not least the working hours of the engine driver should be taken into account: when does he take breaks?

Promising, missing and probable developments
Industrial enterprises are often located outside cities. Plants are equipped with industrial tracks that can however not always be used because: 1) there is no time for coupling and 2) shipment sizes have become too small, both being the results of Just-In-Time production. However, companies would prefer using railways. By introducing this concept, Swedish Railways are improving access to combined transport on behalf of all companies. Potential customers can be found for instance in the brewing industry, where volumes are high, deliveries are frequent and goods are heavy.
Naturally, also small and medium-size enterprises with occasional shipments could use the concept.

The concept has been under development for years, so it is not amazing that it appears very suitable to Scandinavian conditions. If the price of combined transport is competitive with the price of direct road transport the former will be a success. At the moment, certification of Environmental Management Systems (ISO 14 001) for companies is in progress. Soon, companies will have to require this certification from each other in order to comply with their own certificates, stating the environmental friendliness of their transport. This may in turn increase companies' willingness to pay for combined transport or increase their status of environmentally friendly company.

4.2.11 Train Coupling Sharing/Cargo Sprinter

ir. E. Kreutzberger

Baseline of the project
The Cargo Sprinter is a small innovative train consisting of (about) 5 wagons, each of them able to load two containers or swap bodies at lengths of 7.45 m or one container at a length of 13.6 m. Two of the wagons, the head and the tail one, also include a small cabin for the driver (Figure 4.26). Thanks to their innovative coupling component, the Cargo Sprinter can easily be coupled onto other Cargo Sprinters. Splitting a Cargo Sprinter-train into separate Cargo Sprinters is comparatively simple. The Cargo Sprinter also has automatic locks for load units. They save a lot of handling time at the terminals. Because of its running characteristics and coupling, splitting and (un)locking ease, a Cargo Sprinter can:

- run as a shuttle train or form part of other production systems and bundling concepts. Most obvious is the advantage of the Cargo Sprinter in the projected Train Coupling and Sharing system (TCS) of the DB. However, also line services per Cargo Sprinter are envisioned (Deutsche Bahn, 1996). Thus, in the Cargo Sprinter system, load units can be exchanged by trains by vertical transhipment of load units and by exchange of Cargo Sprinters (= new-generation wagon groups) between trains;
- according to the actors - move along both the long distance and the collection- and distribution networks of nodes;
- continuously be adjusted to changing freight volumes;
- efficiently use the infrastructure: large trains of several Cargo Sprinters require less capacity than several independent Cargo Sprinters on the links. The separate(d) Cargo Sprinters near and on the nodes are very flexible.

12 The component includes the automatical coupling of the electrical cable, which provides the following units of energy and data and thus also is important for another innovative component, the electronical brake.
**General features**

The pilot trains\(^1\) of the DB and the ones between Frankfurt/Main and Zürich are powered by diesel engine\(^2\), they are 5 wagons or 91m long, and can be conducted by an integral drive-brake-stick. Apart from containers and swap bodies the Cargo Sprinter can carry logistic boxes. In the airport, pilot plans are to use interchangeable containers that can be inserted as closed-box containers (7.45 metres in length or, especially for the pilot link with Zürich, 13.6 metres). They will be equipped with automatic rolling floors (Schölich, 1996). Jahnke (1995) of DB mentions that the terminals in which TCS-trains are coupled and split, are to be developed. Conventional shunting yards may not be capable of coupling and splitting because in future Cargo Sprinter-trains could well become too long.

Typical operations will know two types of load unit exchange:
- the vertical exchange of load units at initial and final terminals (in complex bundling networks also in intermediate terminals) and;
- the exchange of Cargo Sprinters between Cargo Sprinter-trains at train junctions of the frontiers between trunk networks and collection and distribution networks. The exchange will be carried out without conventional shunting of wagons or wagons groups. Instead, simple coupling and sharing of Cargo Sprinters takes place. Figure 4.27 shows typical operations of the Cargo Sprinter in the TCS-bundling model. It must be mentioned that TCS is not only developed for combined transport, but for conventional wagon as well. This can support the bundling ability, wherever combined freight flows are (too) small.

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\(^1\) Windhof, later also Talbot (Op de Rails, 1997).

\(^2\) Volvo.
Figure 4.27  TCS as bundling concept which is pre-destinated for Cargo Sprinter

1. After loading the TCS-units go to a ‘collection point’
2. There they are united to a train
3. The as train united TCS-units operate synchronized, steered radiographically by the leading unit
4. The train is split again into separate TCS-units or smaller trains
5. After having arrived at the destination terminal, the TCS-units are unloaded


DB is working on networks and operational schemes. An example: in order to keep costs low the surplus of drivers of coupled Cargo Sprinters could do other work after coupling.

Performance and costs
Trains can run from 100 km/hour (at a load of 160 t) to 120 km/u (at a load of 112 t). A Cargo Sprinter of 5 units replaces five trucks. The diesel-powered train uses about 15% less diesel than five trucks would do and - in case three Cargo Sprinters are coupled to a train - 35% less than 15 trucks (Deutsche Bahn, 1996b). The results of pilot performances and costs have not (yet) been published. Performances and costs will also be dependent on the characteristics of networks with Cargo Sprinter, which apparently still need to be elaborated. Transcare (Koch, 1997) indicates, that in their forecasts of costs for the regional line train in the state of Lower Saxonia, a line-bundling network, a conventional train is operated at lower costs than is a Cargo sprinter at longer transport distances.

Phase of implementation, actors and barriers
Cargo Sprinter is being tested by DB (including drivers’ training for personnel). Simultaneously, the first commercial implementation is being prepared. This is a pilot shuttle connection between the airports of Frankfurt/Main and Zürich. Here, advantage is taken of the existing rail facilities at CargoCity South (part of the airport), which were built to supply the airport with building material. The line, a cooperation project of both airports, Lufthansa and SwissAir, is expected to be operational by the
end of 1997. In succession, also the airports of Amsterdam and Frankfurt have
announced their interest in a rail connection. The results of joint research are expected
to be presented in the third quarter of 1997 (Hastings, 1997).
In the meantime DB is active in elaborating the bundling networks for Cargo Sprinter.

Promising, missing and probable developments (actors point of view)
The Cargo Sprinter can be developed in the direction of an even more sophisticated
product. Electric powering is an option. Eventually robotized driving can be intro­
duced, hereby following the SST methods of operation (see chapter 4.6.2). If SST
train construction is furthermore considered, the two projects, Cargo Sprinter and SST
are becoming very similar. A third development is the adaption of Cargo Sprinter to
different kinds of load units. The exact role of Cargo Sprinter in TCS, the two hub­
and-spoke networks and the line network does not yet seem to have been precisely
elaborated.

4.2.12 Nord East Terminal Paris
prof. dr. M. Beuthe, dr. B. Jourquin and L. Demilie

Baseline of the project
The objective of the Paris North-East terminal is to provide sufficient terminal
capacity for combined transport in the Paris region in the future. At the present time,
the combined transport traffic in Ile-de-France, i.e. Paris region, is handled by five
terminals: Valenton, Maison-Alfort-Pompadour, Rungis, Noisy and Paris-Chapelle.
These five terminals handled 4.1 million tonnes in 1994. In 1985, combined transport
in the same region amounted to only 2.56 million tons. Thus, there has been a 55%
increase during that period of time. Extensions and improvements in Noisy and
Valenton will increase the maximum operational capacity to 5 million tons. But,
despite this expansion of capacity, SNCF expects that the five terminals will be
saturated by 1997. In order to solve this problem, a new terminal, Paris North-East,
must be built. When this new terminal has been fully developed, in around
2005/2007, it will double the total capacity available to combined transport in that
region. Although the concept concerns a new terminal at conventional technology, it is
incorporated because there is a clear necessity for new-generation operations in order
to handle growing future volumes in a dense area.

General features
The North-East terminal will cover an area of 50 ha. Figure 4.28 shows the lay-out of
the terminal. Starting from bottom left, the terminal will include:
- an area measuring 750 metres. In length and 36.5 metres. In width with 3 tracks
  with one gantry;
- a second area measuring 650 metres. in length and 30 metres. In width with one
  track for a crane and one stocking area;

15 Sources: Chauvet, 1997; ACT consultants, 1997.
two areas for two additional sets of tracks and gantry cranes, which will be developed at a second stage;
- a parking area for trailers of 22 metres width.
Starting bottom right in the picture we see:
- a reception and storage area made of 8 tracks of 750 metres;
- an area where 5 tracks will be organised at a second stage;
- an area for a locomotive garage and a maintenance workshop for transport units with two tracks.
In addition, there is an administration building on a surface of 2,000 m².

Performance and cost
The track length under a gantry crane will be equal to the maximum length of a train. Hence, it will be possible to handle all swap bodies and containers without moving or reshuffling trains and shunting wagons. The width under a gantry crane will be large enough for 3 tracks. The dimension of the stacking area, corresponding to the capacity of two trains, will permit unloading of trains before the arrival of all the trucks. The availability of tracks for train movements and parking will ease train movements without delaying the loading/unloading operations. Especially unloaded trains will be parked on these tracks so that the unloading of other trains can be carried out. Also, trains to be loaded next can be prepared in advance on these tracks, allowing a so-called dynamic management of freight handling. SNCF expects to unload three trains in approximately 2 h 15.
Following a study by SEMA-GROUP in 1990, potential traffic is estimated at 2 million tonnes per year, with an annual increase of over 10%. In order to cope with that increase, the operational volume of the North-East terminal will reach 5 million tons by 2005/2007. With this new North-East terminal, capacity of the existing terminals in the Parisian region will double.

The land cost is estimated between 20 millions and 90 million FF. The building cost of the first stage of the project, infrastructure plus equipment, is estimated within a bracket of 361 million to 393 million FF. For the second stage, the cost is estimated at 144 million FF in two steps at three-year intervals. In order to finance this project a subsidy is expected from the State and the Region 'Ile-de-France'. It should amount to a minimum of 70% of the total cost, and may reach 85% in the best case. The internal rate of return over a period of 20 years has been estimated at 14.38% in the case of an optimistic cost hypothesis, i.e. 525 million FF spread over the period of development with a subsidy amounting to 85% of the total cost. It goes down to 5.31% in the case of a pessimistic cost hypothesis, i.e. 627 million FF with a subsidy of 70%.

**Networks and locations**

The location of the North-East of Paris (Saint-Mard site) will provide combined transport access to an important potential market north-west of Paris. This market, which has a potential of 2 million tonnes, is practically closed off for the time being because of the very high road congestion in the area. This location will also contribute to a better distribution of combined traffic in Ile de France; at the present time, 90% of that type of traffic is handled at terminals located on the south side of Paris.

The Paris North-East terminal will be linked to the great railway ring around Paris which connects not only all five existing Paris freight terminals, but also the passengers' terminals and the hub point of Villeneuve-Saint-Georges. In this way it will also be linked to the nodal point which may be developed in the Paris region for handling the traffic between terminals which are not connected by direct trains due to lack of traffic.

**Phase of the implementation, actors and barriers.**

According to SNCF, the land should be bought in 1999. The actual building of infrastructure would begin by 1999/2000 and the first gantry crane would be operational by 2002. The actors involved in the project are SNCF, the French National Railways Company, the French state, the Region Ile-de-France and several districts (Saint Mard, Juilly, Thieux). The funding of the project is the main barrier. The creation of a new public corporation called "Réseau Ferré de France" (RFF), which will be responsible for Paris North-East as well as for all the new public terminals was delayed. The decree enabling it was not voted on until May 5, 1997.

**Promising, missing, and probable developments (actors' point of view)**

According to the actors, around 2010/2015 all the Paris terminals, including Paris North-East, will be congested and new investments will be needed in order to cope
with the expected further increase of traffic in Ile-de France. A 10% increase is estimated for the coming years. The recent evolution of combined transports in France and Ile-de-France is illustrated in the following diagram.

### 4.2.13 Irún and Portbou Terminal

**prof. dr. M. Beuthe, dr. B. Jourquin and L. Demilie**

#### Baseline of the concept

One of the main barriers impeding the development of combined transport in the Iberian Peninsula is the different gauge of tracks over the French and Spanish networks. In order to solve this problem to some extent, RENFE has built two terminals at the French border: the Irún terminal and Portbou terminal. These two terminals are mainly aimed at the transhipment of load units from trains onto wagons with the Spanish axle gauge to trains with wagons with a French axle gauge, and vice-versa. Unfortunately, these two terminals are close to saturation. On the Atlantic side, RENFE is planning to expand the cross-border terminal of Irún. With the extension of the Irún terminal, new-generation terminal concepts might be a solution in order to realize continuation of the development of combined transports in the Iberian Peninsula. The new investments which are planned at Irún should triple the capacity of the terminal. The Portbou terminal on the Mediterranean side cannot be expanded because it is blocked by the sea on one side and by mountains on the other side. In this situation the only solution to increase capacity is to increase the number of gantry crane per track or to implement a compact, high-performance terminal concept. Both terminals show a necessity for new-generation operations in order to realise fast and efficient transhipment.

#### General features

The operation is rather simple. The train with load units from the French side is positioned under the gantry crane. A second empty train at a destination on the Spanish side is positioned on another track under the same crane. The load units are then transhipped from the French train onto the Spanish train. In the case of loaded trains from the Spanish side, operations take place the other way round. After transhipment or during the operation, a technical check-up of the train is made. The actual infrastructure at Irún includes two tracks of 300 metres of French gauge (UIC gauge) and one track of 300 metres of Spanish gauge. The new infrastructure will have 3 tracks of 450 metres of French gauge and 3 tracks of 450 metres of Spanish gauge. Two new gantry cranes will complete this infrastructure. Both gantry cranes will operate over 6 tracks. These new gantry cranes will be characterized by better reliability and manoeuvrability. One of the cranes will be equipped with a turning spreader for handling trailers. In addition to these 6 tracks, two other tracks of Spanish gauge will be built in order to handle domestic traffic. The lengthening of the tracks will permit a reduction of unnecessary movement of the gantry crane, and speeding operations.

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16 Sources: SOTO, 1997.
Nowadays, the arrival of trains at Irún is planned in order to avoid possible congestion during peak hours as much as possible.

**Performance and costs**
In 1996, 89,400 TEU went through the Irún terminal. A reliable forecast for future operations is difficult to make. However, RENFE expects an increase of 15% on traffic for 1997. The terminal is opened 24 hours per day from Monday to Saturday. For the time being and at the present infrastructure, transhipment time for a train of 25 wagons amounts to about 2 hours. On average, the transhipment of one load unit takes 2 minutes 15 seconds. The technical check-up of the train takes 1 hour while average waiting time is 45 minutes. Overall time at the terminal is therefore 3 h 45. At the new infrastructure RENFE expects a reduction of transhipment time for a train of 25 wagons to 1 h 15 only. This reduction will mainly result from the avoidance of time lost by unnecessary movement, provoked by the short length of the track. Thanks to these new investments and the resulting efficiency gain, RENFE expects to multiply the capacity of the Irún terminal by 3. In 1996, transhipment costs of one load unit have been estimated at 22 ECU.

**Phase of implementation, actors and barriers**
The new infrastructure at Irún will be put in service in August 1997.

4.2.14 Rail Terminal Maasvlakte

*Y.M. Bontekoning*

**Baseline of the concept**
Forecasts show that container volumes at the Rotterdam Maasvlakte will grow up to 7 million containers in 2020. 1.4 million containers will find their way to the hinterland by rail (Incomaas, 1996a). The existing rail terminal on the peninsular with ECT’s
(terminal operator) marine terminals can only handle 300,000 - 350,000 containers per year. A second and larger rail terminal is planned for January 2000 outside the peninsula. For efficiency reasons the existing rail terminal will only handle dedicated shuttles, while the new terminal will handle multiform shuttles. Although the new terminal starts as a conventional rail terminal, cranes, internal transport equipment and infrastructure have already been designed for automation possible in the future. Automated Guided Vehicles (AGVs) or self lifting vehicles will be used for transport in the future. Van de Ruit (1997) states that the plans for the new rail terminal focus on the first phase: the next 10 years MTS's will be used for transportation and conventional cranes for transhipment.

General features
The rail terminals and the marine terminals are interconnected by an internal transport system. This internal transport system uses transport units with 5 coupled chassis (10 TEU) pulled by a heavy truck. Internal transport is based on a large number of small shuttle connections. All containers on each individual MTS have the same origin and the same destination terminal (for a further description see paragraph 4.6.3). There are four marine terminals and several empty depots. This set-up of the internal transport system and the different origin/destination terminals/depots imply that sorting and grouping of containers will be required when multiform trains are being unloaded and loaded. In order to minimise crane driving (as soon as the internal transport unit is parked somewhere along the track it will stay in that position) the functions of the two terminals in the network differ. The existing ECT terminal only handles dedicated shuttles. On a dedicated shuttle all containers have the same ECT marine terminal as origin or destination. The new terminal handles only trains with containers with multiform origin or destination from/to ECT marine terminals. The following type of trains are handled at the new terminal:

- multiform shuttles: shuttles which carry approx. 30 containers for/from several ECT terminals;
- step in shuttles: shuttles which carry ca. 30 containers. About 15 of these containers are for/from the several ECT terminals, the other 15 are (un)loaded at the Rail Service Centre Eemhaven/Waalhaven (40 km eastwards);
- part shuttles: shuttles which carry ca. 7 containers for/from several ECT terminals. These shuttles are coupled or shared with other part shuttles elsewhere in the network;
- hub trains: trains with a variable length (approx. 20 containers) which are shunted elsewhere from trains with the same origin and several destinations to trains with the same destination (Incomaas, 1996b).

At the existing rail terminal no grouping or sorting is necessary which makes it possible to have fast and efficient transhipment with conventional equipment. At the new rail terminal containers are sorted or grouped in order to fill one destination multi-trailers or one destination trains. In order to realise efficiency (minimising crane driving) six trains are being unloaded and loaded simultaneously. Figure 4.31 shows that the number of wagons of the six trains right next to (the length of) one multi-
Figure 4.30 Maasvlakte area with rail terminals


Figure 4.31 Sorting and grouping at new rail terminal

Source: OTB.

Trailer provide enough containers to fill that multi-trailer. This way crane driving reduced to a minimum.

Both rail terminals are begin/end terminals in the network. Van de Ruit (1997) states that for this reason trains stay at the Maasvlakte for several hours between unloading and loading. At the existing rail terminal empty trains are parked at the yard outside
the peninsular in between unloading and loading, unless no other trains are being handled. The trains are pushed in and towed out by a diesel locomotive. At the yard trains are prepared for unloading and for departure. No change of locomotives is necessary because the trains already arrive with diesel locomotives, the reason for this is that there is no electrification on the track Rotterdam Eemhaven/Waalhaven and Maasvlakte. The yard is also used for conventional trains with coal and ore. The new terminal has enough space to let empty trains wait at the terminal, but if necessary trains can also be parked at the new yard outside the new terminal.

Network and locations
From the Maasvlakte there are connections inside the Netherlands, to Antwerp, Italy, hub Metz, central and south Germany, to Belgium, Poland and the Czech Republic. Most (shuttle) trains arrive in the morning between 0.00 and 12.00 and leave between 12.00 and 24.00 hours. In between the trains stay at the Maasvlakte (for 10 hours on average). Transport takes place during the night so that trains arrive at the hinterland terminal around the opening hour of the terminal (often 6.00 or 7.00 hours). The rail network also has more capacity during the night. Duration of unloading and loading is about 2 hours. Before loading 2 people work for 20 minutes (50 wagons) to position pins at the rail wagons. After loading things like physical checks (train and containers), administration, brake tests and tie up of couplings (tasks of the Dutch Railways) take about 45-60 minutes.

Performance and costs
Forecasts and scenario studies have been carried out to estimate the future rail freight streams. In the table these forecasts per year are presented with an upper and lower bound.

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecast Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>166,000 containers (realised)</td>
</tr>
<tr>
<td>2000</td>
<td>124,000 - 319,000 containers</td>
</tr>
<tr>
<td>2005</td>
<td>150,000 - 542,000 containers</td>
</tr>
<tr>
<td>2010</td>
<td>184,000 - 792,000 containers</td>
</tr>
<tr>
<td>2015</td>
<td>255,000 - 1,087,000 containers</td>
</tr>
<tr>
<td>2020</td>
<td>326,000 - 1,435,000 containers</td>
</tr>
</tbody>
</table>

The existing terminal has 4 tracks of 600 metres, 2 internal transport lanes, 2 rail mounted gantry cranes, one stacking lane and a buffer area for 15 multi-trailers. This buffer is needed to guarantee a smooth continuous operation of the rail crane. The maximum capacity is 50 moves per hour (2 cranes). The existing terminal can handle 350,000 containers per annum. This is based on the opening times of 7 days per week 24 hours per day. However on Sundays no trains arrive or leave because terminals in the hinterland are closed. The new terminal is 200 x 2,000 metres and has 4 transhipment bundles. Each bundle has 6-7 tracks, one crane and 3-4 internal transport lanes. The new terminal can handle 600,000 containers in 2020, 150,000 for each bundle.
The existing rail terminal can only handle maritime containers. The new rail terminal can also handle swap bodies and trailers. Until the new terminal is ready swap bodies and trailers have to go to Europoort (15 km) or RSC Eemhaven/Waalhaven (40 km westward).

**Phase of implementation, actors and barriers**

ECT is operator of the existing terminal and will be the operator of the new terminal. The new terminal starts with two bundles, each with one conventional rail mounted gantry crane. Studies for lay-out and equipment are being carried out for the first pre-design. The Port of Rotterdam is involved in infrastructure and spatial planning. Van de Ruit states that the efficiency of existing rail terminal operations can be improved by things such as better organisation and information. The peak characteristics of rail transport effect on the capacity utilisation. Mixed trains with containers for several Delta terminals require an extra effort to achieve a smooth rail operation and inter-terminal transport. Grouping of containers in the hinterland for the same Delta terminal would help to realise a more efficient operation. Rail wagons need to be standardised in order to enable implementation of automated transhipment.

**Promising, missing and probable developments**

Van de Ruit expects further robotisation of the rail operation, but not within the next 10 years. More than in the past the advantage and disadvantages of automation are under discussion. High tech solutions are not always the best solutions. Rail operations will still be done with MTS’s. A better organisation and management of the process already leads to more efficient operations. Simulation studies of the study group Incomaas (1996b) show that AGV’s in the future (the year 2000) will be more efficient. But up till now the risks of implementation are too high. By including a “wide” rail terminal into the design the possibility of an automated transport system is left open. But no decision has been made yet. This can be an AGV system or a system of self-lifting vehicles. New types of rail terminals offered by companies such as Noell, Krupp and Mannesman are studied by Incomaas (1996b). These concepts realise a faster handling with higher costs.
Because of the position in the network (begin and end terminal) Incomaas and also van de Ruit doubt whether faster handling is an interesting option, because trains stay empty at the Maasvlakte for 10 hours on average. The option to use fully Automated Stacking Cranes (ASC’s), now used at the ECT marine terminals, is also under study. A problem which arises in all automated terminals is the positioning of pins. The Incomaas study of the handling of rail containers in 2020 proposes a device with springs and an optic control device (Incomaas, 1996b).

4.3 Barge Terminal Concepts

4.3.1 Barge Express
drs. J.W. Konings

Baseline of the concept
Barge Express (BEX) is an integrated concept for large-scale barge container transport. The concepts' main strategy is to reduce total costs of sailing and handling by exploiting the economies-of-scale barge transport can offer. The BEX-concept originated from the idea that barge transport could only achieve a large share of the growing hinterland transport of Rotterdam, if it remains a cost-effective mode. In order to achieve this, bundling the transport flows, increasing the scale of operation and introducing automated handling at barge terminals is needed. These elements go together in Barge Express. The concept presumes that the main barge terminals in Europe will be equipped with a terminal facility for automated transhipment. Automation is supposed to give opportunities for lowering the handling costs and the number of handlings. This leads to growing transport flows between these terminals. For optimizing the benefits the largest possible vessels i.e. push boat/barge combinations are chosen and to facilitate an automatic loading and unloading process the barges are equipped with cell guides. The BEX terminals apply New-Generation Technology. The loading/discharging is supported by computers, automated quayside cranes, automated guided vehicles (AGV’s) and automated stacking cranes ASC’s).

General features
Two organisational principles for the automated terminals are distinguished, leading to so called active and passive terminals. At an active terminal the terminal operator determines the sequence of the containers to be picked up and delivered at the BEX-terminal, because only an internal transport system (i.e. AGV’s) serves the BEX-terminal. At the BEX-terminal itself there aren’t stacking facilities and loading and unloading of push barges is a simultaneous process: one push barge for loading and one push barge for unloading. Containers which arrive at the BEX-terminal by AGV’s are loaded into the barge. Next the released AGV’s are used to load containers from the unloading barge. In this way the internal transport can combine the delivery and collection of containers in combi-trips.

At a passive terminal the terminal operator is expected to be unable to control the external transport. Outside transporter (i.e truckers) will pick up and deliver containers
irregular at the BEX-terminal during the day. This requires a large time window for handling truckers and stacking facilities at the BEX-terminal. The loading and unloading of barges is a sequential process. The push boat arrives with a push barge for unloading and leaves immediately with another push barge loaded earlier. When a container arrives at the BEX-terminal by truck it can be moved directly from the truck into the push barge, which then acts as a floating stack. The same truck can leave with a container with minimum delay enabling the trucker to combine the delivery and collection of containers in combi-trips. Containers arrived by barge and to be picked up by truck are first moved into a stack by AGV’s and ASC’s. From this stacking area the containers are manual transshipped to the trucks. Generally, the passive terminal will be the most preferable principle for an inland terminal, while at a seaport terminal the active terminal might best fit.

**Figure 4.33 Barge Express terminal**

Source: TRAIL Onderzoekschool, 1996.
For the automated transhipment the push barge must remain almost still and horizontal. Therefore adaptations of the berth (i.e. a jetty) and the crane are necessary. The concept operates with push boat/barge combinations. The push boats are of a conventional type and are immediately available, because in the market push boats suffer from overcapacity. The push barges will be larger than the conventional ones and equipped with cell guides. The size of the barge is based on physical and legal restrictions for the Rhine shipping to Mainz. This results in a barge of 72 metres x 22.80 metres with 280 TEU capacity. On the route to Duisburg two of these 280 TEU barges could be pushed in one combination (560 TEU).

The automated quay cranes (based on the mechanism of the Automated Stacking Crane) can be operated in automated and manual mode in order to operate conventional vessels as well. Automated Stacking Cranes (ASC's) operate in dual mode too: automated mode in berth side operations and manual mode in land side operations (transhipment to terminal external transport). The transport between the automated quay cranes and the ASC's will be pursued by AGV's.

An active terminal will be smaller, less expensive and easier to extend than a passive terminal. The active terminal operator can use higher stacks and has more lay out options, because it can usually be combined with other stacking facilities for other modalities. The spatial use of an active and passive terminal is estimated at respectively 0.6 ha and 3.2 ha.

Performance and costs
In conformance with demand criteria a daily service (six times per week) with fixed departure times is desirable. To offer this service on the route Rotterdam - Duisburg (243 km) one needs two push boats and four barges; the route Rotterdam - Mainz (518 km) requires four push boats and six barges. When transport volumes exceed 175,000 TEU more transport units become necessary. To Duisburg two barges can be pushed in one combination, extra push boats are not necessary. To Mainz it becomes attractive to sail a two push barge combination to Duisburg where it is split up to sail the barges separately to Mainz. The Duisburg service is of A-A quality; the Mainz service respectively A-B for stream downward and A-C for stream upward services.

At the active terminal push boat and barge stay along berth as long as transhipment takes. The handling time depends on the number of cranes. With two quay cranes two push barges are simultaneously loaded and unloaded within 5 hours. The crane capacity is put at 45 moves per hour. The duration time of the barge is 33 hours. At the passive terminal the duration time of the barge is 25 hours (including 1 hour for change of the push boat). The minimum year capacity of the system, according the mentioned sailing schedule and equipment (i.e. single pushed barges), is 175,000 TEU per route.

The initial investment costs are assumed to be limited, because the components of the BEX terminal are partially based on wellknown technology. The cost of an automated crane are estimated to be around 2.4 million ECU. The investment and exploitation costs for push boat/ barge combinations are much lower than for conventional container
vessels with the same capacity. The push boats can be chartered on the spot market, while barges with cell guides can be built at low price compared to ordinary container vessels. Total costs (seaport terminal costs, sailing costs and inland terminal costs) of Barge Express and conventional barge transport have been compared. According to this exercise the BEX-concept offers savings in the range of 15 to 22 ECU per 40ft container, i.e. 10% to 15%.

Network and locations
In order to maximise the benefits of the large scale transport capacity time losses need to be minimised and therefore the number of visiting terminals is preferably limited. As a result point-to-point transports on routes with large transport volumes are considered to be the target markets. There are two promising routes: Rotterdam - Lower Rhine and Rotterdam - Middle Rhine. In Rotterdam an ideal location for a BEX-terminal would be the Maasvlakte area because of its large transit volume. The proposed inland terminal locations are Duisburg (for servicing the Lower Rhine area) and Mainz or Mannheim (for servicing the Middle Rhine area). The choice of these inland locations is geographically determined and based on the potential catchment areas of the terminals. A third route, Rotterdam - Antwerpen, could be considered as well, but the cost saving potentials are judged much lower than for the Rhine routes.

Phase of implementation, actors and barriers
A study into the concept has been made in 1996, leading to the conclusion that the concept would be technical and economical feasible. The study was initiated to outline the contours of the concept and was meant to be the starting point for further investigations in different technical, logistic and legal (i.e. safety) details of the concept. Terminal operators, barge operators and skippers would be directly involved if the concept would be realised. However, sea shipping lines, road companies and forwarding agents could become interested in participating in Barge Express, because it offers possibilities to strengthen their position in the (intermodal) transport chain.

One of the potential barriers for starting the concept would be the present transport volumes handled at Duisburg and Mainz or Mannheim. In order to have an acceptable utilization rate of the barges it is necessary to bundle all transport flows in the Lower- and Middle Rhine regions to their proposed BEX-terminal locations. Because of financial commitment of sealiner shippers in other Rhine terminals there might be a reluctance to do so. Due to the concentration of flows longer pre- and post trucking distance and as a result higher trucking costs will arise. The cost savings of Barge Express might be too little to compensate for higher pre- and post haulage transport costs, unless concentration has strong cost saving effects due to higher utilisation rates in pre- and post haulage trucking.

Promising, missing and probable developments
It is expected that the market for container barge transport will be more and more segmentated in a carrier haulage and merchant haulage segment (Knight Wendling, 1994). The growing importance of carrier haulage transport contributes to bundled transport flows and will give support in realising Barge Express.
4.3.2 Rollerbarge
drs. J.W. Konings

Baseline of the concept
Rollerbarge is a terminal facility for horizontal transhipment of containers and swapbodies between rail or road transport and barge vessels using a rolling move. The prime objective of Rollerbarge is to reduce transhipment costs and time. The genesis for this concept is primary based on the specific barge problems the Rotterdam harbour is dealing with: high container handling costs and slow container pick-up services, which would make barge transport unable to accommodate the expected and desired growth in container hinterland transport in an efficient way.

General features
A block of prestacked containers (8, 16 or 24 units) will be rolled in one move from the quay on a hydraulic operated platform, which is part of the riverbarge. After the containers are rolled on this platform, it will be lowered to storage deck level. The platform then being even with this deck level, will allow the containers to roll terminal with cranes (for example a mobile crane or reach stacker), before it is transported to the elevating platform.

Performances and costs
The handling capacity amounts to 100 - 120 containerunits per hour; about 4 times the productivity of a modern conventional seaport containerbridge (its maximum turnover is around 30 units per hour). Potential time savings in loading a 234 TEU vessel are 4 to 5 hours. In case the operation could make roundtrips between rollerbarge fitted terminals the timegains would be: horizontally to their final stowage position on board. Energy and facilities to move
the containers horizontally and to operate the platform from quay level to deck level, will be supplied by the vessel as part of its operating tools. To bring the load units on the elevating platform, different means of internal transport could be used. However, a similar roller system to move the units to the platform would enable higher production. In this situation a prestacked block of containers could be formed somewhere else at the 234 TEU vessel - 4 operations - 16 hours 312 TEU vessel - 4 operations - 22 hours

The implication of this time saving is twofold. For the shipper the transit time on the Rotterdam hinterland route can be shortened by about one day. The barge operator can make approximately 30 extra roundvoyages per year on the route Rotterdam - Emmerich - Duisburg. This means a better utilisation of equipment thereby saving costs.

Occupancy of containers is lowered as well. The system is focused on the standard ISO-containers, but reefers, flats and swapbodies can be handled as well. A rollerbarge could be established in any seaport connected with inland waterways (for instance Rotterdam, Antwerpen and Amsterdam) and in any inlandport.

As Rollerbarge differs from the common vertical handling systems at terminals, it may have an impact on the organisation of terminal-internal transport. As a matter of fact Rollerbarge in itself may have an internal transport function. In order to be able to operate the system, conventional vessels have to be adapted or a new type of vessel must be introduced. Promoted is a catamaran type of vessel with a container capacity of 312 TEU. However using a dedicated handling technique together with dedicated vessels might reduce the operational flexibility. An important condition for the Rollerbarge-concept on the Rotterdam hinterlands is that container transhipment in the Rotterdam harbour will be concentrated. The Maasvlakte-terminal would be an option, because of its large transit volumes.
Network and locations
Rollerbarge is aimed at offering point-to-point services. The market to start operations is focussed on the route Rotterdam - Emmerich/Duisburg. Emmerich and Duisburg are considered to be the Backing-Up-Ports of Rotterdam (BUP). This means that these nodes will function as a distribution center for Rotterdam. Due to the Rollerbarge equipped terminals fast transit times and cost savings can be gained and bundled transport flows to these BUP’s will be attracted. From these BUP’s smooth conventional transhipment for further transport by barge and train will be available. In this strategy Emmerich has to become a BUP for transhipment into middle and upper Rhine barges. Duisburg will operate as a BUP for nighttrains all over Germany and other European countries. The sailing schedule of the vessels must be planned in conformance with this goal (i.e. arriving at Duisburg after the Emmerich operation, not later than at 16.00 hrs, enabling the terminal to place containers destined for farway destinations on the night trains). A suitable location for developing a Rollerbarge terminal in Rotterdam.

Phase of implementation, actors and barriers
Rollerbarge is situated in the conceptual stage. A subsidy of the Dutch Ministry of Transport is granted for a technical and economic feasibility study. The system has been developed and designed by Huijsman Consultancy BV in cooperation with Conprose Engineering.

Promising, missing and probable developments (actors point of view)
As the increase in scale in maritime transport still goes on, it becomes neccesary to make effective use of economies of scale at the landside operations as well. This perspective is beneficial for the introduction of systems like Rollerbarge.

4.3.3 Selfunloading vessels
drs. J.W. Konings

Baseline of the concept
Although barge transport is a cheap transport mode the economic circumstances for choosing barge transport in the transport chain are often not optimal. Because of high transhipment costs and the necessity of pre- and post-road haulage, in many situations barge transport cannot compete with ‘door-to-door’ or ‘terminal-to-door’ road transport. Mostly large transport distances and high volumes are needed to compensate these disadvantages. As a result the market for small-scale distribution of containers, characterized by small flows and relatively short distances, is hardly affected by barge transport. In order to penetrate this potential large market, new transhipment techniques have been conceived based on the common idea of ships able to load and unload themselves. Concepts in which transhipment equipment is part of the transport vehicle have been developed in addition to barge and short sea transport for the overland modalities as well. In road transport they are rather wellknown and common (i.e. side loaders). For rail transport systems like ULS (Umschlagfahrzeug Lässig/Schwanhäuser) have been introduced. Finally in the area of internal

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Figure 4.36 Selfunloading vessel

General features
Within the general concept of selfunloading barge vessels 3 concept variants can be distinguished according to the specific transhipment technique:
- Ro-Ro based (Porthopper and OCC);
  Containers are driven with a vehicle on an elevator on board of a vessel. A crane on board puts the containers to their position.
- bow transhipment;
  A crane on board puts the containers directly at the quay (or at trailers at the quay). Transhipment takes place along the bow.
- sideways transhipment.
  A crane on board puts the containers sideways at the quay (or at trailers at the quay). To receive enough crane stability 'legs' are put at the quay. This concept is represented in Figure 4.36.

Within the Ro-Ro based technique there have been launched two subvariants the Porthopper and the One Container Call Line (OCC-)concept. In Porthopper at the bow of the vessel is a lifting device fitted which can move up and down a ramp which can also be moved horizontally onto the top of the quay so that a truck, straddle carrier or trailer can be driven over it. A shipboard travelling crane can take the load unit over from the vehicle and position it on board. The processes in the OCC-concept are very similar to those of the Porthopper, but the main differences are that the lifting device is on the deck of the vessel resulting in some loss of load capacity and that the vessel need to be moored perpendicular on the quay. In contradiction to the Porthopper it can handle 20 ft as well as 40 ft containers.

Performances and costs
For the OCC-concept the annual throughput is estimated at 200,000 TEU, based on a fleet of 30 vessels. Each vessel would be able to load and unload around 27 TEU/day on the basis of 6-7 calls/day and operational services between 06.00 and 22.00 hours. Loading and unloading takes approximately 6 minutes per unit. The cost per ship is put

transport devices selfloading vehicles have been conceived as well (i.e. the selfloading AGV robot). A brief description of these kind of transfer systems is been reported in SIMET (1994).
at 300 kECU per year. For the concept based on sideways transhipment the total investment costs are estimated at 700 kECU (vessel adaptation: 140 kECU; crane investments: 560 kECU). The traffic targets for these selfunloading concepts are the smaller volumes moved by road to/from ports such as Amsterdam, Vlissingen, Schiedam, Moerdijk, Dordrecht etc. as well as intra-dutch road traffic. The vessel capacity in the different concepts varies between 20 to 70 TEU.

**Networks and locations**
All three of the basic concepts have their advantages and disadvantages. To develop them in a promising concept the following requirements have to be taken into account:
- the intended networks are supposed to be ‘terminal-to-door’ or ‘door-to-door’;
- the networks must be characterized by many destinations, small sailing distances and small transport volumes;
- able to use existing quays, without any or only small adjustments (because of the very many quays to be used);
- the system must be able to handle 20 ft as well as 40 ft containers;
- the system must be able to cope with waterlevel differences;
- the height of the crane may not lead to limitations in passing bridges;
- using small existing types of vessels in order to have large market accessibility (vessel dimensions: containers two wide and two high);
- minimizing the vessel capacity loss due to the transhipment system;
- no need to turn the vessel during loading/unloading process.

**Phase of implementation, actors and barriers**
Based on these general ideas for selfunloading barge vessels described here, further investigations in their feasibility have been taken place by the Dutch Ministry of Transport. The concept based on sideways transhipment is at the moment considered to be the most promising. The concepts based on direct bow transhipment and via a ramp (Ro-Ro based) are considered less attractive for logistic reasons (load units need to be removed immediately). One of the reasons for the sideways transhipment variant to be considered as the most attractive design is its wide application possibilities, however according the specific circumstances other designs might fit as well or might be even better. To check for this, a next stage of development could be a pilot project.

One of the problems for realising these selfunloading barge vessel concepts might be the low throughput in relation to the substantial investment costs, leading to rather expensive services per TEU. However, further investigations into these matters are necessary. Therefore the pilot project would be welcome.

**Promising, missing and probable developments (actors point of view)**
A land use policy aimed at stimulating and facilitating establishments of companies along waterways will have a positive influence on the feasibility of these concepts.
4.4 Ro-Ro Terminal Concepts

4.4.1 FlexiWaggon

Dipl. Ing. J. Gröhn

Baseline of the concept

FlexiWaggon is a special low floor railway wagon, which enables road trains and other road vehicles to enter and exit the train anywhere without the help of lifting equipment or a terminal. The body of the wagon can be turned in such a way, that the road vehicles can be driven in and out. The purpose of this project is to make trains more accessible to road vehicles. It allows ro-ro loading and unloading in the middle of the train. During a stop, which may occur also between terminals, the desired number of wagons can be unloaded and loaded simultaneously within a few minutes. The costs and land demands of terminals will be reduced. The quick and simple entrance to the train makes it possible to create new services, like rapid transfer of trucks through areas with congested roads, or transport of delivery trucks in sparsely populated areas. The system can accommodate all kinds of road vehicles and it can be adjusted to other goods as well, which reduces the risk of a low utilisation rate. There is no need for real terminals. There has to be a stretch of road alongside the track so that the road vehicles can be driven in and out. Suitable bundling concepts for the wagon would be of the line type and the point-to-point type.

General features

In a train each FlexiWaggon can be loaded and unloaded independently regardless of other wagons. During a stop one or more road vehicles can be driven into the train or out of the train without reversing. The loading of one vehicle into a FlexiWaggon takes less than 5 minutes. If there is one driver for each road vehicle to be handled during the stop, the unloading and loading of all vehicles is done within ten minutes, after which the train can leave. If one driver handles more vehicles, the stop needs to be longer. Anyway, the loading and unloading is very simple; it is done by driving the vehicle forward. In case of serious traffic interruptions, the road vehicles can be driven out of the wagons without any major arrangements so that they can continue to their destinations. That, of course, is true only if there are drivers available.

Performance and costs

The design of the wagon allows full height (4.5 metres in Sweden) road trains to enter by having a low-built platform between the bogies. Big standard sized wheels give lower maintenance costs and make it possible to drive at higher speeds than in the existing piggyback wagons with small wheels. The carrying capacity of the wagon may depend on its length. With longer wagons, it could be difficult to reach the useful load of 60 tons which is the maximum total weight allowed for road trains in Sweden. The wagon is supplied with electricity so that thermal loading units and truck engine preheaters can be used. The wagon can be easily adjusted to carry containers, swap

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bodies, semi-trailers, other road vehicles, timber, etc. Thus, it can be adjusted according to the transport needs of different seasons.

**Networks and locations**
The terminal can be any flat area beside the rail track. No external handling equipment is required for the handling of road trains. When trailers are transported, there should be a terminal tractor or a truck available at the time of the loading. The wagon concept can be applied best in links, where there are steady flows. It would be used most frequently, if it is applied in shuttle train services. The wagon could be linked to a passenger train if necessary.

**Phase of implementation, actors and barriers**
The concept is approaching its pilot phase. Next step is the financing and building of a prototype that will be tested and evaluated. FlexiWaggon has been invented by Mr. Jan Eriksson, who is an independent inventor. He has presented the concept to Swedish railway companies. One of these companies, Inlandsbanan AB, has helped him to develop it. The FlexiWaggon suits all lines in Norway and Sweden. It can easily be adapted to the different European conditions. According to Mr. Arne Sjödén of the Swedish Railways (SJ) major problems with the stability of the wagon during loading are yet to be solved. Also, because the wagon needs to be very long to carry Swedish road trains (maximum length now 24 metres, later 25,25 metres), and low to
allow 4.5 metres high vehicles, there may be problems with the road clearance at hills.

**Promising, missing and probable developments**

The possibility to avoid terminals helps to reduce the operating costs. The accessibility to combined transport will improve when the train can stop at many places. The quick loading procedures enable frequent stops and shorten the lead times. The FlexiWagon is a wagon concept, which has effect on the bundling of road and rail networks. The organisation of the transport operations is, however, an issue which is yet to be solved by the transport companies. Road hauliers are not interested in the concept, if the driver has to travel by train. As a consequence, the traffic has to be regular, because it is then possible to arrange a driver to the destination. Regularity sets requirements to the goods flows and to the size of the transport company, unless its business is exceptionally steady. One driver could unload several vehicles. The timetable of the train has to suit the delivery rhythm of goods being transported. If the vehicle is loaded with partial deliveries, the delivery route should match with the rail terminal location. If separate trailers are used, the resources of the road haulier need to be sufficient to arrange pulling units when needed.

According to Mr. Mats Nyblom, development manager of SJ Gods, the wagon would be welcome, because at the moment SJ is not able to provide rolling road service for full size road trains. For the currently operated rolling road service smaller road trains are used for destinations in the north of Sweden, where the goods flows are small. The possibility to unload fast in the middle of a train could be useful in delivering daily consumer goods to sparsely populated areas.

4.4.2 G 2000 Ro-Ro

*Dipl. Ing. J. Gröhn*

**Baseline of the concept**

The general idea of the project is to develop a wagon for a fast combined transport train. The wagon can be turned and opened in a special way so that road vehicles can enter and exit without external installations. The need for this type of wagon results from the present trend that is to reduce the number of terminals for combined transport because of high terminal costs. When there are only few terminals the cost efficiency of combined transport is improved but also large areas are left without combined transport service. With this concept it would be possible to increase the number of terminals and at the same time reduce the costs of the terminals. Thus, the break even distance for combined transport would become shorter than with the present concept.

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Purpose and objectives of developing G 2000 RO-RO:
- to raise the capacity of existing tracks with a lower number of wagons by fast terminal operations;
- to make possible the high-speed train transportation of intermodal transport units;
- to increase the number of terminals with capacity to handle intermodal transport units;
- to eliminate the need of cranes in facilitating loading and unloading;
- to make shunting of the wagons unnecessary (shuttle service).

The capacity of railroads depends on the speed of the trains. Freight trains are not able to go as fast as passenger trains because they weight more and they are not aerodynamic. The tracks and the axles or bogies may be broken if there is a heavy load at a high speed. Also, it requires a lot of power to overcome the air resistance, which occurs if a train with open container wagons tried to go over 120 kilometres per hour. If a fast freight train with open container wagons would meet another high speed train, the air resistance could break the loading units.

A shuttle train with this kind of wagons would enable a new fast service in combinetransport. Thus, it would improve the competitiveness of railroad at certain market. A shuttle service with frequent departures could be an attractive alternative to the road transport in congested areas.

In a railway terminal the only requirement for the wagon to turn is a concrete platform in level with the top of the rail. Beside the loading track there needs to be 7 metres wide area to manoeuvre articulated vehicles. The fast shuttle trains would form a corridor. The distance between the terminals would be around 150 kilometres. Due to the frequent stops of the train, the goods would not have to be transported long distances backwards along the line.

**General features**
The wagon itself would be a new-generation equipment, but the handling of the intermodal transport units would be manual. The construction of the wagon body in plastics and/or composites allows better utilisation of railway axle-pressure potential. Adjacent wagons share a bogie. The characteristics of the bogies set limits to the speed of the train. It is possible to build a wagon, which can be opened to the left and to the right, but the basic version is designed to turn only to the left. The ability to turn to both sides might be useful in international traffic. The turning of the body of the wagon is done by hydraulic motors, which get electricity from the train. One end of each wagon in a G 2000 RO-RO train can be turned, so also the wagons in the middle of the train can be loaded and unloaded at all terminals. At the same time when the end of the wagon is turned the sides of the wagon are opened and the roof is raised. A truck with or without a trailer reverses to the wagon. The sides of the floor are formed to guide the wheels of the vehicle. If a rubber wheeled unit is going to be transported, it is secured to the floor in the same way as it is secured in ro-ro ferries. If only a loading unit is going to be transported, it is raised from the vehicle by lifting devices, which are installed in the sides of the wagon body. When the
loading unit is lifted from the vehicle, the vehicle leaves. After the vehicle has left the loading unit is lowered to the floor and it is secured to the wagon with special holders. The lifting devices are operated by men, who place the hooks to the corner fittings of the loading unit. Also the securing of the wheeled transport units is done manually. Each wagon can be loaded and unloaded independently at any terminal, but only the unit that has been loaded last can be unloaded immediately. If another unit needs to be unloaded, the units in front of it have to be unloaded first. This problem sets requirements for the controlling of the transport. The efficiency of the train could be improved by developing a new simple and less expensive loading unit. In the train could be a terminal tractor, which would be operated by the engine driver and his assistant.

**Performance and costs**

There has been studied two possible lengths of the G 2000 RO-RO wagon. The shorter wagon has the loading space of 15 metres and the longer wagon has 19 metres loading space. The corresponding loading capacities are 26.1 and 41.3 tons and the total weights are 45 and 67.5 tons. Because of breaking requirements the maximum speed has been planned to be 100 km/h. The G 2000 RO-RO concept has been compared with direct road transport by MariTerm AB. Because of lack of resources the only compared alternative was the transport of 13.6 metres semi-trailers between two customers. The most important conditions used by the evaluation are described below:
- **Direct road transport;**
  All calculations for the road transport are based on 13.6 metres semi-trailers. The average speed of the transport is set to 70 km/h. The fixed cost by hour is calculated at SEK 291.30 including the driver, SEK 180. The costs by kilometre are calculated at SEK 3.21.

- **G 2000 RO-RO;**
  The piggy-back trains include electric locomotives and 20 wagons of type G 2000 RO-RO. Each wagon carries one semi-trailer. The average speed for the rail transport is set to 90 km/h between the terminals. The transport between terminals and the industry is made by road as per above. The mean speed for the road transport in this case is set to 65 km/h.
  The number of running hours for the trains are 6,000 per year (24 hours per day, 5 days per week). The transport system is based on a shuttle train between two terminals with a 60 minute stop at each terminal. In the terminals a full change of cargo will be made in within 60 minutes. The personnel involved are the train driver and the truck drivers only.
  The capital costs in the study are calculated at 9 per cent annual interest rate. The depreciation time is set to 10 years for the G 2000 wagons and 30 years for the electric locomotives. The price of a G 2000 wagon is SEK 2.15 million and SEK 33 million for an electric locomotive. The administration and overhead costs for each train are set to SEK 350,000. This cost level for administration is set up to handle at least 6-8 trains. A rate on sales (ROS) of 8 per cent is included in the turnover for the rail transport.

A level of used capacity more than 65 per cent on 6,000 running hours for the train is needed to make G 2000 RO-RO competitive on 300 km. This means that a G 2000 system with 13 loaded of the total 20 wagons in a train has the same costs as 13 trucks in a direct road transport. With a trucking service within a radius of 20 km of each terminal, the “longest” rail transport would be 340 km for a distance of 300 km between the shipper and the consignee. In this “longest” train alternative the train would be 60 minutes at the terminal and thereafter 3 hour 48 minutes on the track in 90 km/h and then 60 minutes in the terminal again, and so on. Thus the train uses 79 per cent of its running time for the transport and 21 per cent cargo handling in terminals. Each train would make 5 single trips of 340 km every 24 hours when the maximum annual capacity would be 25,000 trailers.

The financial costs of a rail system are 48 per cent of its total turnover in the break even calculation for 300 km. The consequences of this high share make the total costs for train traffic highly dependant on the price of equipment and financial arrangements. A sensitivity analysis gives attention to the importance of handling time in the terminals. For example if the trucks stayed in the terminal 36 minutes instead of the assumed 18 minutes, the capacity utilisation rate of the train should be 10 per cent higher to even the competition with direct road transport in case where the transport distance is 300 km. Correspondingly an increased price of 20 per cent for the G 2000 wagons demands 5 per cent higher utilisation rate. The capacity utilisation rate of a G
2000 RO-RO service with high annual fixed costs is critical to make the system competitive. A G 2000 system needs to work 24 hours per day so that it can pay the fixed costs.

**Networks and locations**
The wagon concept is suitable for point-to-point or line network. The terminals should be easily entered with road vehicles.

**Phase of implementation, actors and barriers**
The project is in an idea phase. An economic evaluation of the G 2000 RO-RO concept compared to direct road transport of semi-trailers has been carried out by Maritern AB in Gothenburg. The concept has been presented to SJ, the Swedish Railways, and to one potential customer ICA, which is a big wholesale company of daily consumer goods in Sweden. So far an innovation foundation has supported the project financially, but because of its rules it cannot grant more funds to this project. The inventor, Mr. Lars Berglund is looking for partners for collaboration, e.g., a consortium, in order to further advance the project. There are not any known technical problems to realise the wagon, but the final design needs to be decided. One barrier is the price of the equipment. The railway companies are known to be conservative and they may be reluctant to realise the concept. On the other hand, the railroads are being liberated for competition, which opens room for private enterprises.

**Promising, missing and probable developments**
In a letter to the inventor, the SJ has stated that the concept has two benefits compared to the existing concept of combined transport:
- Simple terminals without special need for handling equipment.
- Possibility to use all types of ITUs and also road vehicles that are not especially equipped for combined transport.
In order to be interesting in the Swedish domestic transport it is required that the wagon would be able to carry the maximum size trucks with trailers (4.5 metres high, 2.6 metres wide, 25.25 metres long, and total weight 60 tons). The wagon should be able to go at least 100 km/h, preferably 120 km/h, without any restrictions to the Swedish rail network. If a functioning prototype wagon was built, the SJ is ready to lease it for a year as any normal wagon from the market. The system has not been finally designed in all aspects. The requirement for manual work is a factor, which leads to high operating costs. In case of accompanied transport, the driver is paid for travelling in a train (waiting). If he does not go with the train, another driver has to be ready when the train arrives. That can be avoided by having a terminal tractor in the train, when the train staff could do the unloading and loading.

4.4.3 Shwople Train
I.W. Gordon

Baseline of the concept
The “Shwople” concept, of loading and unloading trains, was designed to address the rapid turnaround of large trainferries that is required within ports operating Ro-Ro ferries. When examining the loading and unloading productivities associated with Ro-Ro and Lo-Lo ferry operations Cholerton Ltd. felt similar benefits could be gained if a Ro-Ro train service could be designed.

General features
The Shwople ‘Monowell’ Ro-Ro wagon is a bogie wagon similar in design to the Lo-Lo pocket wagon. It is slightly longer than the Lo-Lo pocket wagon and in the place of the road wheel recesses is a Wellfloor on which the road semitrailer resides. The Wellfloor is supported within the pocket wagon close to rail level. A Shwople terminal is characterised by a single track with a platform on either side. Between the track are strategically positioned a series of pop-up mechanisms. On arriving at the station the train locates the Monowell wagons over the pop up mechanisms. The individual pop-up devises are then elevated from below the rail level to engage the underside of the Monowell wagon’s Wellfloor. A locking devise is initiated followed by the elevation of the Wellfloor with the semitrailer on top to above the level of the wagon side frames. Rotation of the Wellfloor and semitrailer then takes place through an angle of 35 degrees. The Wellfloor is then lowered to rest diagonally on the platforms on either side of the track. The tractor unit can then remove the semitrailer from one platform and a trailer to be loaded can enter from the other platform.

Figure 4.40b demonstrates the pop-up, elevate and rotate mechanism that is required at the terminals.

a) Mechanism retracted below rail. (The Wellfloors are not shown for clarity).
b) An empty train with its Wellfloors located over the pop-up mechanisms.

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c) The Wellfloors are elevated, rotated and then lowered onto the platforms on either side of the track.

**Performance and costs**

The main benefits that are highlighted are:

- Exceptionally fast train turn rounds. E.g. 30 or more semitrailers can be exchanged in a matter of minutes. It is anticipated that a train can be loaded or unloaded in 15 to 20 minutes.
- Rail transit heights are the same as the existing pocket wagons.
- Non liftable standard semitrailers can use the rail network.
- Random access to any semitrailer(s) in a 30 or more wagon train.
- Consignor's and consignee's truck driver achieve the exchange of arriving and departing semitrailers without terminal labour involvement.
- The Shwople 'Monowell' Ro-Ro wagons will have a similar cost as current pocket wagons.
- Cost benefits from replacing a travelling crane with a series of “pop up” mechanisms can be envisaged.
- A smaller area for loading and unloading trains will be required at the terminal.

**Figure 4.40a and 4.40b   Loading and unloading processes at a “Shwople” Terminal; Pop-up mechanism**

Initial cost comparison of the current Lo-Lo practices versus the proposed Ro-Ro system are listed below.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grapple equipped lift truck *</td>
<td>ECU 350,000+</td>
</tr>
<tr>
<td>Grapple equipped travelling crane *</td>
<td>ECU 650,000+</td>
</tr>
<tr>
<td>Shwople “pop up” mechanism **</td>
<td>ECU 720,000</td>
</tr>
</tbody>
</table>

* Driver required to lift one trailer at a time.
** One Terminal requirement equals 30 units at ECU 24,000 of each.

Terminal and/or network criteria
As previously mentioned significant investment in the ports terminal and all destination terminals would be required. However as previously mentioned there would be a significant improvement in the accessibility of the road vehicles to the road network. There will be a significant reduction in the loading and unloading processes at the terminals compared to the existing Lo-lo practices that are currently employed.

Phases of implementation, actors and barriers
The next phase of this project is the building of a prototype “Monowell” wagon and a prototype “pop up” mechanism followed by testing and evaluation of the results. There may be a way of modifying a second-hand pocket wagon for demonstration purposes. The European Commission’s DG VII-E has shown some interest in the concept in the past.

Promising, missing and probable developments.
The Shwople Train Concept would have a significant effect on the bundling policies within road and rail networks. If the concept was employed one could envisage a significant increase in the volumes of combined transport. However, the requirement of “Shwople Terminals” to load and unload the train is thought to restrict the concept to long haul rail journeys.

4.4.4 Shwople Barge

I.W. Gordon

Baseline of the concept
The “Shwople” concept, for loading and unloading trains, has been developed to address the road to inland waterways loading and unloading process. Using the Roll On - Roll Off techniques Seaform Design, a division of Cholerton Ltd. from the Isle of Man, have developed a concept for both river / short sea services (the “Shwopleship”) and a RO-RO catamaran vessel for the Rhine (the “Swoplecat BA”). The concept presumes that all the terminals will be equipped with the RO - RO adjustable Linkspan Berth Type “SV”. The automation that will result from the introduction of the “Shwople” waterways concept should allow for increased transport flow

through the terminals at a reduced handling cost.

**General features**
The Shwoplecat BA is a vessel designed for transportation along the Rhine. The wide catamaran construction allows the transportation of accompanied semi-trailers and/or road trains each up to 18.0 metres in length and up to 44 tonnes. For off Rhine traffic the “Shwopleship”, a monohull constructed barge, has been designed. This design allows for the stowing of road trailers in a diagonal fashion.

Figure 4.42 demonstrates the operation of a “Swopleship” terminal which comprises of a RO - RO linkspan and a series of berthing “dolphins”, along which the vessel can range fore and aft to align with the side ramp and linkspan. This allows the vehicles to be accessed in any order and opens up opportunities to run a “bus stop” operation if there was a market for this service.

**Performance and costs**
The main benefits are:
- Non liftable standard semitrailers can use the waterways where no RO-RO network is present.
- Random access to any semitrailer(s) within the “Shwople” vessel.
- Consignor’s and consignee’s truck driver achieve the exchange of arriving and departing semitrailers with limited terminal labour involvement.
- The “Shwople” RO-RO vessels will have an effect in reducing the economic break even distance vis-à-vis LO-LO operations.
- Environmentally friendly mode of transportation.
- High throughput, low cost terminals.
Terminal and/or network criteria
As previously mentioned investment in the terminals would be required. However as previously mentioned there would be a significant improvement in the accessibility of road vehicles to the waterways networks. There will also be a significant reduction in the loading and unloading operations at the terminals compared to the existing LO-LO practices.

4.5 Sea Terminal Concepts

4.5.1 Container Pallet Transfer System

*Dipl. Ing. J. Gröhn*

Baseline of the concept
Each operator in line traffic is interested in shortening port time of his fleet as much as possible in order to get increased cargo carrying ability, shortened transit time, higher voyage frequency and increased competitiveness in relation to other operators. This applies especially to fast vessels, whose time savings at sea are easily lost in the ports. The need for fast vessels comes from the interest expenses of valuable goods. The CPT system is developed to load and discharge fast going container cargo vessels. It is built up around the idea where a certain number of containers are positioned upon a mega-pallet, and locked to each other and to the mega-pallet. The mega-pallet may contain up to 20 containers with a total weight of up to 400 tons. By using this concept the handling capacity of loading units can be up to 900 TEU per hour. The Container Pallet Transfer system is shore based and separated from the vessel, to allow for preventive maintenance. That ensures that the system is operating when the vessel arrives. Onboard the vessel the deck has only little obstacles that allows also conventional Ro-Ro handling. The system is automated.
**General features**

The mega-pallets are transferred from the quay side to the vessels hull by transfer trolleys. The transfer trolleys are diesel-electrical driven and require rails on the quay and onboard. The transfer trolleys are equipped with their own hydraulic power pack, hydraulic motor and lifting cylinders. To obtain the described loading capacities, the mega-pallet is designed in a way that allows the transfer trolleys to be driven under the mega-pallet from all sides. In this way it is possible for the total cycle to be broken down into a number of smaller cycles, which operate simultaneously.

Vessel arrives dockside and mores at its destination. The stern door on the vessel opens and the land ramp position itself to the deck that shall be discharged. The ramp has an automated levelling device that keeps the ramp horizontal and in correct height with the deck. To compensate for the tide and the draft of the vessel, a hoist is in position between the ramp and the quay. For the bigger ships the cargo hull will contain two rows of mega-pallets and these are handled in parallel to avoid any listing of the ship.

From the land side the transfer trolleys run into the vessel hull on rails corresponding both on land and onboard. The transfer trolley will position itself under the first mega-pallet onboard, lift the pallet out of its locks and transfer the pallet out of the vessel to a crossing point, where the pallet is lowered to the ground. The trolley returns to the vessel to pick up the next pallet. From the crossing point the mega-pallet will be picked up by a crossing transfer trolley, which takes the pallet to the storage, and returns for the next pallet. The loading of a vessel proceeds in the same way but in reverse. On the quay, the container cranes will proceed to waiting trains or trucks with containers and refill the mega-pallets with new containers before the vessel returns. The transport system between two ports requires three sets of mega-pallets, which are restricted to the quays and onboard the vessel. While the vessel is at sea with one loaded set, the other sets are at ports unloaded and loaded. If there are more than one ship operating with the same concept, the number of mega-pallet sets per vessel may be reduced.

The CPT system can be tailor made to any ship and the mega-pallets can be designed to meet different cargo specifications, as carrying trailers, cars and general cargo in addition to containers.

**Performance and costs**

The system can handle up to 900 TEU per hour. The unloading and reloading of the mega-pallets are done while the vessel is at sea. The capacity that is required for the land side operations depends on how much time there is before the next vessel arrives. Depending on the capacity of the ship, the containers should be at the port 4 - 5 hours before the scheduled departure of the ship. The concept requires a lot of investments; an expensive fast cargo vessel is the starting point, which have not yet been passed.
Networks and locations
The concept is designed for fast cargo vessels so there should be a fast ship service. That requires sufficient volumes of expensive goods to be transported.

Phase of implementation, actors and barriers
The system has not been implemented, despite it is a purchasable product. According to Mr. Keim, the system is under constant development by TTS Drøbak AS. The Volvo Transport Corporation has studied the possibilities to implement this system together with a fast container vessel, which would transport cars from Europe to Halifax, Canada, in three and a half days. If the containers would continue to California with double decker container trains, the total transport time would be 20 days shorter than the present car ship through the Panama Canal. They have calculated that the interest expense of a car is 20 USD per day that means potential savings 400 USD in interest expenses per car. That is more than the present transport cost. However, the system requires large investments in vessel, equipment, and quays, that has so far been the decisive factor to prevent its realisation. Especially the ship owners have been reluctant to go along with progressive technology.

Promising, missing and probable developments
Many companies operate nowadays at global market. The production philosophy is usually Just In Time. The need of transport is expected to increase. However, the shipping companies are doubtful towards fast ships, because they would be too expensive, too uncertain, and there would be too few customers. According to ACL vice president Abbot, there could be a market for fast ships in the North Sea, but not in the Atlantic.

Figure 4.43 CPT Terminal

Source: TTS Drøbak AS.
4.5.2 Thamesport

I.W. Gordor

Baseline of the concept

Thamesport is located on the Isle of Grain in Kent and covers 40 hectares. It is next to the Thames Estuary and about 56 km away from London. The port is located 12 miles from the M2 motorway which gives direct access to the M25 London Orbital and the rest of the UK motorway network. The rail service to and from the port is operated by Freightliner. This guarantees next-day delivery. Scheduled intermodal services are operated to and from key industrial and manufacturing areas within the UK. Daily container trains currently link Thamesport with direct services to: Coatbridge; Cleveland; Leeds; Manchester; Liverpool; and Cardiff. Currently 2 trains are operated per day in each direction but there is the capacity to operate up to 8 trains per day in each direction.

The layout of the port and its equipment is shown in Figure 4.44.

General features

Operation of the Port commenced in 1990 and the port is now thought to be the fastest growing container port in Europe. The port operation is technologically advanced and employs extensive automation. The quay is equipped with 5, high-speed, manually operated, post-panamax ship-to-shore gantry cranes, each with a capacity under the spreader of 40 tonnes. The cranes have an air draft of 30 metres and an outreach of 16 containers across. Larger cranes are on order with an outreach of 17 containers across. Manual vehicles are currently used to transfer containers between the quayside cranes and the container park. Thamesport has been involved in the development of a prototype AGV and trials with this have taken place but these are not yet used in the main operation. The long term goal, however, is to automate this process and produce a fully automated, unmanned, system for loading and unloading cargo. The container park consists of a fully automated crane operation. Within this there are 14 automated, rail mounted, stacking cranes which handle containers in 7 stacks, each 650 metres long, with containers arranged up to 9 wide and up to 4 high. The cranes are produced by Morris (UK) and are capable of tracking their own position to within 25 mm. There is separation of the landside and quayside operations to ensure that each can achieve simultaneous peak performance rather than being in competition with one other. The park has a overall capacity of 25,000 TEUs and is currently being expanded from 7 to 9 stacks with a corresponding increase in capacity. Reception and delivery of containers is also driverless. Final positioning of containers over the road vehicles is remotely operated by the vehicle drivers at the haulage exchange bays. The transfer of containers between crane stacks is carried out by conventional, manned, internal movement vehicles.

Performance and costs
Traffic through Thamesport has seen an increase every year since the Port started from 9,600 TEU in 1990, to 139,500 TEU in 1991, rising to 350,000 TEU in 1996. The current capacity of the port is 450,000 TEUs and this is being expanded to 600,000 TEUs.

The port has direct access to deep-sea shipping routes and a 550 metres long quay that is able to accommodate up to 2 post panamax ships at any point in time. The quay is currently being expanded to a length of 650 metres. It is dredged to a depth of 13.5 metres with a potential to increase this to 15.0 metres. Each of the 14 automated cranes is capable of handling 25 containers per hour. The average throughput of containers on and off large vessels is 70 per hour. Turnaround times for feeder vessels are typically between 2 hours and 4 hours, while the largest vessels (exchanging over 1,000 containers) can take a little over 12 hours. Gross vessel performance of over 100 containers per hour have been achieved. Vehicle turnaround time between receipt
of documents and departure from gate varies between 40 and 45 minutes. The average is 43 minutes. The port operates 24 hours per day 364 days a year.

**Phases of implementation, actors and barriers**
Thamesport has a large number of feeder services linking the UK with other UK ports and European operations. It is an important hub for Irish feeder traffic and acts as an alternative to Rotterdam as a European transhipment port.

The principle activity of Thamesport is container handling but the port has facilities for other cargoes including coal, timber, and other break-bulk or non-containerized cargo.

**Promising, missing and probable developments**
Thamesport's objective is to become one of the largest European container terminals; and to offer its customers a unique port service - seamless and fully integrated - which will combine flexibly and efficiently with competitive handling charges. Having the advantage of being built on a green field site, Thamesport has few physical restrictions on its future growth. Expansion programs are already well advanced with a new 100 metres quay under construction and two additional lanes being added to the container stacks. The latter is anticipated to increase the storage capacity to well over 26,000 TEU.

Future developments that are currently being considered is the extension to the frontage with another 10 acres available for storage. There is also a further 50 acres site that has been set aside for future port related businesses such as haulage, specialist repairs and agencies. The UK’s first container carrying Automatic Guided Vehicle can be seen in prototype undergoing trials at Thamesport. Subject to final evaluation of performance and economics, these vehicles could soon replace the majority of the manned vehicles on the terminal in the near future.

**4.5.3 Coaster Express**

*drs. J.W. Konings*

**Baseline of the concept**
Coaster Express (CoEx) is a shortsea transport concept directed to bundling the transport flows, scaling-up the short sea facilities and standardization and automation of the transition processes. Its background is strongly related to the expected future volumes on the Rotterdam Maasvlakte terminal in relation to the ambition to develop this terminal into a well-functioning megahub. The quality of the short sea feederings will play an essential role in developments in this direction. Therefore CoEx is intended to accommodate large scale feederings. In addition, it may serve continental short sea shipping (coastal interlining). The technological and logistical design of CoEx are a prolongation of the Barge Express-concept (also described in this publication): coastal terminals supported by robotization and automation and special designed container coasters integrated in a new logistic concept.
General features
In a similar way as for Barge Express there are two types of CoEx terminals; the active and the passive. An active CoEx terminal uses the surrounding marine stacks in such a way that the terminal operator activates the external transport in the form of automated 'inter-terminal transport'. A basic transition unit of the proposed active CoEx-terminal consists of two berths, each being equipped with two automated quay cranes. An active CoEx terminal may consist of several transition units. The proposed layout at the Maasvlakte consists of two transition units. Each transition unit operates simultaneously on two coasters; one being loaded and one being unloaded. With this the inter-terminal transport may operate with combi-trips. The active CoEx-terminal on the Maasvlakte is equipped with a small automatic stack for the intermediate stacking for interlining transport.

The rationale for the passive CoEx terminal is that the terminal operator has no control over the external transport and therefore the terminal must be equipped with its own stacking facility. The transition protocol is the same as the protocol for the passive Barge Express terminal. In order to have maximum opportunities for external (road) transport to operate in combi-trips, broad time windows are desirable. Assumed is that the CoEx terminal at the Maasvlakte will be an active one having a high degree of automation; in the peripheral ports passive terminals are assumed. This last assumption is not a must; they may be active as well or eventually they could have manual instead of automated transhipment operations. The possibility of manual transhipment gives the concept much flexibility.

Suggested is a standard type of coaster without hatch covers, but with cell guides for standard containers, having a capacity of 480 TEU. Using standardized coasters enables to use them in circulation, which may reduce the total number of ships needed to maintain the sailing schedule. For economic reasons this coaster is preferable a conventional ship instead of a push/barge combination. The quay cranes are automated and comparable with the ones to be used in Barge Express. This type of transhipment technology has to be developed. The stacking cranes will be automated too. The transport between the stacks and the quay cranes can be executed by AGV's. This basic technology can be borrowed from the full automated Delta Sealand terminal. The automated transition for coasters has to be developed.
Performances and costs
A complete loading and unloading cycle (i.e. simultaneously loading one vessel and discharging another vessel) will take 6 hours and 24 minutes. This transition time is based on the following assumptions:
- 480 TEU capacity vessels;
- average TEU factor of 1.5;
- average loading rate of 80%;
- crane capacity of 40 moves/hour;
- employment of two cranes.
With some time for docking, undocking and delays such a CoEx transition unit can handle 6 vessels in a 24-hours cycle. The total annual capacity of 6 shipping lines in both directions operating on an average loading rate of 80% is about 1.7 million TEU.
Cost analysis for the CoEx terminal operations have been made for respectively intermodal and interline transitions on the Maasvlakte. Based on an average load rate of 80% CoEx was found to be respectively 2 and 3.5 ECU per TEU. The calculated shipping cost savings with CoEx range from 5 to 12 ECU per TEU.

Networks and locations
CoEx can be set up for point-to-point (shuttle) services between the Maasvlakte and other main seaports. Given the expected feeder flows at the Maasvlakte anno 2010 (3.6 million TEU) and the logistic concept of CoEx (daily shuttles, 480 TEU ships) this would result in a market for six shuttle lines. One may think of Le Havre, Hamburg, Hull, Felixstowe, Southampton and Dublin. In addition, the favourable geographical position of the Maasvlakte between Northern and Southern European ports offers opportunities for coastal interlining with CoEx via the Maasvlakte, leading to additional lines (for instance on Riga, Helsinki, Goteborg, Grangemouth, Bilbao and Lisboa). In this way the CoEx terminal on the Maasvlakte would become the hub for the transition of coastal continental containers between the various shuttle lines. This is however commercially feasible only if the transition costs of CoEx on the Maasvlakte are sufficiently low.

Phase of implementation, actors and barriers
The concept has been proposed as a scientific hypothesis in the form of the logistic concept and the basic design. Critical feasibility concerns the market, the technology, the business economy and the organisation. These elements need to be adopted and refined in a R&D-programme.

Promising, missing and probable developments (actors point of view)
CoEx conforms very much the objectives of the European governments in creating alternatives for the road and rail transport over long distances. This might be a reason to stimulate the development and introduction of Coaster Express.
4.5.4 Train Loader
drs. J.W. Konings

Baseline of the concept
The train loader is a shortsea concept aimed at reducing the turnaround time in ports. The concept is based on self (un)loading of units using a roll-on/roll-off system with a special train of platform cars, called a train loader. The train loader is adapted to the special requirements of the ship. By using the train loader, which is triple stacked, so to speak, a Multi Box Unit is created making it possible to (un)load many containers simultaneously in a short period of time. The handling of the containers is carried out, while sailing, by an internal unmanned crane. Transhipment by using a Multi Box Unit (MBU) is considered to be a key for improving the cost/quality ratio of waterborn transport in general and shortsea transport in particular. This MBU philosophy is built upon the following key elements:

- reduction of ship-shore moves, economies of scale;
  Loading or discharging several box units in one single operation cycle offers potential handling cost and time savings. In addition, a reduction in the average labour cost per box can be achieved if the scaled up operations don't require additional labour.

- time independence of loading operation with vessel presence, pre-stacking;
  The time dependence of ship and shore in present container handling requires a high input of labour and fast equipment during a short period of time. If a MBU is used the time window for loading and discharging, originally as wide or as narrow as the ships turnaround time, is enlarged. The terminal handling methods and equipment do not longer need to focus on the shortest possible turnaround time of the ship but can be optimized for low labour input and slower speed processes for loading or discharging the MBU. These terminal process advantages can be optimized if the ship can perform the loading and discharging of a MBU without assistance from shore.

Next to the Train Loader several other concepts based on this MBU philosophy have been presented and evaluated by Wijnolst e.a. (1993). The Train Loader and the Conveyor/Elevator Loader were found to be the most promising concepts. For an outline of the Conveyor/ Elevator Loader and the less perspective concepts is referred to Wijnolst e.a. (1993). Other more recently presented MBU-concepts, Rollerbarge and Container Pallet Transfer System, are described separately in section 4.3.2 and 4.5.1.

General features
The Train Loader features internal overhead cranes on board of the ship and a vertical cellular stowage area. The train is able to carry boxes which can be loaded onto the ships internal cell-guides via the loading bridge. As soon as a train of triple stacked

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23 The upper Pallet Carrier, the Super Pallet Loader, the Six Pack Cradle Carrier, the Conveyor/Elevator Loader, the Unit Loader and the Train Carrier.
platforms is brought aboard the onboard distribution system can start unpacking the train and distributing the individual boxes over the stowage area. This can be done at any convenient moment; at the berthing place, during slow sailing while leaving or entering a port or perhaps while sailing on open sea. Especially the latter as well as the slow sailing option would allow a remarkable reduction in turnaround time. Next, the units which must be discharged in the next port of call are placed on this train loader by the onboard crane. Meanwhile at the terminal in this next port, a train loader is being prepared by taking on units to be loaded onto the ship. When the ship arrives at the port, the train loaders are exchanged, after which the ship leaves. No quay activities are required.

The ship can be typified as an advanced vessel in which mainly existing technology is used in a new application. This technology comprises loading bridges, triple stack trains and an underdeck gantry. The propulsion system of this gantry and trolley must be designed in such a way that the automation of the crane moves is possible. The ship could be equipped with one or two trains via the stern, dependent on the required capacity. The terminal consists of four rail lanes with a gantry crane that is capable of loading and unloading the units from the platform cars of the train loader onto for instance a truck. This is a manual process, although automated handled are conceivable. Each rail lane is equipped with a propulsion system to move the platform
train on the terminal. The propulsion system consists of a small buffer truck, which is fixed to an endless steel rope.

**Performances and costs**
The train loader has a capacity of about 380 TEU of which 90 TEU on the two triple-stack trains (2x3x15). The operational time for moving one Train Loader in or out of the ship is calculated at 11 minutes. As a result, if two train loaders are moved out of the ship and two train loaders are moved in at one port call, the total cycle time for transhipping maximum 180 TEU is 44 minutes. If two trains are moved simultaneously, this time can be halved. The transhipment operation requires 4 crew members. Assuming the system is set up for daily calling nine ports with an interport distance of 100 miles and a roundtrip sailing time of six days, six ships in the system are needed. In addition assuming the average utilization rate of the train loader is 50% the annual throughput records 250,000 TEU.
The required investments in ship and terminal are higher than for conventional feeder vessel services. The extra capital costs generated by a high-tech ship and a dedicated terminal have to be compensated by the high performance of the system and the low handling costs on the terminal. The capital costs of six train unit loaders plus nine terminals were found to be approximately equal to the capital costs of nine 500 TEU open container feeders plus nine terminals. However, the operating costs of the feeder service are higher than the train loader concept due to the larger amounts of ships in the system and the required higher service speed.

Networks and locations
As the trains onboard can be unpacked and re-loaded for discharging any package of containers in the next port of call, the train loader is especially appropriate for a line network. For point-to-point services the re-loading facility is apparently irrelevant.

An interesting service area could be the Swedish coast, characterized by many (small) ports with limited interport distances.

Phase of implementation, actors and barriers
The concept has been presented and subject of study by the Faculty of Mechanical Engineering and Marine technology of the Delft University. Despite positive indications a follow up has not been recorded until now. The present concept is still generic. A detailed design process could only start if all the criteria of the involved parties (such as shippers and receivers, shipowners/operators, port/terminal operators, shipdesigners and shipyards, equipment manufacturers, port authorities and governments) were find out and put together.

The train loader is designed for a dedicated terminal. This means inflexibility in serving other routes. Because of the investment costs, it is risky, especially in the implementation phase of the project, to invest simultaneously in terminals and in ships. In the first phase, the visited ports with a reduced cargo throughput could be equipped with a conventional ro-ro ramp. In stead of a train loader a mafi train on rubber wheels could be loaded on board of the ship. The technology is considered to be of great importance, but not a critical factor for the concept. The cargo-base will be the most decisive factor, because a new concept must be implemented at full scale, to offer the sailing frequency, which is required to compete with existing modes.

Promising, missing and probable developments (actors point of view)
Road transport becomes more and more expensive and congested. This development will open possibilities for short sea concepts, like the Train Loader, aimed at multi-porting, to become competitive shortsea transport systems.

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24 It might have relevance to re-load the package according to the next mode of transport (i.e. rail or truck) to gain benefits in the transshipment to these modalities. However, this presumes reliable pre-information about the ensuing modality of every box.
4.5.5 River Sea Push Barge System
drs. J.W. Konings

Baseline of the concept
The river-sea pushbarge is a transport system in which one and the same push barge is used for the sea- and the river leg in a transport chain. On the river the barge is pushed by a conventional inland push boat. At sea the barge is pushed by a seagoing push boat equipped with a seaworthy coupling system. The system intends to offer an alternative for the shortcomings of the present transport with river seagoing vessels: water fluctuations/limitations on the Rhine, limited vessel capacity, high operating costs and low transit times of the rather expensive vessel. Furthermore it aims to become an alternative for shortsea transports with a conventional barge transport leg. As in the river-sea push barge system a transhipment from barge to shortsea vessel is avoided, this results to cost savings in the total intermodal transport chain. The major technological challenge of the concept is the development of a push barge being seaworthy on the one hand and having a limited draught for accessibility on inland waterways on the other hand.

General features
The inland push boat sails the barge from the hinterland into the seaport, there change of push boat takes place. Next the seagoing push boat sails the push barge to the seaport of destination, where the pushbarge will be discharged or eventually again been taken over by an inland push boat to be sailed to its final inland (port of) destination. For enabling the coupling between the seagoing push boat and the push barge slight modifications of the boat are necessary. For the inland push boat only minor conversions are required. The draught and the height of the barge must allow the barge to pass all bridges and sail during low water periods. Legal restrictions concerning dimensions and classification rules have to be taken into account as well as criteria imposed by the nature of the cargo/load units. The barges can be dedicated designed for different types of load units (for instance containers, trailers, passenger cars or semi-bulk cargo) or eventually be developed for multi-purposes. An important requirement is the ability of easy loading and discharging the barge, in order to preserve the time and cost savings achieved by the unbroken transport chain. In this context the duration time for changing the push boats in the seaport must be kept as low as possible as well.

Performances and costs
The performances and competitiveness of the concept will to a large extent be determined by the vessel size. The dimensions will be determined by both legally allowed dimensions at rivers (i.e the Rhine) and stability conditions at sea. This would result in a barge size of about 110 m (L) x 18 m (W). At 4-high stacking this provides a capacity of 275 TEU and 385 TEU with 5-high (World Cargo News, 1997). The production costs of a 220 TEU capacity barge are calculated between 3.5 and 5 million ECU.
Wijnolst (1995) made an economic evaluation of the concept for car transports between Cologne and Harwich, however based on length dimensions above the present legislation (145 metres). The concept was estimated to be very profitable; the pay back period was only 5 years. The costs for conversions of the seagoing and inland push boats were calculated at 700 kECU and 80 kECU respectively. The costs for the dedicated car transporter barge were found to be 14 million ECU (plus 350 kECU for the ramps).

Networks and locations
The system is primary intended to be operated in point-to-point transports. The routes will be restricted to the main inland waterways, which are able to accommodate the push barge. The main corridor considered to be promising is the route between the United Kingdom and Germany. In Germany terminals along the Rhine river in the Lower and Middle Rhine region are regarded as the main potential destinations. These regions have a considerable U.K. export volume. Going much further stream up on the Rhine might render physical or legal waterway limitations on the one hand and will stacken the competitiveness of the river-sea pushbarge compared to conventional barge transport.

Phase of implementation, actors and barriers
A preliminary study into this concept for passenger car transport between Cologne and Harwich showed technical and economic feasibility of the concept (Wijnolst, 1995).
More recently a container terminal operator in Belgium investigated the concept to enhance the quality of her hinterland transport (World Cargo News, 1997). For this typical situation the transport costs were found lower than for a river seagoing vessel, but higher than for the current generation barge vessels. On the other hand the voyage time was estimated higher than for the river seagoing vessel, but lower than for the present barge vessel. Another study into the feasibility of the concept on the corridor Germany - United Kingdom has been launched this year. This study is however based on a divergent technology for the barge, which has been developed by Vecomar International and Marine Heavy Lift Partners in the Netherlands (Van Velthoven a.o., 1997). The barge construction in this design is expected to enable optimal draught control, which is important for exploiting the concept benefits utmost.

Promising, missing and probable developments (actors point of view)

Compared to other innovative (shortsea) concepts the investment risks are rather limited. This is considered to be important for the willingness of market parties to invest in new systems. In case the concept fails the capital losses mainly relate to the coupling system. The push barge could be modified for other purposes.

As the present market for seagoing and inland push boats suffers from structural overcapacity it might stimulate this new application of push boats.

4.5.6 Combined Traffic Carrier Ship/Barge
drs. J.W. Konings

Baseline of the concept

The Combined Traffic Carrier Ship/Barge (CTCB) is a shortsea concept based on a new type of shortsea vessel: the Trans Sea Lifter (TSL). This vessel is able to carry floating unit load carriers, in particular barges generally used in inland navigation, between inland waterways that are separated by the open sea. Its purpose is to extend the operations of present inland and coastal vessels. Due to the TSL-concept inland navigation between European rivers separated by sea becomes an unbroken mode of transportation. In coastal shipping, barges carried by a TSL are expected to operate more economically than individual coasters. The innovation of the TSL compared to other barge carriers is that it carries existing barges of the size that has proven to be economical in inland navigation and that it loads and discharges any number of such barges fast and economically.

General features

The TSL makes regularly scheduled round trips, calling at fleeting areas just outside the entrances of coastal ports or inland waterways. In such a fleeting area the TSL stops, drops off barges and barges already waiting to leave with TSL are picked up. The TSL subsequently continues its voyage without further delay to the next fleeting area to call, while the unloaded barges are brought to their inland (port of) destination by conventional push boats.

Loading and discharging the TSL is a two step process. First the draught is enlarged by taking ballast. Next the loading platform(s) of the TSL is/are sunked and the barge can
be moved in or out. To ensure efficient ballast displacement in behalf of fast exchange and assure high stability on open sea the TSL is a Katamaran type of vessel. The dimensions of a standard sized vessel are put at 182.3 metres (L) x 76.5 metres (W) x 10 metres (D). This vessel is designed with 3 loading platforms, dimensioned for carrying two standard Europe IIa barges (76.5 metres x 11.4 metres x 3.7 metres) each. Barges of other sizes can however be transported too. Besides barges also motor vessels can be transported, but generally push barges will offer the best conditions, because of lower personnel costs, higher carry-capacity, enabling temporary storage opportunities and better safety conditions.

**Performances and costs**
The standard sized TSL vessel is able to carry 6 (standard Europe IIa) barges with a load capacity of 102 TEU each. Discharging one barge of the sinked TSL and reloading it with another barge takes 25 minutes. The TSL requires less than 90 minutes lay time for dropping off all barges and for picking up another full load.

**Figure 4.49 Traffic Carrier Ship/Barge**

![Traffic Carrier Ship/Barge diagram](source)

Source: NAVTEC Consult.

**Figure 4.50 TSL - Barge operation**

![TSL - Barge operation diagram](source)

Source: NAVTEC consult.
Main advantages of the concept are:
- flexibility concerning suitable freight flows. Barges can be used for different kind of freights and loading units (i.e containers, trailers, swap bodies, pallets) and adopted accordingly. For example tank barges for oil or other chemicals, RoRo barges for transport of trailers and swap bodies or barges specially developed for pallet transport;
- the possibility to combine different types of barges with different kind of freights gives excellent opportunities for bundling transport flows;
- time-independent seaport terminal operations due to the absence of transhipment;
- reduction in roundtrip time of the seagoing vessel due to fast exchange of barges and the location of the fleeting areas, i.e. the border of the coastal port.

The investment costs of a TSL are estimated to be comparable with those of a container vessel having the same carrying capacity. In setting up a daily service between Hoek van Holland and Sheerness in both directions one TSL would suffice. To test the competitiveness of the CTCB a cost comparison between TSL and a river-seagoing vessel on the route Duisburg (Rhine) - Goole (Humber) was made, showing CTCB being over 25% more economical.

Networks and locations
The TSL can be set up in a point-to-point service between main coastal ports. From these ports collection and distribution of barges along the inland waterways by push boats takes place. According to the freight origins/destinations and volumes the TSL could function in a line network as well, serving successive coastal ports. Alternatively, TSL services on adjacent routes could be joined into a TSL-network by calling at a common port, where exchange of barges between TSL's takes place. In this way such a port would develop into a hub for TSL's. This development could further extend the geographical range for barge transport on the one hand. Barge transport can be fortified in remote rivers which in their present isolation from the European network of inland waterways are too confined for sustaining barge operations. On the other hand the concept can rationalise shortsea transport. A service between continental Europe (Rhine river, Hoek van Holland) and the UK (Theems river, Sheerness) is considered to be the most interesting and promising route to start TSL. A connection between the Rhine and Humber river (U.K.) is another option. Other routes to consider are connections between the Scandinavian coast and the German and Dutch river mouths.

Phase of implementation, actors and barriers
The concept initiator, Navtec Consult, Emden, sees possibilities for an introduction of the system in short term because:
- suitable push barges are amply available;
- the construction of the TSL is primary based on known technology with limited high-tech elements;
- infrastructural investments in ports and inland waterways are not needed.
Presently a pilot design of the TSL carrier ship is being developed by Navtec, partly sponsored by the German federal state of Niedersachsen. This will serve as the basis for
developing the 'exemplary design' which will suffice for newbuilding contracts between shipowners and shipyards. Different market parties are involved (total project costs: DM 1 million). The German federal Ministry of Education, Science, Research and Technology (BMBF) will fund up to 60% of the effort. The federal Ministry of Traffic (BMV) has shown willingness to sponsor a study on the economic viability of the concept. As potential operators of CTCB are envisaged barge operators extending their inland barge services and integrators already organising the chain of inland transport and shortsea transport.

Promising, missing and probable developments
The CTCB-concept could extend the pure shortsea trade, using the inland push barges as the standard load units. This would strongly stimulate the development of a European-wide CTCB-network.

4.6 Node Transport Systems

4.6.1 Combi-Road
drs. J.W. Konings

Baseline of the concept
Combi-Road is a new intermodal transport system, next to barge and rail, aimed at transporting large container flows through congested areas in a fast, safe and cost efficient way. It incorporates an automated controlled and unmanned transport system. Containers loaded on ordinary trailers are pulled by automated guided and unmanned vehicles. These vehicles are electric powered and they drive on dedicated lanes. At inland terminals or so called transfer points the trailers with containers can be directly exchanged with ordinary trucks without vertical transhipment. As the number of (vertical) transhipments is reduced and congestion is avoided by using dedicated lanes, Combi-Road intends to offer cost and time savings within the total transport chain. The mainspring for the development of the Combi-Road concept has been the growing concern about the ability to handle and transport the expected large container flows through the port of Rotterdam into the hinterland in an efficient way. These concerns are feeded by the saturation problems coming for road (congestion) and rail (capacity constraints) at the terminals, in the port area and along the main road and rail tracks into the hinterland as well. The concept has been started up as a typical node transport system, but for the longer term it is presented as an alternative for the existing networks of barge, rail and road as well.

General features
Starting the transport chain at the terminal at the Rotterdam Maasvlakte area a container is loaded on a trailer and picked up by a Combi-Road vehicle pulling this trailer. The vehicle entrances the Combi-Road track which is a dedicated track supplying power to the vehicle and guiding the vehicle in longitudinal and lateral way. On the track the vehicle is automatically guided and there is an overall control system to manage the
entire transportation process, including the processing of customer orders, trip planning and traffic control as well as passing speed and route changes to the vehicles. The control system directs the vehicle to a so called transfer point in the hinterland. According to the final destination of the container, at the inland transfer point the container can be unloaded from the trailer and transshipped to a train or barge for further transportation or the trailer with container can be taken over directly by ordinary road tractors for local distribution.

During the concept development a number of requirements for the transfer point have been formulated:
- it must have expansion potential (modular build up);
- able to handle all available types of trailers;
- driving at transfer points unmanned whenever possible;
- physical inspection of containers and trailers will take place when entering and leaving transfer points;
- a container checkpoint at every Combi-Road entrance;
- container exchange of the Combi-Road to the terminals at the Eem/Waalhaven will use existing transhipment facilities at the terminal.
A precondition for developing a transfer point is the availability of space. As on the inland transfer points 'stack on wheels' is intended, enough space at the transfer point is required. As an alternative 'stack on ground' might be more attractive when stack time raises, although this implies an extra vertical transhipment. The spatial demand for a particular transfer point will mainly dependent on the control system scenario (i.e. the application of a push or pull mechanism for transporting the containers to the transfer point). Another issue is how the exchange at the transfer point takes place from an automated mode to manual activities. This has not only relevance for safety procedures but for the logistic operations at the terminal as well. These aspects are still open in the concept.

**Performances and costs**
The Combi-Road vehicle is a rubber-tyred robot tractor which is electric powered and able to drive at approximately 50 km/h. The vehicles drive uncoupled and are able to transport one trailer at one time. The minimal headway of a Combi-Road vehicle is 12 sec. (180 metres). At a rate of five vehicles per minute, 24 hours/day and 360 days/year, maximum capacity of Combi-Road would amount 2.6 million containers per year in a single direction. In practice this is not feasible, but it is reckoned that a real capacity of 1.5 million containers per year is achievable. The system can be used for maritime and continental containers. According to Combi-Road is supporting long distance transito traffic or is used for national/regional distribution container traffic, the function of the transfer points will be different. For transito traffic an interconnection with rail or barge at the inland transfer point is important. In regional container traffic collection and distribution to and from the transfer points will take place by ordinary trucks and the accessibility by road is important. At an inland transfer point one can usually expect both functions.
At the Maasvlakte-terminal the transhipment of containers to the trailers could be carried about by ASC's. At the inland transfer point a transhipment for further road transport is unnecessary. The type of equipment to be used for transshipping to rail or barge is still open. The handling capacity per single direction is estimated for the Maasvlakte at 108/hour and for the inland transfer point at 130/hour. Because at the Maasvlakte there is no stacking on wheels, additional space for stacking is not necessary. The number of parking places needed at the inland transfer point is estimated at 1,800, corresponding with an area of about 56,250 m².

Combi-Road is intended to replace a large share of the growing road transport within the expected modal-split. This potential is estimated to about 56% of the container flows by road through the port of Rotterdam to the hinterland in 2020. In container numbers this would mean approximately 750,000 units.

The estimated budget for the basic construction of a track with two lanes, not counting for bridges, tunnels and pillar sections etc., is put at 7,000 kECU per km of Combi-Road track. Besides this there are costs for the transfer points and the vehicles. The investment costs of a vehicle are estimated to be around 180 kECU.

According preliminary results of economic feasibility studies on the section Maasvlakte-Gorinchem the required throughput for break even is about 300,000 containers per year.

Networks and locations

In general the market for Combi-Road will consist of intensive, relatively short corridors (up to 100 kms), as a means of downstreaming major intermodal transfer facilities to off-port locations, or as a new type of shuttle between two points. In both situations however it is applied to large bundled container flows.

In the initial stage the Combi-Road network begins at the Maasvlakte and goes via the Eem/Waalhaven, to a hinterland location 60 to 100 km from the Maasvlakte (i.e. Moerdijk or Gorinchem), outside the congested Rotterdam area. From Moerdijk the network could eventually be extended further south to Antwerp and from Gorinchem on to KAN (the Arnhem/Nijmegen node) and then to Venlo and even into the Ruhrgebiet area, providing direct access to the German rail net too. The transport axis Rotterdam-Amsterdam (Schiphol and Westpoint) could be included in the Combi-Road network as well. At the Maasvlakte the network will give access to the terminal processes regarding maritime transport. There are three conceivable locations to link the network with the terminal:

- at a Combi-Road Service Centre;
- at the Automated Stacking Crane;
- directly below the quay crane of the seagoing vessel.

The choice of this location strongly determines the number of required transshipments and therefore the cost efficiency of Combi-Road.

In the other nodes of the network i.e the inland transfer points, efficient connections with road and rail and/or barge must be provided.
Phase of implementation, actors and barriers
The Combi-Road project started in 1994. Extensive studies into the logistical, technological and implementation aspects of the concept have been carried out. This phase of the project expired in 1996 with the recording of real-scale tests on a test track (200 metres), where the vehicle, the control system and the power supply have been tested.

In the next project phase the construction of a pilot track (2 km) to test the concept in practice, the set up of a logistic concept for continental transport and the exploration of legislation and plan procedures have been studied. Combi-Road is one of the projects of the Centre for Transport Technology, an organization founded by the Dutch government to emphasize the development of technology for goods transport in general and intermodal transport in particular. As a result the Dutch government has been financially involved in the concept development. A serious barrier for realising Combi-Road are the high investment costs, especially in infrastructure.

Promising, missing and probable developments
A serious quality improvement of barge and especially rail transport on the hinterland axes of Rotterdam will reduce the need for a supplementary transport system like Combi-Road. On the middle long distances (100 - 250 km) barge and rail have good prospects for improved operations. Therefore a transport system based on individual transport movements, like Combi-Road, could become less competitive with these large
scale transport systems on this distance range. The promising market for Combi-Road seems to be the short distance transport market in congested areas.

4.6.2 SST and SOG

ir. E. Kreutzberger

Baseline of the project

DB’s ultimate solution to meet the demand for flexible and demand guided rail freight transport, is:
- SST (= selbsttätiges signalgeführtes Triebfahrzeug) or self-active signal guided vehicle;
- SOG (= selbstorganisierendes Güterfahrzeug) or self-organising freight vehicle.

In both projects a single rail vehicle moves driverless to the programmed destination. But keeping distance to other vehicles and influencing the route (like the switches) is achieved in a different way.

In the SST or SOG system freight is transported in small amounts with single vehicles (Frederich and Lege, 1996; Figure 4.52.) or in very small trains (DB, 1996b). This means that the bundling of freight is hardly necessary a can be compared to road transportation. SST/SOG can respond quickly to changing volume demands. The reasons for this flexibility are the driverless operations, the restricted size of the transport units, and the fact that the transport units can make use of unused and unplanned time-space-paths on the infrastructure between time table determined trains.

SSTs can run in mixed operations with conventional trains. SOGs can only run on special networks. The secondary infrastructure of SOG-networks is simpler, because in the SOG-system the major part of the information and intelligence required is included in the vehicles, no expensive control centres and (block) signal systems and such a like, are required. STT is to be realised in the short term, SOG is planned for the longer term. SOG is supposed to become a cheap and flexible alternative to road transport. The principle of STT/SOG can be applied for combined and conventional rail transport.

Figure 4.52 Self driving vehicle (SST or SOG)
General features

The SST uses automatic train protection (ATP) systems featuring an infrastructure of detecting and signalling equipment along the tracks to recognise signals, speed and direction of the vehicles. Unlike conventional operations the train can read the signals automatically and react to 'green' and 'red' signals. The vehicles are dependent on control centres to operate the switches for them. Every protection system is provided with backup systems to ensure security.

The SOG is operated by means of radio transmission of information about speed, position and direction between vehicles. All equipment to process the information is located on board of the vehicles. Switches are influenced directly by the vehicles. A SST-transport unit in the Volkswagen-pilot consists of a diesel locomotive and three closed wagons. Closed wagons have more volume than wagons with combined load units. Volkswagen prefers therefore closed wagons for inter-factory transport, provide the transport chain allows the use of combined load units (Fritzen and Tichelkamp, 1997). A good example of this is Volkswagen factory Braunschweig (Deutsche Bahn, Deutsche Reichsbahn, 1993).

In the Volkswagen pilot engines and components are carried from the engine and components manufacturing plant in Salzgitter to the assembly plant in Wolfsburg (48 km). The transport volumes change daily, fluctuating from 1,700 to 7,000 pieces a day (DB, 1996b). Demand may increase instantly.

Typical operations are also described in abstract terms for SOG. A transport will start with convenient handling for the customer. An employee of the shipper will type the destination of the loaded SOG on a simple keyboard incorporated in the vehicle (comparable to using a fax). Then the employee will turn a key handle and hand the vehicle over to the network. The SOG will calculate the route and inform other vehicles. After a few minutes the vehicle will start on its way. While moving the SOG will maintain a continuous contact with other SOGs. They will exchange information about positions, speeds and destinations and solutions for conflicting situations. If a switch is reached, a radio message will be transmitted to the switch containing information about the required position.

Networks and locations

Because of the small dimensions of SST or SOG-vehicles, these systems require much less bundling. The typical SST/SOG network is that of point-point connections on the basis of relatively small or strongly fluctuating flows. The SOG train protection generates exclusivity: if not all rail operations are changed to the SOG logic, there necessarily will be islands of SOG-networks, connected by conventional trains or SST (Frederich, Lege, 1996; Figure 4.53) or a parallel infrastructure for different systems. It is obvious that transhipment can be necessary along the borders of the system, if a

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25 This so-called EUROLOOP system is based on a train protection system which has already been tested in England.
double infrastructure is to be avoided. The system borders should match with exchange points in bundling networks.

Performance and costs
The conclusion of the tests that features in all publications is that it is sure that mixed operations between automated and conventional transport units are possible in practice, and that complementary use of infrastructure with conventional traffic by SSTs increases the capacity of the infrastructure (Frederich en Lege, 1996).

Phase of implementation, actors and barriers
The SST is developed at TU Aachen in co-operation with DB and Alcatel SEL. It has been tested between 1994 and 1996 on an intensively used track between two stations near Aachen. The vehicle was deployed in mixed operations with conventional freight and passenger trains. Since 1996 a pilot operation with SSTs has been tested between the two Volkswagen factories Wolfsburg and Salzgitter. On both routes an adjusted conventional diesel locomotive with cargo wagon (in the Volkswagen-pilot three wagons) has been used as STT. This makes control of the automatic operations possible in the implementation phase before the vehicles are really deployed without a driver on board. In the Volkswagen-pilot the fully automated transport is to be started in 1999 (DB, 1996b), after a security-check has been evaluated. In the meantime the route between the Volkswagen plants Braunschweig and Wolfsburg is to be prepared for SST.
One major problem will yet have to be solved before fully driverless operations can be launched. This problem concerns the protection of the tracks against interruptions, such as animals. Fences and provisions like that would make the project expensive. TU Karlsruhe will provide the basic answers to this problem.

Promising, missing and probable developments
The principles of SST or SOG are not restricted to single vehicles. Capacity requirements may make it desirable to deploy trains instead of stand alone vehicles. Other innovative transport units (like Cargo sprinter) are man driven, but on the longer

Figure 4.53 From SOG area to SOG area by STT

term, robotisation of its operations may be an interesting option. The train building of STT/SOG and robotisation of Cargo sprinter can eventually lead to a fusion of both projects.

4.6.3 Node Transport Rotterdam Maasvlakte

ir. Y.M. Bontekoning

Baseline of the concept

In 1984 terminal operator Europe Combined Terminals (ECT) started a marine terminal at the Rotterdam Maasvlakte, 40 kilometres westward from the ECT Home Terminal in Rotterdam. A barge terminal and a rail terminal were built too. In that time a new technology for more efficient terminal and internal transport operations was introduced, the Multi Trailer-train pulled by a heavy truck. In 1993 the second marine terminal DSL started its terminal operations. The DSL is the first terminal in the world where a part of the operations is robotised. Automated Guided Vehicles (AGV's) have been introduced for terminal internal transport between the quay cranes (sea side) and robotised Automated Stacking Cranes (ASC). In 1996 the third terminal (DDE) started its operations with the same technology as the DSL-terminal. A fourth terminal (DDW), the third with robotised operations, is planned to be operational in 2000.

With the growing of the volumes at the Maasvlakte the number of terminals increase and also the number of internal transport connections between terminals and the volumes of these streams. The study group Incomaas studied the question: "which internal transport system will be able to handle future container flows at the Maasvlakte-node most efficiently?" The following systems have been compared: AGVs, Multi Trailer-trains and self (un)loading automated. For the future the study group concludes that AGVs are preferred regarding costs and logistic performance. For the short term Multi Trailer-trains will be used (Incomaas, 1996c).

In the short run internal transport with Multi Trailer-trains will be improved by organizational changes and an information system to support the planning processes. It has not yet been decided which transport system will be used at ECT in the long run. However, all newly constructed infrastructure and equipment are designed with the possibility of easy adjustment to automated operations (Meel, 1997).

General features

Typical Operations of Multi Trailer System

Internal terminal transport (ITT) with heavy trucks pulling Multi Trailer-trains is based on a large number of small shuttle connections. All containers on each individual Multi Trailer-train have the same origin and the same destination. Each terminal has one or more buffers where full and empty Multi Trailer-trains are parked, either to be loaded or unloaded or to wait. The buffer has a function to absorb differences in speed of the (un)loading and transport processes. The buffer is the point where two types of operational dynamics, that of the ITT and that of the marine, rail
or barge terminals, empty depots or distriparks, are unlinked. It is characteristic that a full Multi Trailer-train is transported on the way up and an empty one on the way back or vice versa. The possibility to carry loads both ways depends on the number of parking lanes in the buffer, the speed of unloading and loading at both ends of a transport link (depending on the amount of equipment at the terminal) and the balance in transports between two terminals. The following describes an example of unloading a barge. Multi Trailer-trains are loaded underneath the quay crane at the barge terminal. Loaded Multi Trailer-trains are positioned in the buffer at the barge terminal waiting for a heavy truck. This truck transports the Multi Trailer-train to the buffer of one of the marine terminals. The Multi Trailer-train waits to be unloaded. The crane at the barge terminal has to be provided with empty Multi Trailer-trains to continue unloading the barge. The chance that another barge is being loaded at the same time and can provide empty Multi Trailer-trains is small, so the heavy truck will have to take an empty Multi Trailer-train from the terminal where it has just dropped off the full one. For transports between two marine terminals it is easier to plan the transports within a time frame such that Multi Trailer-trains can be transported full both ways. Conditions are that the transport orders are of the same size and both terminals have enough equipment to load and unload Multi Trailer-trains at the same time.

Typical operations of the AGV system

Internal transport by Automated Guided Vehicles (AGVs) is based on individual vehicles which can transport one container (20', 40' or 45') at a time. The AGV is a self-driving and navigating robot. A grid navigation in combination with odometry (calculating the travelled path by pulse- and direction-counters on wheels) is used (Simet, 1994). Traffic induction wires are applied along the lanes destined for AGV traffic. The AGV receives its transport orders from the central computer. The interface between the AGV and the central computer consists of transponders located in the pavement and a transmitter and antenna at the AGV.

While the MTS system is based on the uncoupling of ITT and terminal operations in the buffers, an AGV moves directly underneath the rail or barge crane or - if a terminal has Automated Stacking Cranes (ASCs) - underneath an ASC. The AGV is loaded or unloaded by the barge or rail crane or the ASC. The ITT process is more or less integrated in the terminal operations. For terminals without ASCs the AGV still has to move to a buffer, where a straddle carriers handles the container. The ASC at ECT is a rail-mounted crane which is fully automated. Each stacking crane covers 6 rows of containers. Three containers can be stacked on top of each other.

Figure 4.54 Multi Trailer System

Performance and costs
Multi Trailer System
The Multi Trailer-train has a fixed composition of five chassis, which means a capacity of 10 TEU. The chassis are coupled with special coupling technology which enables the chassis to follow each other along the same curve as do the heavy trucks. One chassis can either hold one 40' or 45' container or two 20' containers. The maximum number of chassis that a heavy truck can pull is 10 chassis.

A trip between two buffers takes about 20 minutes. Loading or unloading one Multi Trailer-train takes about 15 minutes at the barge and rail terminal (including time to sort out containers over different marine terminals (unloading)). Unloading or loading at the marine terminals takes about 20 minutes. Both times are average times for five 40' containers and ten 20' containers. The integral ITT-time is about 55 minutes for one Multi Trailer-train. This means that the cycle time of a Multi Trailer-train between two buffers is 70 minutes. Because unloading a train or barge is an ongoing process, a transport order of 25 40' containers requires 5 Multi Trailer-trains (70 : 15) and 3 heavy trucks (40 : 15). The utilization rate of a loaded Multi Trailer-train lies between 70 and 80%, which means an overall average utilization rate of about 40%. In case of an urgent transport order the lead-time for one single container is about 25 minutes. 12 heavy trucks and about 40 to 50 Multi Trailer-trains can handle the present (1996) ITT volumes. This capacity enables a number of between 40 and 60 trips per hour (Meel, 1997). Incomaas (1996c) estimates this flow at 600,000 containers. The Incomaas simulation study indicates a requirement of 28 heavy trucks, 145 Multi Trailer-trains and 32 straddle carriers for the handling of the ITT volumes by 2005, at a 99.9% service level.
### Table 4.4 Transport volumes between terminals in 2005 (x 1,000)

<table>
<thead>
<tr>
<th></th>
<th>DMU</th>
<th>DSL</th>
<th>DDE</th>
<th>DDW</th>
<th>DEPOT 1</th>
<th>DEPOT 2</th>
<th>DEPOT 3</th>
<th>ED-</th>
<th>BSC</th>
<th>RT</th>
<th>RSC</th>
<th>VC</th>
<th>Road</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMU</td>
<td>0</td>
<td>15</td>
<td>18</td>
<td>18</td>
<td>150</td>
<td>0</td>
<td>380</td>
<td>8</td>
<td>0</td>
<td>380</td>
<td>810</td>
<td>190</td>
<td>420</td>
<td>28</td>
</tr>
<tr>
<td>DSL</td>
<td>150</td>
<td>0</td>
<td>13</td>
<td>13</td>
<td>70</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>180</td>
<td>170</td>
<td>260</td>
<td>150</td>
<td>190</td>
<td>28</td>
</tr>
<tr>
<td>DDE</td>
<td>180</td>
<td>13</td>
<td>0</td>
<td>15</td>
<td>110</td>
<td>6</td>
<td>0</td>
<td>290</td>
<td>200</td>
<td>200</td>
<td>150</td>
<td>280</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>DDW</td>
<td>180</td>
<td>13</td>
<td>15</td>
<td>0</td>
<td>110</td>
<td>6</td>
<td>0</td>
<td>290</td>
<td>200</td>
<td>200</td>
<td>150</td>
<td>280</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>DEPOT 1</td>
<td>80</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>90</td>
<td>20</td>
<td>70</td>
<td>14</td>
<td>n.a.</td>
</tr>
<tr>
<td>DEPOT 2</td>
<td>40</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>10</td>
<td>-40</td>
<td>7</td>
<td>n.a.</td>
</tr>
<tr>
<td>DEPOT 3</td>
<td>200</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>220</td>
<td>60</td>
<td>190</td>
<td>55</td>
<td>n.a.</td>
</tr>
<tr>
<td>BSC</td>
<td>920</td>
<td>16</td>
<td>23</td>
<td>23</td>
<td>20</td>
<td>1</td>
<td>1</td>
<td>60</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>n.a.</td>
<td>3</td>
<td>n.a.</td>
</tr>
<tr>
<td>RSC1</td>
<td>270</td>
<td>17</td>
<td>17</td>
<td>17</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>40</td>
<td>85.6</td>
</tr>
<tr>
<td>RSC2</td>
<td>420</td>
<td>20</td>
<td>32</td>
<td>32</td>
<td>20</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>100</td>
<td>149.6</td>
</tr>
<tr>
<td>distripark</td>
<td>170</td>
<td>10</td>
<td>15</td>
<td>15</td>
<td>160</td>
<td>8</td>
<td>6</td>
<td>620</td>
<td>90</td>
<td>30</td>
<td>160</td>
<td>0</td>
<td>n.a.</td>
<td>177</td>
</tr>
<tr>
<td>Road</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>50</td>
<td>100</td>
<td>n.a.</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>261</td>
<td>120</td>
<td>157</td>
<td>157</td>
<td>650</td>
<td>34</td>
<td>11</td>
<td>188</td>
<td>1820</td>
<td>900</td>
<td>1670</td>
<td>178</td>
<td>140</td>
<td>1,624</td>
</tr>
</tbody>
</table>


At the marine terminal a buffer has 4 to 6 lanes, whereas at the empty-depot it has 2 lanes. One buffer lane is 80 metres long and 5.5 metres wide. 25 metres’ extra length are needed on either end of the buffer lane in order to drive in and out of the buffer. The heavy truck always uses one side to drive into the buffer and the other side to drive out of the buffer. Therefore it actually runs through the buffer. There are two lanes (backward and forward) destined for internal transport between all buffers. The total width of these two lanes is 10 metres. Spatial requirements for lanes is 116,950 square metres and for buffers 138,710 square metres (Incomaas, 1996c).

**AGV system**

AGVs are already being used in marine operations; not yet, however, for internal transport. The performance criteria for these two operations differ. Internal transport requires AGVs to run faster and to be able to move in convoy. A simulation study of Incomaas (1996c) shows that, in order to arrive at a 99.9% service level, 224 AGVs and 16 straddle carriers are needed to handle ITT flows by 2005 (Table 4.4). The study does not state AGV speed or distances between terminals. However, a maximum technical speed of an AGV at 5 m/sec and an average distance between terminals of about 2.5 kilometres is common. An AGV buffer lane is 5.5 metres wide and 19 metres long. An AGV buffer lane allows access over roughly 19 metres. The same access is used for driving in and out. The spatial requirement for lanes is 101,630 square metres while for buffers it is 40,040 square metres. (straddle carrier handling) or 31,240 square metres (ASC handling) (Incomaas, 1996c).

The Incomaas study draws a cost comparison for the year 2005 (99.9% service level) without stating actual costs. Below, the Incomaas cost data have been indexed. Its basis is formed by the Multi Trailer-train costs (100).
Table 4.5 Relative costs with index 100 for MTS

<table>
<thead>
<tr>
<th></th>
<th>MTS</th>
<th>AGV (ASC)</th>
<th>AGV (SC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
<td>100</td>
<td>21</td>
<td>42</td>
</tr>
<tr>
<td>Equipment</td>
<td>100</td>
<td>124</td>
<td>131</td>
</tr>
<tr>
<td>Spatial/infrastructure</td>
<td>100</td>
<td>74</td>
<td>71</td>
</tr>
<tr>
<td>Information systems</td>
<td>100</td>
<td>161</td>
<td>140</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>67</td>
<td>81</td>
</tr>
</tbody>
</table>

MTS = Multi Trailer System  
AGN = Automated Guided Vehicle  
ASC = Automated Stacking Crane  
SC = Straddle Carrier

Source: Adjustment by OTB of Incomaas, 1996c.

Implementation phase, actors and barriers

Over the next few years ECT will improve the efficiency of internal transport systems with Multi Trailer-trains. In the meantime more research on the use of AGVs for internal transport will be carried out. In order to be able to implement the AGV system, which is already in use for marine terminals operations, studies will have to be made on convoy driving, traffic control and higher speed. A simulation study of the Incomaas project group (1996c) shows that in the short run Multi Trailer-trains are cheaper in handling internal transport volumes; yet in about 5 years AGV will be cheaper. ECT works closely together with the Port of Rotterdam and research institutes in order to further develop the Maasvlakte terminals and internal transport between the terminals.

Promising, missing and probable developments

Van Meel (1997) is of opinion that in the long run internal transport with AGVs might be required in order to be able to handle the large volumes expected. The complexity of transports may require a fully automated system. The cost-benefit ratio of robotisation is not clear and is subject to discussion. Van Meel is of opinion that labour costs for operations will certainly be reduced by robotisation; yet he is uncertain whether it will compensate for the extra costs incurred on information systems, software and technical support. The financial and operational risks run in implementing non-proven technology are extremely high. Over the next few years savings will be realized by smart planning, the pooling of heavy-truck drivers and the introduction of board computers in heavy trucks.
Baseline of the concept
The aim of the project was to identify a cost effective method of handling stowing and transporting rolls of steel products through the different modes of supply chain. This involved in the movement of the products from the UK to Sweden and from Sweden back to the UK through various different modes of transport.

General features
The transportation of these “cassettes” is a result of a project involving the co-operation and input of the port and railway companies in both the UK and Sweden together with Tor Line. The train containing steel or paper arrives at the port’s rail terminal. The rolls of steel or paper are off loaded from:
- the train onto the “cassettes” (see Figure 4.56) using a large fork lift truck.
- The “cassettes” containing the steel or paper are then moved from the rail terminal to the despatch zone at the port using a customised shunter;
- the “cassettes” containing the rolls of steel are then loaded onto the Ro-Ro ship;
- the ship then sails to its destination;
- the “cassettes” containing the rolls of steel or paper are then off loaded from the Ro-Ro ship using the customised shunter. Figure 4.57 shows one of the customised shunters moving a “cassette” from the ship to the rail terminal;
- the “cassettes” containing the rolls of steel or paper are then moved from the receiving zone within the Port to the Rail terminal, the lorry freight despatch zone or in the case of the paper a small transitionary warehouse using the customised shunter;

Figure 4.56 “Cassette” loaded with steel
the rolls of steel are then loaded onto the train from the “cassettes” using a large fork truck. In the case of the paper a customised adapter to the forks is present to clamp the rolls. The train containing the steel or paper then departs from the port.

Performance and costs
During 1997 Tor Line anticipate moving in excess of 12,000 “cassettes” loaded with steel using this method. Tor Line have a fixed schedule of 6 sailings per week between Immingham and Gothenburg. This mode of transportation has also resulted in a significant reduction in lead times within the overall supply chain. The specially built “cassettes” also have an increased pay load of 60 tons compared with a conventional 12m unit of approximately 20 tons. There has also been a 14% improvement in the utilisation of the space on the ship. The “cassettes” are able to be stowed 8 wide in the ships hold compared with 7 conventional trailers.

During 1997 Tor Line anticipate moving in excess of 700,000 tons of paper products using the “cassettes” method to their ports at Immingham (UK) and Ghent (Be). Tor Line have a fixed schedule of 6 sailings per week between Gothenburg and both the ports at Immingham and Ghent. This mode of transportation has also resulted in a significant reduction in lead times within the overall supply chain. The specially built “cassettes” have also allowed an increased pay load. Onboard, the “cassettes” are block-stowed which results in efficient utilisation of resources and allows for the cargo to be stowed securely. The “cassettes” have also been designed to be nestable in order to reduce storage space and potential freight space, on the ships, if realignment of the “cassettes” is required.

Figure 4.57  Shunter moving “cassette” loaded with paper

Source: Tor Line, 1996.
The AngloBridge Service offers 16 sailing's per week between Immingham, Harwich and Gothenburg. This service currently has annual volumes in the region of 500,000 lane metres. The EuroBridge Service operating between Gothenburg and Ghent in Belgium was started in 1994. The service offers six ro/ro sailings per week in each direction. The service has a annual volume of 950,000 lane metres. The loading and discharging of the ships is carried out overnight with the vessel arriving at port at 21.00 and departing at 03.00 hrs. This means that products made during that day can be loaded the same evening. The goods can therefore be released from the port early and have sufficient time to reach their final destination in the morning. The Schedules for this services is detailed below.

Phases of implementation, actors and barriers
The development and introduction of the “cassette” system has been found to be well suited for the distribution of steel rolls between a steel manufacturing site and a steel processing site one of which is located in the UK and the other in Sweden. Further development of the concept has resulted in “cassettes” being designed for the distribution of paper rolls between Sweden and ports in both the UK and Belgium. In the last 10 years, major industrial companies such as Avesta Sheffield Ltd. and Storra have signed long term contracts for the distribution of their products between the UK and Sweden. The AngloBridge service operated by Tor Line (part of the DFDS group of companies) between the ports at Immingham (UK) and Gothenburg (S) is being used to transport their goods during the sea bound legs. Volvo use the EuroBridge Service in the transportation of both cars and components between their factories in Gothenburg and Ghent.

Promising, missing and probable developments
From the actors view point this project appears to be a success for the movement of steel products and has been developed for various other product groups e.g. paper products. The future see the concept is being further developed with the use of the “cassettes” being further refined to enable them to be used in the rail leg of the supply chain of these product groups. At the minute there appears to be one major problem with the future developments associated with the weight limits that can be transported on the Swedish railway network. If the steel or paper products can be loaded onto the “cassettes” at the rail terminal, close to the supplier, this will result in the product not being touched again until it arrives at the rail terminal at the customers end of the supply chain. Significant labour, time, shrinkage savings are anticipated. As yet these have not been quantified.
5

COMPARISON OF CONCEPTS

ir. Y.M. Bontekoning and ir. E. Kreutzberger

5.1 Introduction

In the previous chapter many concepts have been described. In order to identify promising directions we want to compare these concepts with each other. In this chapter the concepts are made comparable and a first indicative comparison will be made. A first step to a comparison has already been made in chapter 4, where the concepts have been categorised by type of modality. In this chapter a set of indicators is formulated and the concepts are compared for these indicators. As indicated in chapter 3 (Methodology) there is no reference framework for indicators and criteria available, yet. It has to be constructed. Generally spoken, indicators and criteria for the terminal and node concepts should be derived from the networks. First, the required quality must be made operational on the network level. Then, the performances and costs must be assigned to links and nodes, hereby taking alternative bundling concepts into account. In TERMINET this reference framework is being constructed from a top-down approach, which is from the network (from shippers and network operators) and a bottom-up approach.

In this stage on the research a part of the framework is constructed from the supply side, which means that indicators are distilled from the terminal and node concept descriptions. Two restrictions have been taken into account during the distillation of indicators from the terminal and node concepts. The indicators must be useful for:
- the identification of directions which lead to a substantial improvement of the cost quality ratio;
- the integration of the concepts in bundling networks.

With the indicators concepts can be evaluated and compared. This evaluation is presented in section 5.2. In section 5.3 the tables and concept descriptions are used for the comparison. This comparison takes place on a rather global and indicative level, while it is based on the actors point of view.
5.2 Set of indicators

Which indicators can be distilled from the concept descriptions and are useful for the identification of promising directions and the integration of the concepts in bundling networks? In order to meet the first condition, indicators descriptions which provide information on costs, achievements, efficiency and chances of realisation must be distilled from the concepts. For the later indicators which provide information on the measure of effectiveness of the concept in terms of its bundling task must be distilled. But which indicators are useful to be compared upon?

To start with the bundling task; the type of bundling which takes place at the terminals, how the bundling is done, the dimensions (tracks/berths) of the bundling operation and the technical compatibility of the operation in relation to technical characteristics of transport units and loading units are relevant. Information about investments, integration in existing situation, barriers and implementation aspects is relevant to indicate chances of realisation. Information on input, costs, performances, capacity, spatial use, annual volumes and peak hour volumes is needed to compare concepts on efficiency and cost quality ratio. This information on efficiency and cost quality ratio depends largely on the dynamics of the freight flows in the network (arrival and departure time rhythms of trucks, trains, barges and vessels) and the dwell time of load units in the stack. Although the indicators are comparable the figures presented by actors are not always comparable, because assumptions used by actors on network dynamics and opening hours of the terminal differ. It is not always clear which assumptions have been used by the actors. Therefore figures for indicators which are related to network dynamics sometimes have been converted and/or interpreted, which actual already is researchers’ point of view. Figures which have been retrieved by conversion or interpretation are marked in footnotes.

In the following part of this section the selected indicators are explained. In section 5.3 the concepts (by category) are evaluated against the selected indicators. This evaluation is presented in tables per category of operation (rail, barge, Ro-Ro, sea or node internal transport). If a concept has two or more variants they are also evaluated and presented in the table. The reader should keep in mind that it is the actor’s point of view which is presented in the tables.

**Bundling model**

For the type of bundling in the network the indicator *bundling model* is used. Four types of bundling models are distinguished: line (L), point-to-point (P-P), trunk with line or fork collection/distribution (Tcd) and hub and spoke (H). The model applied should be assessed against the long haul transportation network. The type of bundling model gives information on the position of the terminal in the network. Line networks have intermediate terminals and most often also begin/end terminals. Quality discussions usually focus on the intermediate terminals, because of the typical characteristics of the line networks. Networks with point-to-point connections naturally have
begin/end terminals. In trunk C-D networks and hub and spoke networks splitting and grouping of transport units or freight flows take place at intermediate (hub) terminals.

**Modalities (Seq/Sim)**

This indicator shows the modalities between which transhipment takes place. The distinguished modalities are rail (Ra), road (Ro), barge (Ba) and deep-sea/shortsea (D/IS). In case of unimodal transhipment the additions Seq and Sim indicate sequential or simultaneous exchange of load units. Examples: Ra - Ro stands for transhipment between rail and road and Ra - Ra (Seq) for sequential rail - rail transhipment. In multimodal operations simultaneous transhipment between several transport units of the same modality is unusual.

**Trains : exchange / barges : exchange**

The indicators trains: exchange or barges : exchange express the dimension of the bundling for trains or barges respectively. The indicator shows the relation between the maximum number of trains/barges which can be handled at the same time and the number of trains/barges between which direct (simultaneous) exchange takes place. The meaning of “direct exchange” is twofold: 1. load units are picked up from one train/barge and dropped off at another within one move, or 2. the load units are exchanged via a terminal node internal transport system (e.g. conveyor, AGV). Three ratios are used in the table. For example: 6:3, 6:3(x2) or 6:3(-4). 6:3 means that 6 trains can be handled at the same time and between 3 trains simultaneous exchange of load units is possible. The addition (x2) in “6:3 (x2)” means that there are 2 operational units where exchange between 3 trains takes place. The addition (-4) means that it is possible to have exchange between 1 to 4 trains but it is not the intention of the concept.

**Load unit**

The distinguished load units are containers (C), swap bodies (S), trailers (T) and barges (B).

**Electrification**

This indicator shows how the problem of electrification wires is incorporated. We distinguish change lock(omotive), because there are no power lines at the terminal, under, which implies that the cranes can work underneath the power lines, flexible, which implies that the power lines can be moved aside and other, which implies that none of the other possibilities is applicable and that another solution is chosen. This solution is mentioned in a footnote.

**Moves/h : cranes**

The indicator moves/h : cranes expresses the peak performance of the terminal in one hour and the input of cranes on the rail or water side. For some terminals the same cranes are used for both rail/barge and road transhipment. This is marked with **Ro**, which stands for combined rail/road operation. The peak performance (moves/h) is a rather theoretical indicator. Only in specific situations (maximum capacity of rail
tracks or berths in use) and under certain conditions (all cranes and other operational equipment working) this peak performance will be achieved. Indication for performance of the terminal in other than peak situations (for example the minimum duration of a train in a terminal) can be retrieved from the number of cranes, the number of tracks/berths and the peak performance. When these three figures are combined it is possible to obtain information on the performance per crane and on the maximum number of cranes per track/berth.

**Stack capacity**
The indicator *stack capacity* shows the initial number of TEU which can be stored at the terminal. It includes long term storage and short term buffers.

**Stack flexibility**
This indicator provides information about the possibilities to meet different stack capacity requirements. Or in other words the flexibility of concept to adjust the initial stack capacity. Two figures are distinguished: *variable*, which expresses the possibility to adjust initial stack capacity and *no changes*.

**Container visit : moves**
The ratio *container visit : moves* indicates the number of handlings of one load unit at the terminal. A container visit is not the same as a move. One container visit can consist of several moves depending on the design of the operational process. For example: one container visit can imply one rail-stack move and one stack-road move, which is two moves for one container. In case a container is directly transhipped from rail to truck one container visit is equal to one move.

The container visit/move ratio gives an indication of the number of times the same load unit is lifted by rail/barge crane, conveyor, stacking crane and road crane. In one situation 5 moves for 1 visit could be very efficient, while in other situation it is not efficient at all. The indicator can be stated as *1:1*, which means for example rail-rail or rail-road direct transhipped. *1:2* means that a load unit is not directly transhipped; for example rail-stack, stack-road. This means that the crane directly put containers in the stack or that the rail and road side are connected by a cross conveyor. *1:3* implies three moves for one container: rail-cross conveyor, cross conveyor-stack, stack-road. This means that a separate device is used in the stacking area. However, *1:3* can also mean that 50% of load units are directly handled (1:1) and 50% of the load units are handled via a stack with a separate stacking device (1:4). In combination with the indicator *modalities* it is possible to draw up a broad reconstruction of the operational process at the terminal. This indicator can provide information about efficiency in combination with information on peak volumes, annual volumes and costs.

**Direct labour**
The indicator *direct labour* presents the number of operational workers who directly are part of terminal operations (like drivers, crane operators, etc.) during 8 hours. Computer operators, mechanics and staff are not included. In combination with infor-
Information on wages and opening hours the total direct labour costs for the concept can be calculated.

Spatial use
Spatial use indicates the initial surface area needed for the terminal. The surface area is given in square metres. Rail yards for sorting wagons or 'waiting room' for trains are not included in the indicator. Tracks which lay however outside the terminal but are unavoidable for the terminal operations, in order not to split and couple wagon groups before and after handling, are included in this figure. An example: a terminal of 300 x 100 meter and a train of 750 metres. Just part of the train (300 m) is inside the terminal for unloading and loading purposes. So 450 (metres) times the approximately width of the track, 5 (metres), is added to 300 x 100 (metres).

Amount of investment
This indicator shows the amount of investment in million ECU for the transhipment, stack facilities and information technology. Other additional costs like land, land preparation and buildings are therefore not included. Of hardly any concepts the total amount of investment is known. For these concepts part of the amount of investment which is available is stated. In combination with information about peak performances, network dynamics, interest rates, deprecation period and variable cost (operational costs like labour) this indicator can be used to calculate the costs per lift.

Initial volume
This indicator shows the initial volume for which the concept has been designed. The figure is either stated in TEU or in LU and per day or year.

Integration
This indicator expresses the possibility for a concept to be integrated in an existing terminal and in an existing node. Terminal and nodes are distinguished here conform the definition in chapter 1.3 A new concept can be integrated in an existing terminal as a device, a module or a terminal. A device replaces an existing transhipment device or can be added as a new transhipment device. As Module means that the concept is built up of several modules which can be implemented separately. As Terminal means that the concept can only be implemented as a complete terminal.

In an existing node a concept can be integrated integrally, as individual terminal connected by ITT (node internal transport) or as a stand alone terminal. An integral terminal means that the terminal sort of merges with existing parts of the node. ITT means that the concept can be added to the node by connecting it with other parts of the node by node internal transport system. A concept is stand alone if there is no integral or ITT integration possible. In the table first the integration in an existing terminal is stated, than the integration in a node is stated. For example: terminal/ITT.
Major barrier
New concepts often face several kinds of barriers. As an indicator for feasibility the indicator major barrier is used. Major barrier expresses the type of barrier which hinders successful implementation of the concept. One should keep in mind that the barrier experienced is related to the stage of the concept and the time progress. Categories of barriers which are distinguished are:

- financial, which means that the concepts ought to be feasible but the amount of investment is a problem;
- market, which means that a concept is either not feasible because the necessary volumes cannot be realised in the market or feasible but it is not competitive compared to road transport;
- political, which means waiting for public administrative decision;
- technical, which means that still technical problems have to be solved;
- research, which means that more research like feasibility studies and designs have to be done.

Implementation
Implementation shows the stage in which the concept is. Distinguished stages are operation, being built, pilot, stopped, feasibility studies - Financial, Operational, Design, Simulation- and idea. “Studies-f/s” means that a financial feasibility study and simulation have been carried out.

Capacity/TU
This indicator is used for internal node transport concepts, and expresses the capacity of a transport unit.

Distance
This indicator states the distance for which node internal transport concepts are designed.

Throughput/km/h
This shows the number of trips one node internal transport unit can carry out during one hour over a distance of 1 kilometre.

Convoy
This indicator states if node internal transport units can drive in convoy or that a minimum distance in between units is required.

Transport lane
Which indicates if the node internal transport system requires special (dedicated) infrastructure or not.
5.3 Evaluation of concepts

The above mentioned indicators have been used for the evaluation of the concepts. As was stated before the actors' point of view stands central in this evaluation. The concepts and indicators are presented in Tables 5.1 to 5.5. The concepts have been categorised by operations. We distinguish rail terminal concepts, barge terminal concepts, Ro-Ro rail and barge terminal concepts, sea terminal concepts and node internal transport systems. There are several reasons why these categories are chosen. Rail, barge and sea terminal concepts are put into different categories, because they are different modalities, using different infrastructure and involved with different types of transport units. These aspects influence the network dynamics and terminal characteristics. Ro-Ro rail and barge terminal concepts is a separate group, because horizontal (ro-ro) transhipment has different characteristics than vertical transhipment (lifting). Actually there should be two categories of Ro-Ro concepts: one for rail and one for barge. But because there is only one Ro-Ro barge concept both modalities are put together in one category. The reason that node internal transport systems are put into a separate category is quite obvious: node internal transport and transhipment are two different things.

The concept Steel and Paper cassettes is not presented in a table, because indicators can not be applied to the category to which this concept belongs to. The indicator electrification is only relevant for rail and rail Ro-Ro concepts. The indicator moves/h : cranes cannot be applied to Ro-Ro concepts, because most concepts are based on the fact that truck drivers drive simultaneously on and off the transport unit. The indicator has been replaced by stop time TU, which shows the time for a train or barge to stop at the terminal for unloading and loading.
Table 5.1  Rail terminal concepts

<table>
<thead>
<tr>
<th>INDICATORS</th>
<th>bundling model</th>
<th>modalities (Sim / Seq)</th>
<th>trains exchange</th>
<th>load unit</th>
<th>electrification</th>
<th>moves/h : cranes</th>
<th>stack capacity TEU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noell Megahub</td>
<td>H</td>
<td>Ra - Ro</td>
<td>6:6</td>
<td>C,S</td>
<td>other(^1)</td>
<td>600:19(^6)</td>
<td>405</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ra - Ra (Sim)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commuter</td>
<td>H</td>
<td>Ra-Ra (Sim)</td>
<td>9:9 - 11:11</td>
<td>C,S</td>
<td>flexible</td>
<td>-/30</td>
<td>600</td>
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<tr>
<td>Krupp Fast Handling System</td>
<td>L, H</td>
<td>Ra - Ro</td>
<td>1:0</td>
<td>C,S,T</td>
<td>change</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ra - Ra (Seq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact</td>
<td>L, P-P</td>
<td>Ra - Ro</td>
<td>1:0</td>
<td>C,S,T</td>
<td>change</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ra - Ra (Seq)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td>1:0</td>
<td>C,S,T</td>
<td>change</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td>1:0 - 2:0(-2)</td>
<td>C,S</td>
<td>under</td>
<td>40(^6):1</td>
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</tr>
<tr>
<td>High Rack</td>
<td></td>
<td></td>
<td>1:0 - 2:0(-2)</td>
<td>C,S</td>
<td>under</td>
<td>40(^6):1</td>
<td></td>
</tr>
<tr>
<td>Mannesman Transmodal</td>
<td>L, P-P, H</td>
<td>Ra - Ro</td>
<td>1:0 - 2:0(-2)</td>
<td>C,S</td>
<td>under</td>
<td>40(^6):1</td>
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</tr>
<tr>
<td>Noell Fast Transshipment</td>
<td>L, P-P</td>
<td>Ra - Ro</td>
<td>1:0</td>
<td>C,S,T</td>
<td>change</td>
<td></td>
<td></td>
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<tr>
<td>SUT 400</td>
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<td>Ra - Ro (Seq)</td>
<td>3:0 (3)</td>
<td></td>
<td></td>
<td>38(^6):2</td>
<td>108 LU</td>
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<tr>
<td>SUT 800</td>
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<td>Ra - Ra (Seq)</td>
<td>3:0 (3)</td>
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<td></td>
<td>76(^6):4</td>
<td>324 LU</td>
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<tr>
<td>SUT 1200</td>
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<td>Ra - Ra (Seq)</td>
<td>3:0 (3)</td>
<td></td>
<td></td>
<td>111(^6):6</td>
<td>324 LU</td>
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<tr>
<td>CCT Plus</td>
<td>L, P-P</td>
<td>Ra - Ro</td>
<td>1:0</td>
<td>C (also under 10(^6), S</td>
<td></td>
<td>20(^6):1</td>
<td>12 TEU</td>
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<tr>
<td>Small</td>
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<td>Ra - Ra (Seq)</td>
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<td></td>
<td></td>
<td>40(^6):2</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td>1:0</td>
<td></td>
<td></td>
<td>40(^6):2</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td></td>
<td></td>
<td>1:0</td>
<td></td>
<td></td>
<td>40(^6):2</td>
<td></td>
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<tr>
<td>RoadRailler</td>
<td>P-P, L</td>
<td>Ro - Ra</td>
<td>1:0</td>
<td>T</td>
<td>under</td>
<td>6:0</td>
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<tr>
<td>Compact Terminal Tuchschmid</td>
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<tr>
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<td>Tc 2/100</td>
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<td>3:3</td>
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<tr>
<td>Tc 3/350</td>
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<td>3:3</td>
<td></td>
<td></td>
<td>40(^6):1</td>
<td>150</td>
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<tr>
<td>Tc 3/600</td>
<td></td>
<td></td>
<td>3:3</td>
<td></td>
<td></td>
<td>68(^6):2(^7)</td>
<td>variable</td>
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<tr>
<td>HUPAC</td>
<td>H, P-P</td>
<td>Ra - Ra</td>
<td>5:5</td>
<td>C,S,T</td>
<td>change</td>
<td>-/30(^4)</td>
<td></td>
</tr>
<tr>
<td>Gateway Terminal</td>
<td>H, P-P</td>
<td>Ra - Ra</td>
<td>5:5</td>
<td>C,S,T</td>
<td>change</td>
<td>-/30(^4)</td>
<td></td>
</tr>
<tr>
<td>Lättkombi Terminal</td>
<td>L</td>
<td>Ra - Ra</td>
<td>1:0</td>
<td>C,S</td>
<td>under</td>
<td>15:1</td>
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</tr>
<tr>
<td>Train Coupling Sharing/Cargo Sprinter</td>
<td>C-D</td>
<td>Ra - Ra</td>
<td>-</td>
<td>C,S</td>
<td>other</td>
<td>-</td>
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<tr>
<td>Nord East Terminal Paris</td>
<td>L, P-P</td>
<td>Ra-Ro</td>
<td>3:0</td>
<td>C,S</td>
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<td>-1</td>
<td>165(^4)</td>
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<tr>
<td>Iran Terminal</td>
<td>n.a.(^5)</td>
<td>Ra-Ra (Sim)</td>
<td>6:2</td>
<td>C,S,T</td>
<td>-</td>
<td>54:2</td>
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<td>Rail Terminal Maasvlakte</td>
<td>P-P(^6)</td>
<td>Ra - DS</td>
<td>24:6(^7)</td>
<td>C</td>
<td>change</td>
<td>120:4</td>
<td>at marine terminals</td>
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See page 136 for footnotes.
<table>
<thead>
<tr>
<th>Stack flexibility</th>
<th>Container visit : moves</th>
<th>Direct labour</th>
<th>Spatial use m²</th>
<th>Initial volumes x 1,600</th>
<th>Investment mECU</th>
<th>Integration terminal/node</th>
<th>Major barriers</th>
<th>Implementation</th>
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<tr>
<td>no</td>
<td>1:2 - 1:1</td>
<td>0 Ra/10 Ro³</td>
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<td>no</td>
<td>1:1 - 1:2</td>
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<td>-</td>
<td>6.3eu /night</td>
<td>-</td>
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<td>financial</td>
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<td>-</td>
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<td>module/ ITT</td>
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<td>pilot</td>
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<td>0 Ra/2 Ro</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>no</td>
<td>1:1 - 1:3</td>
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<td>10,500</td>
<td>-</td>
<td>-</td>
<td>device/ ITT</td>
<td>-</td>
<td>studies (s)</td>
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<td>no</td>
<td>1:2 - 1:4</td>
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<td>16,800</td>
<td>36,400</td>
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<td>-</td>
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<td>0</td>
<td>36,400</td>
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<tr>
<td>yes</td>
<td>1:2 - 1:4</td>
<td>1</td>
<td>5000/200 hu/year</td>
<td>0.6³⁶</td>
<td>device/ integral</td>
<td>market</td>
<td>studies</td>
<td>pilot, device/ political</td>
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<tr>
<td>yes</td>
<td>1:1</td>
<td>0</td>
<td>100 teu/year</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>yes</td>
<td>1:1 - 1:2</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>yes</td>
<td>1:1 - 1:2</td>
<td>2</td>
<td>15,100³¹</td>
<td>0.6/0.8hu/day¹²</td>
<td>10.5</td>
<td>module/ ITT</td>
<td>financial</td>
<td>studies</td>
</tr>
<tr>
<td>yes</td>
<td>1:1 - 1:6</td>
<td>3</td>
<td>16,200³¹</td>
<td>1/1.4 hu/day¹²</td>
<td>15</td>
<td>-</td>
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<tr>
<td>yes</td>
<td>1:1 - 1:6</td>
<td>5</td>
<td>17,600³¹</td>
<td>1.3/1.7 hu/day¹²</td>
<td>18.5</td>
<td>-</td>
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<tr>
<td>yes</td>
<td>1:2 - 1:4</td>
<td>8</td>
<td>94,000</td>
<td>1 hu/day</td>
<td>terminal/ ITT</td>
<td>financial</td>
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<td>operational</td>
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<tr>
<td>no</td>
<td>1:2</td>
<td>0</td>
<td>9,000¹²</td>
<td>0.5³⁴</td>
<td>device/ stand alone</td>
<td>market</td>
<td>studies (o/f)</td>
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<tr>
<td>yes</td>
<td>1:2</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>device/ integral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>1:5</td>
<td>8</td>
<td>400,000</td>
<td>1,100 hu/year</td>
<td>module/ ITT</td>
<td>financial</td>
<td></td>
<td>studies (d)</td>
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### Table 5.2 Barge terminal concepts

<table>
<thead>
<tr>
<th>INDICATORS</th>
<th>bundling model (Sim/Seq)</th>
<th>modalities</th>
<th>barges exchange</th>
<th>load unit</th>
<th>moves/h : cranes</th>
<th>stack capacity TEU</th>
<th>flexibility stack TEU</th>
<th>container visit moves^3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barge Express active terminal</td>
<td>P-P</td>
<td>DS - Ba Ba - Ro</td>
<td>2:0</td>
<td>C</td>
<td>45:1 (x2)</td>
<td>-</td>
<td>-</td>
<td>1:3 - 1:4</td>
</tr>
<tr>
<td>Rollerbarge</td>
<td>P-P</td>
<td>DS - Ba Ba - Ro Ba - Ra</td>
<td>1:0</td>
<td>C,S</td>
<td>11:0</td>
<td>-</td>
<td>-</td>
<td>1:2 - 1:3</td>
</tr>
<tr>
<td>Selfunloading vessel (OCC)</td>
<td>L</td>
<td>Ba - Ro</td>
<td>1:0</td>
<td>C</td>
<td>10:1</td>
<td>-</td>
<td>-</td>
<td>1:2</td>
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### Table 5.3 Ro-Ro concepts

<table>
<thead>
<tr>
<th>INDICATORS</th>
<th>bundling model (Sim / Seq)</th>
<th>modalities</th>
<th>trains/barges exchange</th>
<th>load unit</th>
<th>electrification</th>
<th>stop time TU minutes</th>
<th>stack capacity TEU</th>
<th>flexibility stack TEU^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>FlexiWaggon</td>
<td>L, P-P</td>
<td>Ra - Ro</td>
<td>1:0</td>
<td>T</td>
<td>under</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>G 2000 Ro-Ro</td>
<td>L, P-P</td>
<td>Ra - Ro</td>
<td>1:0</td>
<td>T, C, S</td>
<td>under</td>
<td>10 - 30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Train Shwople</td>
<td>L, P-P</td>
<td>Ra - Ro</td>
<td>1:0</td>
<td>T</td>
<td>under</td>
<td>15 - 20</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Barge Shwople</td>
<td>L</td>
<td>Ba - Ro</td>
<td>1:0</td>
<td>T</td>
<td>n.a.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 5.4 Sea terminal concepts

<table>
<thead>
<tr>
<th>INDICATORS</th>
<th>bundling model (Sim / Seq)</th>
<th>modalities</th>
<th>vessels exchange</th>
<th>load unit</th>
<th>moves/h : cranes</th>
<th>stack capacity TEU</th>
<th>flexibility stack TEU^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Pallet Transfer System</td>
<td>L</td>
<td>DS - Ra DS - Ro</td>
<td>1:0</td>
<td>C</td>
<td>900 TEU^2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thamesport</td>
<td>L</td>
<td>DS - Ra DS - Ro DS - DS (Seq)</td>
<td>2:0 - 4:0</td>
<td>C</td>
<td>75</td>
<td>25,000</td>
<td>3571</td>
</tr>
<tr>
<td>Coaster Express active terminal</td>
<td>P-P, L</td>
<td>S - D S - Ro S - Ra</td>
<td>2:0</td>
<td>C</td>
<td>80/2 (x2)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>River-Sea Push Barge System</td>
<td>P-P</td>
<td>S - Ba</td>
<td>1:0</td>
<td>C/push barge^1</td>
<td>220^TEU/0</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Combined Traffic Carrier Ship/Barge</td>
<td>L, P-P, H</td>
<td>S - Ba</td>
<td>1:0</td>
<td>C/push barge^1</td>
<td>816^TEU/0</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Train Loader</td>
<td>L</td>
<td>S - Ro (?) S - Ra</td>
<td>1:0</td>
<td>C</td>
<td>90 TEU/2^2</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

See page 136 for footnotes.
<table>
<thead>
<tr>
<th>direct labour</th>
<th>spatial use m²</th>
<th>initial volumes x 1,000</th>
<th>amount of investment mECU</th>
<th>integration terminal/node²</th>
<th>major barrier²</th>
<th>implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>32,000</td>
<td>175 teu/year</td>
<td>2.4²</td>
<td>module/integral</td>
<td>market</td>
<td>study (f/d)</td>
</tr>
<tr>
<td>yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>terminal/ITT</td>
<td>-</td>
<td>idea</td>
</tr>
<tr>
<td>0</td>
<td>-</td>
<td>6.7 teu/year</td>
<td>0.7</td>
<td>device/integral</td>
<td>financial</td>
<td>study(d/o)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>container visit : moves²</th>
<th>direct labour</th>
<th>spatial use m²</th>
<th>initial volumes x 1,000</th>
<th>amount of investment mECU</th>
<th>integration terminal/node²</th>
<th>major barrier²</th>
<th>implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>module/integral</td>
<td>technical</td>
<td>study(d)</td>
</tr>
<tr>
<td>1:1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>0.18³</td>
<td>module/integral</td>
<td>research</td>
<td>idea</td>
</tr>
<tr>
<td>1:1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>0.72⁹</td>
<td>module/integral</td>
<td>research</td>
<td>idea</td>
</tr>
<tr>
<td>1:1</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>module/integral</td>
<td>research</td>
<td>idea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>container visit : moves²</th>
<th>direct labour</th>
<th>spatial use m²</th>
<th>initial volumes x 1,000</th>
<th>amount of investment mECU</th>
<th>integration terminal/node²</th>
<th>major barrier²</th>
<th>implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1 - 1:3</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>terminal/ITT</td>
<td>financial</td>
<td>studies(f/o/d)</td>
</tr>
<tr>
<td>1:4</td>
<td>-</td>
<td>400,000</td>
<td>450 teu/year</td>
<td>-</td>
<td>module/ITT</td>
<td>technical</td>
<td>operational, pilot¹²</td>
</tr>
<tr>
<td>1:4</td>
<td>0</td>
<td>-</td>
<td>1,700 teu/year</td>
<td>-</td>
<td>module/integral</td>
<td>research</td>
<td>studies(d/o)</td>
</tr>
<tr>
<td>n.a.</td>
<td>-</td>
<td>n.a.</td>
<td>-</td>
<td>15.1</td>
<td>module/stand alone</td>
<td>market</td>
<td>studies(f/o/d/t)</td>
</tr>
<tr>
<td>n.a.</td>
<td>-</td>
<td>n.a.</td>
<td>-</td>
<td>module/stand alone</td>
<td>-</td>
<td>studies(d)</td>
<td></td>
</tr>
<tr>
<td>1:1 - 1:3</td>
<td>4</td>
<td>-</td>
<td>28 teu/year</td>
<td>-</td>
<td>terminal/ITT</td>
<td>research/</td>
<td>studies(o/d)</td>
</tr>
</tbody>
</table>

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Footnotes by Table 5.1

1. There are no wires in the crane operational area, however no change of locomotives has to take place. The train has enough speed to cover the distance without wires and stops exactly at a location at the end of the terminal where the wires start again.
2. Although the terminal has a separate road transhipment module trucks can be handled by rail crane. This depends on the location of the load unit at the terminal.
3. This includes time to unload and load side loader; 10 LU in 40 minutes.
4. The stacking area has capacity for two trains. Estimated: 2 trains x 55 LU per train x 1.5 (TEU) = 165 TEU.
5. The terminal cannot be placed in one of the four typical bundling models. Due to different gauges direct connections cannot be realised, so load unit have to be transhipped.
6. The specific function of the terminal is sorting out and grouping containers for and from the several marine terminals at the Maasvlakte. Thus towards the network is a begin/end terminal in a P-P network, towards the node it has a C-D function.
7. Possible is also 24:6 (x4) (actors' point of view).
8. For some concepts interpretation by the researcher has taken place.
9. Rail handling is fully automated, while road handling is semi-automated.
10. Not included are: hydraulic equipment rail wagon (8 -28 kECU) and truck (7 - 10 kECU).
11. Estimated additional metres outside the terminal: 3 tracks x 5 m. x 450 m.
12. The first figure is based on 16 hours operation, the second figure on 24 hours operation.
13. Estimated: 40 meters wide and a length of approximately 450 m. (20 wagons of 60').
15. 2 million tons per year. Estimated: 15 tons per lu, is 130,000 lu.
16. Estimated: 6 tracks x 5 m. X 450 m. (Length) = 13,500.

Footnotes by Tables 5.2, 5.3 and 5.4

1. For some concepts interpretation by the researcher has taken place.
2. No cranes involved but 2 trolleys.
3. Push barges can contain containers, trailers, passenger cars or semi-bulk. Here push barges with containers are described.
4. No cranes involved but just the change of push boats, which takes less than a hour. Actually one push barge is "transshipped". The number of containers which are transshipped at once depend on the capacity of the push barge, here 220 TEU.
5. In 90 minutes 6 push barges are unloaded from the shortsea vessel and 6 push barges are loaded. Each push barge has a capacity of 102 TEU: 12 x 102 = 816 TEU.
6. No cranes involved but 2 special trains.
7. Investment for one automated quay crane.
8. Additional investment for one rail wagon body (without boogies) compared to a conventional wagon.
9. Investment for 1 unit with 30 “pop-up” devices.
10. Automated guided vehicles are being tested for transport between stacking area and quay cranes.
### Table 5.5 Node internal transport systems

<table>
<thead>
<tr>
<th>INDICATORS</th>
<th>capacity/ TU</th>
<th>load unit</th>
<th>distance (km)</th>
<th>throughput/ km/h</th>
<th>convoy</th>
<th>transport lane</th>
<th>initial volumes x 1.000</th>
<th>amount of investment</th>
<th>major barrier</th>
<th>implementation phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi Trailer System (MTS)</td>
<td>2-16 teu</td>
<td>C</td>
<td>4</td>
<td>7.5</td>
<td>yes</td>
<td>dedicated road</td>
<td>600 lu/year</td>
<td>-</td>
<td>-</td>
<td>operational</td>
</tr>
<tr>
<td>Conbi Road</td>
<td>2 teu</td>
<td>C</td>
<td>100</td>
<td>50</td>
<td>no, 180 m.</td>
<td>dedicated road</td>
<td>1.500 lu/year</td>
<td>track: 7000 kECU/km</td>
<td>financial</td>
<td>pilot</td>
</tr>
<tr>
<td>Automatic Guided Vehicle (AGV)</td>
<td>1 LU</td>
<td>C</td>
<td>4</td>
<td>18</td>
<td>yes</td>
<td>dedicated road</td>
<td>1.625 lu/year</td>
<td>-</td>
<td>technical</td>
<td>study (d,o,f)</td>
</tr>
<tr>
<td>SOG</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>yes</td>
<td>dedicated rail</td>
<td>-</td>
<td>-</td>
<td>technical</td>
<td>study (d,t)</td>
</tr>
<tr>
<td>SST</td>
<td>3 TEU pieces</td>
<td>pieces</td>
<td>33</td>
<td>-</td>
<td>yes</td>
<td>common rail</td>
<td>1.7 - 7 pieces per day</td>
<td>-</td>
<td>technical</td>
<td>pilot/operational</td>
</tr>
</tbody>
</table>

1 For some concepts researchers interpretation.
5.4 Comparison of concepts

The identification of promising directions is an iterative process of ordening, making comparable, comparing, evaluating and analysing. In chapter 4 concepts have been described and ordered into categories of operation (by modality). In section 5.1 and 5.2 the concepts have been made comparable and evaluated for certain indicators, which is presented in Tables 5.1 to 5.5. These tables can be used as tool for further ordening, evaluation and comparing, which are next steps in the identification process. The line of the actors’ point of view is still followed. Researchers’ point of view is only added in order to make concepts more comparable. Interpretation of the tables is split up in a specific part and a general part. For some of the indicators (like bundling model, modalities, load unit, peak volume) the concepts are discussed within in one category of operations (section 5.3.1 to 5.3.5). Other (more general) indicators are discussed in the general part (section 5.3.6).

5.4.1 Comparison of rail concepts

There are 12 rail terminal concepts described. As far as information is available 6 of the 12 concepts are designed for large volumes, which is for 150,000 and more load units\(^1\). Commutor and Rail Terminal Maasvlakte have been designed for volumes above the million load units per year. CCT Plus and Lättkombi Terminal have been especially designed as small terminals for freight streams between 10 (3,120/year) and 250 (78,000/year) load units per day. But also the Compact Terminal of Tuchschmid knows two small scale variants for 20 (6,240/year) to 100 (31,200/year) lifts per day.

Rail terminals always have to find a way to deal with the electrification. Eight of the 12 rail terminals have found a solution to avoid changing of locomotives. In these concepts the catenary can either be moved away or the operation can take places underneath the catenary. In the other terminal concepts either a special locomotive is needed or the arriving trains run unpowered and decelerating through the terminal. In the Krupp Fast Handling System the change of locomotive is unavoidable because of the fact that the train is unloaded and loaded while the trains slowly moves through the terminal.

We can distinguish three sub-categories: megahub terminals, terminals for line networks and other concepts.

**Concepts for hub and spoke networks**

Mega hub terminals are Noell Megahub, Commutor and Gateway Terminal HUPAC. The first two concepts are designed for large scale fast simultaneous exchange of load units, in order to replace shunting yards. Trains stay no longer than 1.5 hours at those terminals. The relative high peak performance per hour is realised with a fully robotized rail operation. Both terminals have a cross conveyor systems which moves

\(^1\) Information in the column “initial volume is converted to figures in LU/year. Herefor it is assumed that the existing figures are based on open hours of 6 days per week (300 working days) and that the 20’/40’ ratio is 50% to 50% (yTEU / 1.33 = x LU).
containers in the longitude direction along the trains, in order to minimise crane driving. Information technology and electronic data interchange have an important role in the Noell Megahub and Commutor concepts. Noell Megahub also has a road transhipment module for which the same cranes are used during day time, while the hub function of the terminal is carried out during night, when no trucks are handled. Truck handling is carried out in a semi automated mode of the cranes.

The Gateway Terminal HUPAC is a different type of hub and based on conventional technology. At the Gateway Terminal mainly sequential transhipment between trains takes places, which means that the load units stay longer at the terminal. Only 5% of the load units are directly exchanges between trains. In contradiction with the other two terminals, the Gateway Terminal is able to handle trailers.

The Gateway Terminal needs more space (94,000 sq.m) than the Noell Megahub (50,400 sq.m.), while the later handles a larger annual volume (500,000 against 300,000 lu/year for Gateway Terminal). The spatial use for Commutor is not described, but there are 14 tracks of about 5 meter wide and 750 meter long plus a storage area of approximately 1,200 sq.m.², which means a surface of approximately 53,700 sq.m. for 1.4 million load units.

All three rail terminals are equipped to handle containers and swap bodies. Trailers can only be handled at the Gateway Terminal Hupac.

**Concepts for line networks**
Krupp Fast Handling System, Transmann Handling System, Noell Fast Transhipment, CCT Plus, Compact Terminal Tuchschmid and Lättkombi Terminal are terminal concepts designed for operations in line networks. The main part of these concepts can only handle one train at the time, because the terminal only has one track, one crane or both. The medium and large variants of Noell Fast Transhipment and Compact Terminal Tuchschmid have capacity for the handling of 3 trains at the same time. The Krupp concept and the Transmann Handling machine have the possibility for a second track but it was not the initial intention.

CCT Plus, Lättkombi Terminal and the small variant (CT 2/100) of the Compact Terminal Tuchschmid are designed for small freight streams (<10,000 LU per year). The other Tuchschmid variants can handle between 150,000 and 450,000 load units per year. The Krupp medium sized terminals handles 158,000 load units per year. The surface of the terminals varies between 9,000 sq.m. and 32,400 sq.m. The Krupp and Tuchschmid concept need less space than the Noell Fast Transhipment concept.

There is quite some variation in the peak performance per hour, which varies between 15 and 220 moves per hour. The Krupp Fast Handling Machine (large and high rack variant) is relatively very fast, 220 moves/hour only for the rail operation. However

² 30 containers (40') long and 10 containers wide.
the day throughput of Krupp is lower than that of Tuchschmid. This could be explained by different assumptions of network dynamics and utilisation rate of equipment.

All concepts except Krupp Fast Handling System have in common that load units are stored parallel direct next to the track, which minimises crane driving. In the Noell Fast Transhipment, Transmann Handling Machine and Compact Terminal Tuchschmid concepts, trucks are handled direct next to the train in order to realise direct transhipment rail-road. Condition is that truck and train are available at the same time. The terminal operation at the Krupp terminal is based on a different concept, the so called “Rendez-Vouz” technique. Unloading and loading is carried out simultaneously. While the train drives slowly through the terminal two cranes are unloading, while some metres along the track two cranes are loading. The load units are delivered and picked up by two cross conveyors (one for unloading and one for loading). Krupp is the only concept where trucks are handled at the other side of the terminal with special semi-automated cranes. However the Compact Terminal also has a separate road module beside the truck handling next to the rail tracks.

In the concepts CCT Plus, Noell Fast Transhipment, Transmann Handling Machine and Compact Terminal Tuchschmid the equipment can be semi-automated as well automated. The direct labour input which is mentioned in table 5.1 depends on the level of automation. Lätkombi Terminal is based on conventional technology but has a new form of organisation (lifting dence is on board of the train) in order to realise low costs.

Krupp Fast Handling System, Noell Fast Transhipment, Compact Terminal Tuchschmid and CCT Plus are flexible in their terminal lay-out. The concepts are based on modules and components (such as cranes, stack units) and can be composed for different initial volumes, but also be adjusted to growing or decreasing volumes.

Containers and swap bodies can be handled in all these concepts. CCT Plus (is the only rail concepts which can) handle 10’ containers, but it can not handle 40’ containers. Trailers however cannot be handled in the Transmann, CCT Plus and Lätkombi concept.

Other concepts
RoadRailer, Train Coupling Sharing/Cargo Sprinter and Rail Terminal Maasvlakte belong to this category. The Train Coupling and Sharing/Cargo Sprinter concept suits in a C-D network. The concept actually is not a terminal concept, but rather a technique which makes transhipment at a C-D terminal redundant. Information on peak performance, terminal operations and annual volumes are not available. RoadRailer is an existing concept which uses special rail boogies to couple trailers: no vertical transhipment is necessary. It has a performance of 6 trailers per hour, which is compared to the other concept very low. It would be interesting to study why this concept is viable and which markets it serves. At first stage it seems to be a solution for a niche
market. The Rail Terminal Maasvlakte is a begin/end terminal located in a large marine node. The concept does not aim at fast transhipment, but on efficient node internal transport operations in the node. For this reason the terminal has a sorting and grouping function. The actors mention that fast transhipment is not necessary, because trains stay between 8 and 12 hours at the terminals before they leave again. This is also the reason why the terminal has so many tracks and so few cranes. The terminal can only handle containers.

Above we discussed the concepts on their primary function in the network. It is remarkable how often actors indicate their concept to be suitable for several types of networks. The characteristics of a line, point-to-point, C-D or hub and spoke network are rather different, which would imply different design and performance criteria for terminals in such networks. Here we discuss shortly the possibilities of concepts for the secondary function. The developers of the Krupp Fast Handling System, Transmann Handling Machine and Noell Fast Transhipment concepts state that these terminals are also suitable for hub and spoke networks, but no (or rather limited and/or with additional handlings) simultaneous transhipment can take place. In order to be a hub terminal, the Krupp terminal needs a yard where trains can be parked, because only one train (according to the actor 2 tracks should also be possible) can be handled at a time and it has to drive through the terminal. At first sight it seems a rather complicated operation. The same type of operation with trains being parked outside the terminal would be necessary for the TransMann Handling machine. Noell Fast Transhipment concept has the possibility to exchange between 3 trains, but in order to do so containers have to be lifted more often, because exchange has to take place via the highbay rack in between the rail tracks. This could affect the performance per hour. At this stage the is no reason to assume that a function as begin/end terminal in a point-to-point network for the concepts which claim this, would not be possible.

5.4.2 Comparison of Barge Concepts

There are three innovative barge terminal concepts described, Rollerbarge, Barge Express and self(un)loading vessel. The first two are concepts for large scale (>100,000 load units per year) point-to-point networks, the self(un)loading vessel is developed for small scale line networks. Rollerbarge is a concept in which badges of containers on large pallets are transhipped. With these badges a performance of 110 moves per hour could be realised. The transhipment of these pallets is automated, but the (un)loading of the large pallets is done by a conventional crane or reach stacker. Barge Express is a fully robotized terminal with a performance of 45 moves per hour. The advantages and disadvantages of both concepts should be studied in order to find out how these terminals will perform in a point-to-point network.

5.4.3 Comparison of Ro-Ro Concepts

In the category Ro-Ro concepts three rail Ro-Ro concepts are presented by the actors as both line and point-to-point terminal. These concepts are able to realise fast transhipment. A whole train with 50 wagons can be unloaded and loaded in 30
minutes, however there is one very important condition which has to be met: truck drivers should be in time, because in the concept it is assumed that they will do the unloading and loading simultaneously. This seems rather optimistic. G 2000 Ro-Ro could also handle containers and swap bodies, but this takes extra time for transhipment. All three concepts focus on an easy access of trailers onto rail wagons. Therefore in all concepts rail wagons or special swivel frames at rail wagons can turn about 35 degrees. In the FlexiWaggon and TrainShwople concept this goes automatically, while in the G2000 Ro-Ro concept a manual operated machine has to be used. In this later concept the wagons are covered because the train is designed as a fast train.

The only barge Ro-Ro concept is presented as suitable for a line network. While in the rail concepts just the trailer stays on the wagon, in this concept also the engine truck stays at the barge. This implies that truck drivers should stay ready at the terminal in order to drive the truck and trailer on and of the barge. The combination of the following facts; relative slow transport, relative low utilisation (in tons) of the barge and transport of both load unit and truck and trailer, makes one wonder in which situation/market this concept will be viable.

5.4.4 Comparison of Sea Concepts
Within this category we can distinguish three sub-categories: concepts which are based on the transhipment of badges of containers, concepts which aim to avoid transhipment and concepts which apply vertical transhipment.

Train Loader and Container Pallet Transfer System (CPT) belong to the sub-category transhipment of badges containers. The Train Loader concept applies (two) special trains and CPT mega pallets. The trains and mega pallets are (un)loaded at the quay while the vessel is at sea. The Train Loader seems to suit better (more flexible) in a line network, because on board the trains are unloaded and later loaded again, while the composition of the mega pallets cannot be changed on board. The transhipment of trains and mega pallets is automised, while the loading and unloading at the quay (and on board in the train loader concept) is carried out manually, although automation is possible. Train Loader is designed for small scale freight streams, while CPT is designed for a large scale freight streams.

River-Sea Push Barge System and Combined Traffic Carrier Ship/Barge are concepts which aim to avoid transhipment of load units. In these concepts complete barges are “transshipped”. In the first concept only push boats have to be exchanged and in the second concept six push barges sail simultaneously out and a few minutes later six other push barges sail into the vessel. Because of this exchange of complete push barges transhipment is carried out very fast and many containers (but also other cargo) are involved. These concepts are designed in order to strengthen shortsea/barge networks. Although this is a specific part of the market, these concepts could be very promising (because of the relative low investment and adaptation of transport units) if freight streams are large enough.
Coaster Express and Thamesport apply vertical transhipment. The first is a fully automated terminal, the later a conventional terminal which will switch to automated guided vehicles in the near future. In relation to the two other categories is the peak performance of these concepts rather low. Coaster Express is designed for a yearly throughput of 1.7 million TEU, which is rather large.

Remarkable is the fact that the Combined Traffic Carrier Ship/Barge suits in a hub and spoke network. Several sea vessels from different sea transport links meet in the same harbour. They exchange push barges and return with a new set of push barges to their origin. This hub and spoke network is limited to countries with a good inland waterways infrastructure.

5.4.5 General comparison of terminal concepts
In the previous sections the concepts have been discussed on performances, volumes and function in the network. For a more realistic comparison of the concepts costs should be taken into account. Unfortunately limited information on costs is available. If the amount of investment is already available it is often only the amount for one transhipment device. In order to compare the available investment information on new-generation technology with conventional technology: a conventional common rail-road inland terminal crane costs 1 million ECU (European Commission, 1995). To identify promising, probable and missing directions and to evaluate concepts on the cost quality ratio, information on amount of investment and operational costs is essential. On behalf of further analyses it should either still be obtained or a way should be found to estimate these costs.

A large part of the concepts require adjustment of transport units. Although the adjustments vary between attaching special plates for positioning and complete new development wagons or barges, it reduces the flexibility to allocate transport units in the network and it causes small or large extra investments on top of the terminal investment.

As far as barriers are mentioned by the actors, five times the height of the amount of investment is mentioned as major barrier for implementation. For 4 concepts the market situation is mentioned as major barrier. These concepts are either feasible but not competitive enough to road or not feasible due to a too small volume in relation to the costs. Political barriers are not mentioned. Two concepts still suffer technical problems which have to be solved. For four concepts further research has to be done. Three of this concepts are still in the idea stage of the implementation process.

Most concepts (15) are in the stage of feasibility studies and design. Some of these projects are already at the end of this stages and are searching for finance to start a pilot or have already proven their innovative technology in pilot plants (4 concepts). All projects in the pilot stage are searching for orders to build. Feasibility studies and pilots are often subsidised by national or regional governments and sometimes by the European Union. Commutor has been stopped, because a new fleet of rail wagons had
to be built (while the network operators did not wish to change their wagons) and the
taxiarchs seemed to become too high in order to be viable. However, the automatic
handling device of the Commuton concepts is still in development. Operational are
already Thamesport, Gateway Terminal HUPAC and RoadRailer. The first two do not
apply innovative technology. The AGV of Thamesport is still in a pilot phase. The
Noell Megahub is close to implementation. The expectation is that in December 1997
the German Railways was provide an order to build the terminal in Hannover/Lehrte.
However, due to the liberalisation the decision about this order has been postponed.

German actors are strongly involved in the development of innovative rail terminal
concepts, while the Dutch are strongly involved in barge innovative terminal concepts.
In Germany the involved actors are equipment manufacturers, while in the Nether­
lands the new concepts mainly appear from research institutes and consultants, how­
ever often in co-operation with equipment manufacturers and transport or terminal
operators. Four innovative concepts (one partly Dutch and partly Swedish) have a
Swedish background. The involved actors are the Swedish Railways (twice) and
private inventors (twice). Great Britain is involved with 3 concepts; involved actors
are respectively twice (the same) inventor and a terminal operator. Italy, Switzerland,
Norway and France are involved with one concept each. The Italian concept (however
not innovative) is developed by a transport operator. The Swiss and Norwegian con­
cepts are developed by equipment manufacturers, the France concepts also, but in co­
operation with the France Railways.

There seems to be a relation between certain terminal developments and the countries
where they are developed. In Germany the Deutsche Bahn policy is among others
attracting more cargo to the rail by setting up national networks. The largest part of
the concepts presented by Noell, Krupp and Mannesman in the first place where
developed for terminals in a line network. These concepts however have evolved due
to feedback from the market, further research and new plans of the Deutsche Bahn to
develop hub and spoke systems. Now these concepts can be used in different type of
bundling networks and can be built for several volumes of freight streams.

In Scandinavia freight streams are rather small and distances are high. Road is the
main mode of transportation. To attract road cargo to intermodal transport, terminals
must be simple and easy to access, while transhipment costs must be low. In the Neth­
erlands barge transport has a strong position and carries large volumes from and to the
mainport Rotterdam from and to the hinterland (Germany and Antwerp). Future
volumes are expected to raise enormously. Concepts like Barge Express and Roller­
barge are based on these facts.

5.4.6 Comparison of node internal transport systems
Concerning the distance the Multi Trailer System (MTS) and the automatic guided
vehicle (AGV) system have been designed for a concrete relative small scale sea
terminal node. The AGV system is developed with the aim to handle increasing
volumes. AGVs for terminal internal transport are already operational, but these
AGVs are technically (speed and convoy driving possibilities) not suitable for internal node transport. Combi-Road is designed for large congested nodes and claims to be able to cover a distance of 100 kilometres. Major barrier is however the high investment for dedicated infrastructure. SOG and SST are concepts for node transport by rail. SST is the only concept which does not need dedicated infrastructure. Convoy driving can be carried out by all concepts except Combi-Road.

5.5 Preliminary conclusions

Within the category rail terminal concepts the investigation has resulted in concepts for each of the four basic bundling concepts. Rail terminal concepts for small freight streams as well large freight streams have been investigated. Within the category barge terminal concepts there are two concepts for point-to-point medium and large networks and one concept for small scale line networks. For both categories Ro-Ro concepts have been investigated, too. Within the category sea terminals mainly line and point-to-point can be applied, but also a hub terminal concept can be distinguished. Most of the concepts are designed for large freight streams.

No Barge, Ro-Ro and Sea terminal concepts which are developed for simultaneous exchange between transport units, are part of the investigation.

No tri-modal inland terminal is part of the investigation.

So far only a very global comparison have been made, because figures for certain indicators depend on network dynamics. Figures for indicators of performance, capacity and annual volume should be confronted with the dynamics of different network in order to identify which terminal(s) performs the best in which network.

The reasons why concepts are developed differ, but most actors say they focus on fast transhipment and/or low costs. Compared to conventional transhipped (25 moves per hour per crane) indeed most concepts perform better.

It is difficult to determine whether concepts realise low costs, because the information on investments and operational costs is too limited for a realistic evaluation of concepts on the cost/quality ratio and a comparison between the concepts. This must be overcome in further research to be able to compare concepts.

The amount of investment, the minimum volume, and the low price of road transport are most mentioned as barriers.
LITERATURE

AA. VV., 1997, Intermodalità nell’area milanese, Transporti in Lombardia.


AngloBridge, 1996, Tor Line (DFDS Group of Companies) brochure.

Berglund, L., 1997, telephone interview by J. Gröhn, Berglund is the inventor of G2000 Ro-Ro.


BTZ company, Brochure.


Cargo Systems, 1996, European Intermodal Yearbook; Directory of Intermodal transport, equipment and services.

Chauvet, C., 1997, interview by L. Demilie, Chauvet is employee of SNCF-intermodal.

Cholerton Limited (I.O.M.) promotional literature.

Clarke, M., 1997, interview by I. Gordon, Clark is employee of Cranfield University.


Deutsche Bahn, 1995b, *Kundenbrief* nr. 3 (Mürz, 40. Jahrgang), Mainz.


Dihlmann, 1997, telephone interview on the 16th of April (Delft-Düsseldorf) by E. Kreutzberger, Dihlmann is employee of Mannesmann.


Eriksson, J., 1997, interview by J. Gröhn, Eriksson is the inventor of FlexiWaggon.

Erni, I., 1997, interview by T. Spiciarelli, Erni is employee of Tuchschmid Engineering AG.


Fabel, P., 1997, interview on the 21st of March in Minden by E. Kreutzberger, Fabel is head of the research and development department for innovative freight systems of the German railways (DB).


Franke, K.P. and M. Brumme, 1997, interview on the 28th of May in Würzburg by E. Kreutzberger, Franke is development manager at Noell, Brumme is also employee by Noell.


Guigon, Marc and Lorain, interview, June 1997 by L. Demilie, Guigon is employee of SNCF and responsible for research. Lorain is employee of CNC and responsible for the infrastructure.

G 2000 RO-RO The Ultimate Goods Train; an animated 3 minute video without sound describing the system.


Huijsman, H., 1997, telephone interview on the 11th of April by R. Konings, Huijsman is consultant of Husson Huijsman consultancy bv Rotterdam.


HUPAC S. A., La sfida per il terzo millennio.

Incomaas 1996a, Masterplan, Rotterdam, Centrum Transport Technologie.

Incomaas 1996b, Deelstudie Spoorcontainers, Rotterdam, Centrum Transport Technologie.

Incomaas, 1996c, Deelstudie Inter Terminal Transport, Centrum Transporttechnologie, Rotterdam.


Keim, J-E., 1996a, correspondence with E. Kreutzberger, Keim is sales manager of TTS Drobak AS.

Keim, J-E., 1996b, telephone interview by J. Gröhn, Keim is sales manager of TTS Drobak AS.

Kinna, A., 1997, interview by I. Gordon, Kinna is employee of Avesta Sheffield Ltd.


Koch, J., 1997, interview on the 28th of April in Wiesbaden by E. Kreutzberger, Koch is employee of Transcare consultants.


Lehtonen, M., 1997, interview by J. Gröhn, Lehtonen is employee of Metsä-Serla, R&D department.

Lövgren, S., 1997, interview on April 15 by J. Gröhn, Lövgren is employee of Proveho AB, the developer of CCT Plus.


Palmqvist, M.O., 1997, *interview* by I. Gordon, Palmqvist is employee of Tor Line Limited.


Projectbureau Combi-Road, 1996, *Combi-Road*, Eindrapport, publicatiereeks Centrum Transport Technologie.


Schölch, M., 1996, Developing an intermodal global strategy to meet changing customer requirements, in: European Intermodal Association, Intermodal 96 conference documentation. Track IV: Air Cargo, London. Schölch works at Flughafen Frankfurt Main AG.

Segerberg, L., telephone interview by J. Gröhn, Segerberg is employee of Volve Transport Corporation.

ShortBridge, 1996, Tor Line (DFDS Group of Companies) brochure.

Sjödén, A., 1997, interview on March 21 by J. Gröhn, Sjödén is employee of the Swedish Railways, strategic planning.

SNCF Commutor brochure.

Sondermann, K.-U., and D. Zimek, 1997, interview in Essen on the 10th of April by Y. Bontekoning and E. Kreutzberger, Sondermann and Zimek are employees of Krupp.

Soto, 1997, interview by L. Demilie, Soto is employee of RENFE.


TRAIL Onderzoekschool, 1996, Barge EXpress; innovatief perspectief voor de internationale binnenvaart, Delft.


Tuchschmid Engineering AG, 1995, Compactterminal, Frauenfeld, Switzerland.
Van Erven Dorens, P.J., 1995, **OCC (One Container Call) Line**, concept submitted for the competition of Bureau Voorlichting Binnenvaart, July.

Van Erven Dorens, P.J., 1997, telephone interview on the 28th of May by R. Konings, Van Erven Dorens is employee of Innovatiecentrum Zuid.


Volvo op zoek naar alternatief transport, 18/3/1997 in: a Dutch newspaper article.

Volvo Transport Corporation, video about with a brief animated description of the CPT mega-pallet system.

Wede, J-O., 1997, interview by J. Gröhn, Wede is employee of SJ and project leader of the Lättkombi project.


Wijnolst, N., 1995, **Design innovation in shipping**, Delft.

Woxenius, J., 1998, **Development of small-scale intermodal freight transportation in a systems context**, Department of Transportation and Logistics, Chalmers University of Technology, Göteborg, Sweden.

World Cargo News, 1997, **Looking for a big push off**, nr. 5, May.

Zimmermann, V. and D. Zimek, 1997, correspondence, Zimmermann and Zimik are employees of Krupp.

Zunder, T., 1997, interview by I. Gordon, Zunder is employee of Avesta Sheffield Ltd.
## APPENDIX I
### EXCLUDED CASES

Table 1.1  Cases Germany and The Netherlands

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial interest</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Hamburg/Bremen area</td>
<td>considering new generation sea terminal and important rail hinterland connections</td>
<td>no priority</td>
</tr>
<tr>
<td>Rail Distribution Netherlands</td>
<td>new national intermodal rail network with fast transhipment terminals</td>
<td>no priority</td>
</tr>
<tr>
<td>Thyssen Hangbahn</td>
<td>fast transfer on small surface; containers hang underneath something like a monorail and move along</td>
<td>too late awareness</td>
</tr>
<tr>
<td>Zilveren Spoorlijn</td>
<td>board/board transhipment barge/sea</td>
<td>not enough information</td>
</tr>
<tr>
<td>Cargo Sprinter Airport Frankfurt - Zurich</td>
<td>Cargo Sprinter in operation</td>
<td>no priority</td>
</tr>
<tr>
<td>Logistic Box</td>
<td>small container and new bundling possibilities</td>
<td>well known concept</td>
</tr>
<tr>
<td>Node Valburg</td>
<td>new to build rail hub terminal; expected need for NG-solutions</td>
<td>no priority</td>
</tr>
<tr>
<td>NDX Intermodal</td>
<td>type of actor</td>
<td>not enough information</td>
</tr>
<tr>
<td>Trailstar</td>
<td>type of actor</td>
<td>no interest in participating</td>
</tr>
<tr>
<td>Scansped</td>
<td>type of actor</td>
<td>not involved in intermodal transport</td>
</tr>
<tr>
<td>ACTS</td>
<td>new technology for fast direct rail-road transhipment</td>
<td>well known concept</td>
</tr>
</tbody>
</table>
Table 1.2 Excluded concepts Finland, Denmark, Sweden en Norway

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial interest</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port of Turku (FinnCarriers/Railship)</td>
<td>rail ferry traffic and bogie change station; appeared to be a need for NG-solutions</td>
<td>no interest in participating</td>
</tr>
<tr>
<td>Kesko (big wholesaler)</td>
<td>type of actor</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>Finnish Post</td>
<td>automated handling of letters and parcels, own handling units</td>
<td>not involved in intermodal transport</td>
</tr>
<tr>
<td>Kvaerner Masa-Yards</td>
<td>involved in development fast ships; expectation that they have ideas about past terminal operations</td>
<td>no interest in participating</td>
</tr>
<tr>
<td>Finnish Forwarders</td>
<td>type of actor</td>
<td>neglectable involvement in intermodal transport, no NG-technology</td>
</tr>
<tr>
<td>Inland waterway terminals</td>
<td>type of actor</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>TECO-Engineering</td>
<td>Wheelless cassette system</td>
<td>no interest in participating</td>
</tr>
<tr>
<td>LIFTEC</td>
<td>container mover with automated guided wheels</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>Rail Combi Sweden</td>
<td>type of actor</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>Volvo Transport Corporation</td>
<td>tests with concepts of TTS Drobak (CPT) and Thornycroft Giles (air cushion train)</td>
<td>not enough information</td>
</tr>
<tr>
<td>Port of Trelleborg</td>
<td>fast intermodal transport</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>Rail Terminal Malmö</td>
<td>increasing importance as a node due to new Øresund bridge</td>
<td>no interest in participating</td>
</tr>
<tr>
<td>Rail terminal Hallsberg</td>
<td>most important shunting yard in Sweden</td>
<td>not involved in intermodal transport</td>
</tr>
<tr>
<td>Port of Gothenburg</td>
<td>involved in fast terminal operation project</td>
<td>no interest in participating</td>
</tr>
<tr>
<td>Alnabru Rail Terminal</td>
<td>fast growing terminal for combined transport in Norway; appeared to be a need for NG-solutions</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>Kvaerner Norway</td>
<td>Integrated Port/Ship Interface</td>
<td>not enough information</td>
</tr>
<tr>
<td>Danish Railways</td>
<td>type of actor</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>Fredericia/Vejle/Taulov</td>
<td>appeared to be a need for NG-solutions</td>
<td>not enough information</td>
</tr>
<tr>
<td>Padborg Transport Centre</td>
<td>new concept of transport centres</td>
<td>no NG-technology</td>
</tr>
<tr>
<td>Port of Copenhagen</td>
<td>important multimodal node</td>
<td>not enough information</td>
</tr>
</tbody>
</table>
Table 1.3 Cases Belgium, France, Spain and Portugal

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial Interest</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail terminals Cirkeldyk and Zomerweg</td>
<td>congested terminal with a need for expansion; appeared to be a need for NG-solutions</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Followers of Commutox</td>
<td>automatic handling load units with the existing gantry crane</td>
<td>too late awareness</td>
</tr>
<tr>
<td>Autoroute Ferroviaire</td>
<td>new rail concept</td>
<td>too late awareness</td>
</tr>
<tr>
<td>Euro-Combi Est Terminals Liège</td>
<td>tri-modal terminal for small streams</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Noisy Terminal</td>
<td>congested terminal with a need for expansion; appeared to be a need for NG-solutions</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Athus Terminal</td>
<td>new rail terminal</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Tri-modal terminal Brussels</td>
<td>new tri-modal terminal</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Flanders Containers Terminal Zeebrugge</td>
<td>applying and developing new technology: twin spreader and information system which allows simultaneously unloading and loading</td>
<td>applied NG-technology does not meet the Terminet criteria for NG-technology</td>
</tr>
<tr>
<td>Uzeren Lijn</td>
<td>improvement rail hinterland connection</td>
<td>no response</td>
</tr>
<tr>
<td>Noordzee Terminal</td>
<td>new sea terminal with rail terminal</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Mouscron Terminal</td>
<td>new terminal to replace, because Lille terminal which cannot further be enlarged; appeared to be a need for NG-solutions</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Muizen Terminal</td>
<td>important hub for Northwest Europe with simultaneous rail-rail exchange</td>
<td>no NG technology, shunting yard</td>
</tr>
<tr>
<td>Hub Metz</td>
<td>large European hub</td>
<td>no NG technology, shunting yard</td>
</tr>
<tr>
<td>Terminal of Valenton</td>
<td>large begin/end terminal for mainly national freight streams, plans for expansions</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Port of Le Havre</td>
<td>possibilities for NG operations expected</td>
<td>no response</td>
</tr>
<tr>
<td>Intercontainer</td>
<td>possibilities for NG operations expected</td>
<td>no response</td>
</tr>
<tr>
<td>Terminal Alcantra-Sud</td>
<td>expansion plans; appeared to be a need for NG-solutions</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Port of Douro and Leixoes</td>
<td>possibilities for NG operations expected</td>
<td>no response</td>
</tr>
<tr>
<td>Port of Lisbon</td>
<td>possibilities for NG operations expected</td>
<td>no response</td>
</tr>
<tr>
<td>Centre Logistic Barcelona</td>
<td>possibilities for NG operations expected</td>
<td>no response</td>
</tr>
</tbody>
</table>
### Table 1.4 Cases Italy, Austria, Greece and Switzerland

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial interest</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gateway Terminal Operator</td>
<td>Hub terminal with direct rail-rail</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>CEMAT</td>
<td>transshipment</td>
<td></td>
</tr>
<tr>
<td>MedCenter Container Terminal</td>
<td>possibilities for NG operations expected</td>
<td>no NG technology</td>
</tr>
<tr>
<td>LaSpezia Container Terminal</td>
<td>possibilities for NG operations expected</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Voltri Terminal</td>
<td>possibilities for NG operations expected</td>
<td>no NG technology</td>
</tr>
<tr>
<td>Swiss Railways</td>
<td>type actor</td>
<td>no interest in participating</td>
</tr>
<tr>
<td>Centro Studi Confetta</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>FS (logistics division)</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Assodocks</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Saima Avanderio</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Bologna Interport</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Tecnologistica</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>DANZAS</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Zust Ambrosetti</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Ambrogio</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Italcontainer (ICF group)</td>
<td>possibilities for NG operations expected</td>
<td>not enough information obtained</td>
</tr>
</tbody>
</table>

### Table 1.5 Cases UK and Ireland

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial interest</th>
<th>Reason for exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thornecraft Giles</td>
<td>air cushion train</td>
<td>not enough information obtained</td>
</tr>
<tr>
<td>Freight Village</td>
<td>possibilities for NG operations expected</td>
<td>well known concept</td>
</tr>
</tbody>
</table>
APPENDIX II
QUESTIONNAIRES

TERMINAL CONCEPT

Introduction

This questionnaire is developed to gather information inside WP2 on the area of new generation (= NG) terminal concepts (including concepts with transhipment for new generation transport units such as fast vessels or auto-loading vessels) and terminal concepts of which parts may be robotized and automated on the longer term (retrofit). The terminal concepts may have been developed for a certain terminal-location or for the market of unknown future buyers.

Which questions are to be asked during the interview? Distinguish two situations:
- The starting point is a concrete terminal-location in which the implementation of a (NG-)terminal-concept is considered. Start at block A.
- The starting point is an abstract terminal-concept which could be implemented at any suitable terminal-location. Start at block C.

A. GENERAL INTRODUCTION concrete TERMINAL LOCATION

1. What is the project in general terms about?

1a. Why is the terminal location being developed?
Possible answers:
- implementation of an innovative bundling concept (which one?). The existing terminal can’t meet the cost quality requirements which are the consequence of the new bundling concept;
- existing terminal doesn’t meet the demands even though the bundling concept generally hasn’t or won’t change;
- new transport units (like fast or auto-(un)loading vessels) or load units (like swap bodies or Commutor containers) to be introduced.
1b. What are and will be the general characteristics of the terminal location?
Like type of terminal, size, modality, kind of load units, market characteristics, function and location in the bundling network, public or private, general flow dynamics.

Type of terminal (not exclusive):
- parallel or sequential (un)loading of transport units like necessary in hub-terminals of hub and spoke networks;
- big volumes;
- quick simultaneous unimodal exchange of units (like rail-rail-exchange);
- quick simultaneous multimodal exchange of units (like road-rail in rail-line-networks);
- for quick simultaneous exchange of big volumes of units (like in hub-terminals of rail-networks);
- for the coupling and splitting of transport units (trains, barge combinations);
- for the exchange of transport units (like train wagons and train parts on shunting yards);
- flow dynamics are like: trains are always loaded in the afternoon, trucks come mostly early in the morning and between 15.00 and 20.00 hour, etc.

The mentioned characteristics can be of importance for the choice of a terminal concept. Example: the Noell Mega-hub terminal concept, and some terminal concepts inside Commutor are suitable for quick exchange of load units between simultaneously loading and unloading trains on the major network. The same is true at a smaller scale for the Compactterminal of Tuchschmid.

If possible, distinguish dominant (like quick rail-rail-exchange is the central issue) and other operations of the node.
- load units: maritime containers, continental containers, other continental load units;
- Market characteristics: time and reliability sensitive goods (e.d. express or high value), partial loads (LCL).
- Is the terminal open to customers of a network (like trucks to a rail terminal) or is it a technical terminal, only of importance for the network operator (like a shunting yard)?
- If it is open to customers, does the terminal-location have a public function (like a terminal with train shuttles for any customer) or is its use restricted to one or a small number of users (like a terminal with train shuttles for only one or a few shippers, ocean lines or other transport operators)?
- Typical location in the network are: on the boarder between long distance and CD-networks (example: the floating container terminal-concept in Rotterdam was designed for terminals on the border between CD- and long distance networks of barges), inside long distance network (e.g. terminals for quick exchange).
B. SPECIAL FEATURES CONCRETE TERMINAL LOCATION

2. Can a concrete indication of the present and expected (2000, 2010, 2020) volume of transhipment, stack and of modal split be given? What are important assumptions or expectations?
   - in load units, TEU, tonnes, per modality and total;
   - in number of trains, barges, trucks etc.;
   - for both points distinguish: per year, per week, working day and in peak hours;
   - example assumption/expectation stack: dwell time stack (this is the time load units stay in the stack. This can vary from several hours to several months.

3. Which measure will meet the objectives of the development of the terminal location?
   Measures: like spatial layout and organization, operational measures like information logistics or optimization of physical operations, technical measures, infrastructural measures.
   A very important technical measure inside Terminet is the implementation of technical concepts the fast transhipment, compact hub and harbour-terminals of Noell, Tuchschmid, Krupp, Mannesmann, Technicatome, Nelcon/Holec, TTS Drobak, Thorneycraft Giles. Don't forget that some producers have several concepts or one concept in different sizes and modalities or with alternative stack-concepts.
   Why these concepts? Are concepts chosen by demand or tenders?

C. GENERAL INTRODUCTION ABSTRACT TERMINAL CONCEPTS

4. What is the concept in general terms about?
   State in a few sentences: which load unit (maritime container, continental container, other continental load unit), which scale (large, medium, small), which transhipment (rail/rail, road/rail, etc), which objective at the start, which objective now a days (like kind of (innovative) bundling concept or new transport unit the terminal-concept is developed for).
   Distinguish the following types of bundling concepts and combinations of them:
   - (direct) point to point-connections;
   - medium and long distance connections with collection and distribution forks in the regions of origin and destination;
   - line networks;
   - hub and spoke networks.

5. Give a general description step by step of the chain of terminal operations (for each modality)
   Chain of operations is the flow of load units through the concept. For example at a deepsea terminal: ship arrives, discharge, transport to stack, transport into stack, transport from stack to landside, transport to truck, truck leaves. Distinguish parts of the chains which are robotized.
6. Give a general description of the technical and spatial lay-out characteristics of the concept
Give general information about the lay-out, static capacity and the equipment used for the operations.
For example at a deepsea terminal: 1200 m. quay, 7 cranes: 39 m. height, can handle 18 container wide vessels, crane driver, 55 AGVs (automated guided vehicles): robotized, diesel/electro engine, linear fixed routes due to gridlines with transponders result into extra quay space due to "wings", etc. ASC (automated stacking crane): rail, robotized, 3 containers high (1 over 2), etc.
Try to get designs, lay-outs, artist impressions, pictures or if they have scale models take pictures of them, etc.
The terminal concept may include a terminal internal transport system. If relevant, distinguish the functions of this. Does it support crane movements? Is it a connection between stack and transhipment units? Does it have a terminal-external function (like inter terminal transport)? If the last is dominant, the questionnaire about node transport concepts may be useful.
Examples of static capacity:
- operational quay number/length of berths (split into deepsea/shortsea and inland navigation);
- number of transhipment tracks and operational track length per track (distinguish inside and outside the terminal concept);
- number of truck transhipment points;
- number of internal transport facilities;
- stack (assumption towards dwell time or differences in frequencies or rhythms of different transport systems?)

D. TRANSPORT MARKET

7. For which (market) demand criteria is the concept designed and how are they incorporated in the concept?
Which type of cost and quality requirements have (potential) customers (transport operators/companies and shippers) announced like throughput time, (un)loading time, stack requirements, freight volumes per year, day and peak hours, reliability, interconnectivity, spatial characteristics and restrictions, environmental restrictions, time or reliability targets, cost targets, opening hours and labour independence, flexibility etc.
Do not forget that a lot of criteria are related to the bundling concepts.

8. What kind of load units and/or type of cargo can the concept handle?
Load units like continental container, maritime container (MT-containers), piggy back-units, swap bodies, roll-on roll-of, small units such as logistic box, air freight box, etc., special units like Commutor-units, reefers (refrigerated), etc.
Type of cargo: does the producer believe that the concept is special suitable for certain freight characteristics such as high value freight or time and reliability sensitive freight.
Other possible considerations:
- perishable, dangerous goods (certain chemicals), heavy loads etc.
- Tuchschmid has a concept specially designed for combined transport of bitumen in standardized load units with specific not public accessible terminals.
This question about load units cannot always be asked. There are concepts which do not have the type of load unit or type of cargo as starting point but the transport unit. For example for a certain shunting yard concept the load unit and/or type of cargo does not matter.

9. Which multi- or unimodal transhipment takes place and which of them is dominant?
Multi modal transhipment like rail/road, rail/water, water/road, rail/air, road/air, water/air. For water distinguish between deepsea, shortsea and inland water ways.
Unimodal transhipment is barge/barge, rail/rail, truck/truck, deepsea/deepsea, shortsea/shortsea
Dominant is the type of transhipment with the largest throughput (example: in a bi-modal concept with rail/rail and rail/road-transhipment, the rail/rail-transhipment can be dominant).

E. CHARACTERISTICS AND DETAILS OF THE CONCEPT

Capacity

Distinguish static capacity (no time dimension) like tracklength and stackpositions (refer to 7.), and dynamic capacity (always with time indication).
The terminal concept may include an internal transport system. The capacity of this can be measured in moves of load units per time unit.

10. For each mode, the stack, the internal transport system and in total: how many moves per peak hour, day (8, 16 or 24 hours) can be handled (dynamic capacity)?
Like number of load unit moves, transport units per hour, day or year. The dynamic capacity is the maximal intensity of load or transport unit flows.
Load units and TEU;
Transport units: trains and wagons etc.
Capacity in moves. One move = one lift.

11. On which opening hours is the dynamic capacity in moves based?
How many weeks/year, days/week and hours per day?

12. What is the duration of unloading and loading for a transport unit of a certain mode?
Transport unit: like train, barge, truck, or parts of these (wagon, trailer, unit in the push-towing-barges). Distinguish nett and gross times. Nett is loading/unloading. Gross
includes entering and leaving the terminal, change of locomotives and the possible
necessity to enter the terminal twice per visit. Often one can distinguish handling times
related to call size and vessel sizes. The allocation of the number of cranes depends on
the size of the vessel.

13. Is there a more or less fixed relation between the different types of equip­
ment, quay and track lengths, stack capacity and internal and external trans­
port system? Which?
Fixed relation: often a concept has a fixed relation between the different types of equip­
ment and the throughput. For example at a deepsea terminal this relation is:
1,200 m. quay: 7 cranes: 50 AGV: 26 ASC: 6 Straddle Carriers: 6 MTS lanes for in­
ternal transport.

Time

14. What is the expected average leadtime of the following operations and what
are the expected variations:
a. between arrival a transport unit or load unit (please both; distinguish modalities) at
terminal and the departure of the same transport resp. transport unit? Gross and nett
(see below)?
b. between the moment right after unloading and the moment just before loading (for a
concept with stacking)?
c. between moment just after unloading and the moment of arrival at the stack posi­
tion?
d. between the of departure from the stack position to moment just before loading?

Notice that duration of transport unit in the concept may not include the necessary han­
dling (e.g. waiting, splitting, coupling, possible changing of locomotives (for electric­
ity), the entering and leaving of the terminal. Try to get an idea of possible assumptions
made.

15. What kind of disturbances can take place in the chain of operations and how
will this effect the reliability?
A disturbance can be a computer break down, a break down of a certain of equipment,
shortage of labour, bad weather conditions, late arrival of transport units, late informa­
tion, etc. The flexibility to deal with these disturbance determines the reliability of the
concept.

Network implications

16. Is the concept designed for certain flow dynamics?
Which relation is there between the batch size and frequency on the one hand and the
capacity (number of moves or amount of equipment), lead time and integral costs of op­
erating the terminal concept on the other hand?
The batch size of a transport unit is the total number of load units to be unloaded and loaded within one arrival (call) at the terminal.
Example: a certain terminal-concept may fit better to some transport rhythms on the networks than to other ones.

17. (Only if interview started at C)
Does the terminal concept implicate changes in the bundling concept?
Example: The barge express-concept would - if implemented - introduce the bundling concept with CD-forks in the inland navigation. At the present line-bundling is dominant.

Labour

18. What is the labour input?
- total;
- per move;
- per equipment;
- control room?
Labour input is the number of personnel which operates the different types of equipment.
Labour in the control room are process operators and IT-specialists monitoring the operations on the level of the computer interfaces.

Information

19. Give a general description of the information flows in relation to the step by step operation chain

Costs

20. How much investment is necessary to implement the concept? Does this include R&D-costs? If so, which part?
- Investments without land costs.
- Relate costs to capacity. For example the Noell Highbay fast transhipment terminal has three concepts; for 400 units, for 600 units and for 800 units.

21. What are the estimated exploitation cost per year:
- fixed: for investment and financing, rent for land use. What is the estimated technical depreciation period?
- variable: e.g. labour (inc. taxes, etc.), maintenance and repair, fuel/electricity?

22. What are the costs per move per modality?
Environment

23. What is the fuel and electricity consumption per year?

24. What noise level do the different types of equipment produce (in dba)?

25. Can the terminal be covered by roof?
   Example: Noells Mega hub, Krupps Fast transhipment terminal.

F. FLEXIBILITY, COMPATIBILITY AND ADAPTABILITY

26. Can the concept be integrated in/combined with existing or new concepts? If so, how?
   (possibilities: see sheet introduction speech Kreutzberger on 15th of november 1996 called 'WP 4 Analysis of the potential of terminal concepts (example)').

27. Can the concept be adapted to another, size, bundling concept e.d.?
   Like adapting a rail terminal concept to a barge terminal location.

28. How flexible is the concept towards changing transport volumes and changing characteristics of the volumes, like type of load units?
   (possibility and easiness to add or change equipment)

29. What kind of standardization is required?
   This can be about load units, transport units, legislation, data exchange, information technology, equipment, union agreements, etc.

30. What kinds of cooperation on the field of R&D between competing or complementary actors has taken place or can take place to reduce R&D-costs?

G. IMPLEMENTATION

31. In which stage (phase) is the concept?
   Idea, study, pilot, implementation.
   When will the following phase of the project be realized (year and month)?

32. Who are the actors involved and which role do they play in developing and implementing the concept?
33. On which assumptions if relevant for the implementation, is the concept based?
   Like cost developments of conventional road transport, or the distribution of costs and benefits between different functions or actors?
34. Which barriers have to be solved to be able to implement the concept? There can be conceptional barriers on the one hand side and political, technical, operational, economical, spatial, legal etc. on the other hand side. Conceptional barriers are missing answers to functional problems. What are critical success factors for implementation?

H. SIMULATION

35. Which kind of simulation models or other modelling has been executed to test the theoretic performances?

I. USERS GROUP (if of interest for us)

36. Are you interested in participating in a User Group, to give feedback on the project?

37. May we ask for additional information later?
NODE TRANSPORT CONCEPT

Introduction

This questionnaire is developed to gather information inside WP2 about new generation (= NG) node internal transport concepts (= NITCs), NITCs in which robotization and automation may take place in the future and other innovative NITCs which help improve the terminal and node efficiency. These NITCs are different from conventional road transport. The NITCs mat have been developed for a certain node or for the market of (not known) future buyers.

Which questions are to be asked during the interview? Distinguish two situations:
- The starting point is a node (terminal or terminal node) in which the implementation of a NITC-concept is considered. Start at block A.
- The starting point is an abstract NITC-concept which could be implemented at any suitable node. Start at block C.

A. GENERAL INTRODUCTION CONCRETE NODE FOR NITC

1. What is the project in general terms about?

1a. Why is the NITC-location being developed?
Possible answers:
- implementation of an innovative bundling concept (which one?) on the long distance or CD-network. The existing NITCs (= usually conventional road transport) can't meet the cost quality requirements which are the consequence of the new bundling concept;
- the cost quality demands are changing even though the bundling concepts are not. The existing NITC can't meet the changing demands;
- a NG-terminal concept is being implemented. Its internal transport system will be extended to a node transport system.

1b. What are and will be the general characteristics of the node in which the implementation of a NITC is considered?
Like spatial node size, freight volume, kind of node-transport, kind of load units, market characteristics, function in different bundling networks, general flow dynamics?
Possible answers:
- the node-specific demand for a NITC has the following characteristics:
  - big volumes;
  - quick exchange;
- exchange between terminals, like between:
  - a terminal with a lot of maritime transport and another one with a lot of continental transport;
- a rail and a sea terminal;
- a high and a low value terminal;
- two similar terminals;
- the collection and distribution of combined (and other?) freight from and to shippers or areas with spatial concentrations of shippers;
- different distances:
  - very short: inside a terminal;
  - short: inside a industrial or harbour site;
  - medium: inside a harbour area or part of a town;
  - long: inside a town/agglomeration;
  - very long: regional or longer distance.
- different load units: maritime containers, continental containers, other continental load units;
- market characteristics: time and reliability sensitive goods (e.d. express or high value), partial loads (LCL);
- different amounts of operational flexibility (trains of or stand alone vehicles?).
- flow dynamics are like: trains are always loaded in the afternoon, trucks come mostly early in the morning and between 15.00 and 20.00 hour, etc.

A hybrid character (e.g. good for short and medium distance?) be of advantage for the transport demand of the node?

B. SPECIAL FEATURES CONCRETE NODE LOCATION

2. Can a concrete indication of the present and expected (2000, 2010, 2020) volumes of internal transport be given? What are important assumptions or expectations?
- in load units, TEU, tonnes, per modality and total. Distinguish: per year, per week, working day and in peak hours.

3. What kinds (combinations) of measures are being considered to respond to the objectives of the development of the node?
Like organizational, operational, spatial, infrastructural or technical measures/concepts.
Operational/organizational measures:
the introduction or enforcement of 24 hour operations; the reduction of empty container or truck movements. The reduction is not possible without improved matching of freight flows. This makes the use of standardized electronic data exchange by more actors necessary. Will the NITC have a public function or is it an exclusive system for one or a small number of actors?

Technical concepts:
Hollandia Kloos' CombiRoad, different AGV-concepts (Mannesmann, Mercedes etc.), different special NITCs (like in the terminal-concepts of Noell, Technicatome, B+, A+T, TTS Drobak, Thorneycraft Giles).

Why these concepts? Are concepts chosen by a procedure of tenders?
If technical measures as NITC(-implementation) are considered, what amount of robotization is desired?

Infrastructure:
Does the NITC have exclusive infrastructure or is a mixed operation necessary?
Mixed operations: e.g. with conventional road or with general rail transport.

C. GENERAL INTRODUCTION abstract NITCs

4. What is the concept in general terms about?
State in a few sentences:
- on land or water;
- single vehicles or vehicle clusters (trains?);
- which central technology is used (air cushion, mechanical drive on steel or rubber wheels, electro-magnetic drive);
- NITC for combined transport only or also for other freight types?
- which objective at the start which objective now a days (like designed for inter-terminal-transport, designed as general CD-system, designed to avoid time losses of barges and trains on the nodes, designed for quick or reliable drayage, designed as complement to certain types of changes on the major networks).

5. Give a general description step by step of the chain of internal transport operations (for each modality).
The chain of operations means flow of the load units through the concept. Example: inter-terminal-transport: load units are discharged from train direct onto NITC, transport to stack by NITC, transport in to and out of stack, transport from stack to barge terminal by NITC, barge leaves. Distinguish parts of the chains which operate robotized. Mention also which transhipment equipment is used.

6. Give a general description of the technical and spatial lay-out characteristics of the concept
What central technology is used?
Give general information about the lay-out and the used equipment for the operations like: number, height, length, control system (automation or manual), etc. For example CombiRoad: dimensions (width, height, curves, maximum inclined plains) of infrastructure, for rail or for rubber wheel operations, and transport units (diesel/electro en-
D. TRANSPORT MARKET

7. What kind of load units and/or type of cargo can the concept handle and how many units per vehicle and vehicle-cluster?
Load units like continental container, maritime container, (MT-containers), piggy back-units, swap bodies, roll-on roll-off, small units such as logistic box, air freight box, etc., special units like Commutor-units, reefers, etc.
Type of cargo: does the producer believe that the concept is special suitable for certain freight characteristics such as high value freight or time and reliability sensible freight. 
Other possible considerations: perishable, dangerous goods (certain chemicals), heavy loads etc.

8. For which market demand criteria is the concept designed and how are they incorporated in the concept?
Which type of requirements have (potential) customers (transport operators/companies and shippers) announced like throughput time, (un)loading time, stack requirements, big volumes per year, high peak throughput, reliability, costs, interconnectivity, short distance, etc.
Do not forget that a lot of criteria are related to the bundling concepts on the node external networks.

E. CHARACTERISTICS AND DETAILS OF THE CONCEPT

9. In relation to the objective what are characteristics of the NITC?
Distinguish the following characteristics:
- the ability to (easily?) transport single load units or to establish small trains. A consequence of this will also be the kind of service the NITC can deliver inside its node;
- fast acceleration and deceleration enabling a lot of stops, or not;
- high or low operational speeds;
- network of NITC-terminals;
- lightness of the system.
Capacity

Distinguish static capacity (no time dimension) like track length and stack positions, and dynamic capacity (always with time indication). The dynamic capacity is the maximal intensity of flows.

10. What is the static capacity of the NITC?
Mention number of NITC equipment, number of position at NITC equipment, number of vehicles-lots on an trailer exchange-area (for example CombiRoad), number and length of NITC, etc.

11. Dynamic capacity: how many units per peak hour, day (8, 16 or 24 hours) and year can be handled by the NITC?
Like number of load units and transport units per hour, day or year (on a link), or load unit-kms or transport unit-kms per time unit (in a network).

12. On which opening hours is the dynamic capacity based on?
How many weeks/year, days/week and hours per day?

13. What is the duration of unloading and loading of a transport unit of the NITC?
Transport unit like AGVs (automated guided vehicles), Multi trailer systems, NITC-trains, NITC-barges etc. Distinguish net and gross times. Net is loading/unloading. Gross includes entering and leaving the terminal, change of locomotives and the possible necessity to enter the terminal twice per visit.

14. Does the NITC have a fixed relation of equipment and infrastructure?
Like number of trailers to tow trucks or vehicles to length of infrastructure.

Time

15. What is the average leadtime for the following NITC-constellations or activities:
- a link with a length of 0.5, 1, 2, 5 kms and ... without stops;
- same as above but with 0, 1, 2, 3, 4, 5 ... intermediate stops at NITC-specific terminals for (un)loading;
- the complete NITC from begin to end (relate to system capacity, if known);
- the complete NITC round trip.

16. What kind of disturbances can take place in the chain of operations and how will this effect the reliability?
A disturbance can be a computer break down, a break down of certain equipment, shortage of labour, bad weather conditions, late arrival of transport units, late information,
etc. The flexibility to deal with these disturbance determines the reliability of the concept.

Network and terminal implications

17. (Only if interview started at C)
Does the NITC implicate the change of bundling concepts or of the terminal-concepts?

18. Is the concept designed for certain flow dynamics?
Is there a relation between the batch size of transport and the frequency of transport on the major network and its terminal on the one hand side and the dynamic capacity, lead time and integral costs of operating the NITC on the other hand side? Which?
Example: a certain NITC may fit better to certain freight flow rhythms than to other ones.

Labour

19. What is the labour input?
- total;
- per move;
- per equipment;
- control room?
Labour input is the number of personnel which operates the different types of equipment.
Labour in the control room are process operators and IT-specialists monitoring the operations on the level of the computer interfaces.

Information

20. Give a general description of the information flow in relation with the step by step operations description

Costs

21. What is the amount of investment of the concept? Does this include R&D costs? If so, which part?
- Investments without land costs.
- Relate costs to capacity. For example the Noell Highbay fast transhipment terminal has three concepts; for 400 units, for 600 units and for 800 units.
22. What are the estimated exploitation costs per year:
   - fixed: for investment and financing, rent for land use.
   - What is the estimated technical depreciation period;
   - variable: e.g. labour (inc. taxes, etc.), maintenance and repair, fuel/electricity?

23. What are the handling costs for one load unit in the NITC?

Environment

24. What is the fuel and electricity consumption per year?

25. What noise level do the different types of equipment produces (in decibel)?

26. Can or must the NITC be covered by roof?

F. FLEXIBILITY, COMPATIBILITY AND ADAPTABILITY

27. Can the concept be integrated in or combined with existing concepts or other new concepts? If so, How?
   - Interfaces with terminal (= question 7)?
   - Are mixed operations (e.g. with conventional road or with general rail transport) necessary or possible?
   - Are combinations with other NITCs possible, in general or on special parts like nodes (example CombiRoad and Metro Freight)?

28. How flexible is the concept towards changing transport volumes and changing characteristics of the volumes, like type of load units?
   (possibility and easiness to add or change equipment)

29. What kind of standardization is required?
   This can be about load units, transport units, terminal interfaces, legislation, data exchange, information technology, equipment, union agreements, etc.

30. Can the NITC be adapted to another node-environment (objectives, characteristics like distances or volumes) than it was developed for?

31. What kind of cooperation on the field of R&D between competing or complementary actors has taken place or can take place to reduce R&D-costs?
G. IMPLEMENTATION

32. In which stage (phase) is the concept?
   Idea, study, pilot, implementation.
   When will the following phase of the project be realized (year and month)?

33. Who are the actors involved and which role do they play in developing and implementing the concept?

34. On which assumptions which are relevant for the implementation, is the concept based?
   Like cost developments of conventional road transport, or the distribution of costs and benefits between functions or actors?

35. Which barriers have to be solved to be able to implement the concept?
   There can be conceptional barriers on the one hand side and political, technical, operational, economical, spatial, legal etc. on the other hand side. Conceptional barriers are missing answers to functional problems.
   What are critical success factors for implementation?

H. SIMULATION

36. Which kind of simulation models or other modelling has been executed to achieve performances?

I. USERS GROUP (if of interest for us)

37. Are you interested in participating in a User Group, to give feedback on the project?

38. May we ask for additional information later?
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