TERMINET is a strategic and tactic project researching new possibilities for intermodal freight transport in Europe. It investigates innovative bundling- and new-generation terminal concepts and analyses their technical and economical feasibility for the European transport network. Innovative network 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 robotised, have integrated operations and have a compact layout.

The TERMINET research resulted in new network and terminal designs, cost and performance analyses, simulation and animation tools and an identification of implementation barriers.

The TERMINET study was performed by a Consortium of 8 partners:

Project Co-ordinator:
- Technische Universiteit Delft (Delft University of Technology), The Netherlands

Partners:
- Economic & Social Institute Free University ('ESI VU'), The Netherlands
- Noell Stahl und Maschinenbau Gmbh ('NOELL'), Germany
- Tuchschmid Engineering AG ('TUCHSCHMID'), Switzerland,
- Cranfield University Centre for Logistics and Transportation ('CCLT'), United Kingdom
- Technical Research Centre of Finland, VTT Communities and Infrastructure ('VTT'), Finland
- Centro Ricerche Applicate All'Economia E Alle Scienze Sociali ('CERIAS'), Italy
- Facultés Universitaires Catholiques de Mons ('FUCAM'), Belgium

The research study has been co-ordinated by F. Minarini and P. Mercier-Handisyde in the framework of the activities of the R&D division of DG Transport.

The project covered a period from 1 January 1997 till 1 January 2000.

ii

SUMMARY

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 ratio[1] 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 models feasible, i.e. bundling models that have additional transhipment at intermediate terminals for bundling purposes. These, however, cause more complicated operations at the nodes, that conventional terminals or shunting yards cannot execute. For this, a new generation of intermodal terminals is required.

In recent past years, various terminal equipment manufactures have presented new terminal concepts for intermodal transport, the manufacturer of this new-generation terminals claim more efficient operations, shorter handling times and lower costs compared to conventional operations, thanks to automation and new and compact layouts.

The TERMINET research project is based on the following expectations:
- complex bundling models need smart (robotised) operations;
- automated and robotised transhipment will allow more complex bundling models;
- large volumes, in the future, will allow fast large scale robotised transhipment;
- small intermodal volumes will lead to innovative bundling concepts in order to reach a substantial improvement of the cost quality ratio;

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[1] The criteria of the cost-quality ratio are: utilisation rates, frequencies, costs, speed, cycle times and reliability.

- innovative networks in combination with new-generation terminals will lead to a quality jump in intermodal transport.

The *central objective* of TERMINET is to identify promising innovative developments for the bundling of networks and new-generation terminals for combined unimodal and intermodal transport within Europe[2].

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 relative short distances;
- better services for small shipments and small flows;
- higher reliability;
- more flexibility in time and location;
- more suitable operation times for shippers and other customers at terminals;

The knowledge needed to respond to the project's central objective and the major research projects was developed gradually. Hereto the project was divided into 9 workpackages, which can be seen as 9 research tasks. WP1 and WP2 have an inventorial character, while the subsequent WP's are more analytical. The investigation (WP1) and identification (WP3) of innovative networks and the investigation (WP2) and identification (WP4 task 1) of new-generation terminals started separately and continued integrally for both subjects in WP4 task 2. In WP5 indicators and criteria for costs and performance have been formulated from the perspective of the 'client'. WP6 investigates which harmonisation measures at an EU level could improve the feasibility of new-generation operations. Five cases were selected in WP4 task 3, being Metz, Valburg, Busto Arsizio, Venlo and Duisburg. Case studies (WP7) have been elaborated in order to design innovative networks and new-generations terminals for realistic nodes. Based on these designs terminal investment and costs calculations have been and chain costs comparisons have been made between unimodal road and intermodal transport with new-generation terminals and innovative networks. Business plans have been elaborated to further analyse the economical feasibility of the case studies (WP8 task 1). Furthermore, implementation barriers have been investigated (WP8 task 2). In WP9 the case studies and feasibility conclusions were generalised and combined with the conclusions of the other WP's.

The major results and conclusions of Terminet are:
- There is a hierarchy of networks in which the size of flows is the central factor. Wherever the flows are sufficient to allow large transport units to move with high loading degrees, on the desired frequency level, and to a large number of destination terminals, begin-end-operations deserve priority. However, given a certain departure frequency, complex bundling concepts allow integration of rather small rail-road or

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[2]   In the following parts of this report 'combined unimodal and intermodal transport' will be called 'intermodal transport'.

barge-road terminals into the network. And given a certain network and terminal volume, complex bundling concepts allow a relative high departure frequency from any begin-end-terminal, compared to begin-end-operations. In other words, the complex bundling concepts integrate small flows and allow operating with small begin-end-terminals and at the same time to generate the quality and cost features of large-scale operations. Hub and spoke networks will be more suitable for medium-sized flows with medium to long distance. Trunk-collection-distribution networks are rather suitable for small flows with long distances. Line networks with loading at begin-end and line-terminals at the beginning of a journey and unloading at the end should have longer distances. Line-networks with (un)loading at any line-terminal may be suitable for smaller distances as well and therefore for regional networks.

- The crucial problem of the feasibility of new-generation terminals is that costs can hardly be compared with costs of conventional terminals and shunting, for two reasons. First, existing terminals and shunting yards are subsidised and/or these terminals/shunting yards are already depreciated, with the consequence that only operational costs are considered, while in the cost calculations for new investments all costs are considered. Furthermore, the cost analyses clearly show that the actual tariffs do not cover the real costs (capital and operational costs) of existing terminals and shunting yards.
  New-generation terminals demand large volumes (>200.000 load units) before the terminals start to be economical feasible. This implies that especially in the start up phase financial support is necessary or a more scalable set-up of new-generation terminals is needed.

- Another problem is that high investment costs are located at the nodes, while most advantages occur in the network. Therefore a redistribution of income, from the links to the terminal, is necessary to make the implementation of new-generation terminals more feasible. Co-operation and chain management are needed to enable the introduction of new-generation terminals.

- Most important barriers which hamper implementation of new-generation terminals at this moment are:
  - Lack of clear statements about benefits and costs of new-generation terminals and complex networks.
  - Large dependency the development of complex networks, which hardly exists except for networks which use shunting yards.
  - Practical and operational problems such as break tests, pin setting, seal and damage checks, change of locomotives and train drivers at borders, change of locomotives at terminals and priority for passenger trains on congested rail infra.
  - Lack of clear fall back procedures that are needed in case the new-generation terminal operations fail. This especially applies to operations with largely depend on automation and robotisation.
  - Limitation of easy access of test facilities for potential adopters. However, Krupp, Noell and Transmann have a test site.

- Accessibility of information. Many actors in the transport field hardly know which information is available. And if they do, it is not easy to access this information, either because information is only disseminated among researchers and policy makers, publication of reports takes place one year or more after finishing a study or results are not public.

CONTENTS

x

1
INTRODUCTION

1.1   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 ratio[3] 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 models feasible, i.e. bundling models that have additional transhipment at intermediate terminals for bundling purposes. These, however, cause more complicated operations at the nodes, that conventional terminals or shunting yards cannot execute. For this, a new generation of intermodal terminals is required.

In recent past years, various terminal equipment manufactures have presented new terminal concepts for intermodal transport, the manufacturer of this new-generation terminals claim more efficient operations, shorter handling times and lower costs compared to conventional operations, thanks to automation and new and compact layouts.

The TERMINET research project is based on the following expectations:
- complex bundling models need smart (robotised) operations;
- automated and robotised transhipment will allow more complex bundling models;
- large volumes, in the future, will allow fast large scale robotised transhipment;

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[3]   The criteria of the cost-quality ratio are: utilisation rates, frequencies, costs, speed, cycle times and reliability.

- small intermodal volumes will lead to innovative bundling concepts in order to reach a substantial improvement of the cost quality ratio;
- innovative networks in combination with new-generation terminals will lead to a quality jump in intermodal transport.

1.2 Central objective and major research questions

The *central objective* of TERMINET is to identify promising innovative developments for the bundling of networks and new-generation terminals for combined unimodal and intermodal transport within Europe[4].

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 relative 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.

By answering the following major *research questions* we want to achieve the central objective of the TERMINET research project:
1. Which innovative bundling networks and new-generation terminals for intermodal freight have recently been or are being developed and implemented in Europe?
2. If we analyse these innovative developments can certain trends, chances and threats be discovered? Do the new bundling concepts and terminal concepts match functionally and technically? Which concepts in which regions and which corridors for which transport markets show the most promise?
3. Will the new-generation terminals function as expected in innovative bundling concepts? Can this be shown in actual case studies? Which technical, operational and spatial concepts and designs lead to the best performance and costs?
4. What exactly are the performances and costs that new-generation terminals and terminal-nodes have to meet? Which criteria and indicators which are specific towards the bundling and new-generation qualities?
5. Can the identified promising innovative directions be confirmed by feasibility studies? If not, can economic and/or other measures make promising innovations feasible after all?
6. What contribution can harmonisation make to the functional and economic feasibility of new-generation operations?

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[4] In the following parts of this report 'combined unimodal and intermodal transport' will be called 'intermodal transport'.

7. What final conclusions can be drawn and recommendations made to encourage and support new-generation terminals and innovative operations in the field of intermodal transport within Europe?

1.3   Structure of the TERMINET project

The knowledge needed to respond to the project's central objective was developed gradually. Hereto the project was divided into 9 workpackages, which can be seen as 9 research tasks (Figure 1.1). The backward arrows in Figure 1.1 represent feedback activities. Feedback might result in new insights which will be incorporated in the project by evaluating results of finished workpackages. This might result in recalculations.

WP1 and WP2 have an inventorial character, while the subsequent WP's are more analytical. The investigation (WP1) and identification (WP3) of innovative networks and the investigation (WP2) and identification (WP4 task 1) of new-generation terminals started separately and continues integrally for both subjects in WP4 task 2. In WP5 indicators and criteria for costs and performance have been formulated from the perspective of the 'client'. WP6 investigates which harmonisation measures at a EU level could improve the feasibility of new-generation operations. Five cases are selected in WP4 task 3. Case studies (WP7) will deepen the knowledge about promising innovative directions. Business plans are used to analyse the feasibility of the case studies (WP8 task 1) and implementation barriers are investigated (WP8 task 2). In WP9 the case studies and feasibility conclusions are generalised and combined with the conclusions of the other WP's. Appendix 1 provides a detailed overview of the main objectives of each workpackage. The research outcomes of the various workpackages have been published in 15 deliverables. Appendix 2 provides an overview of the produced deliverables.

1.4   Outline of this report

This report focuses on the main outcomes of Terminet. However the smaller results and applied methodology are covered, too. In Chapter 3 (and Appendix 1) for each workpackage (task) the main objective, applied methodology and major results are shorlty described. For a better understanding of the context of Terminet a background chapter (2) about innovative networks and new-generation terminals has been included. Chapter 2 describes the main theories behind the Terminet project and the major new fundamental insights which have been obtain during the course of the Terminet project. An important task in the Terminet study were the five cases studies in which innovative networks and new-generation terminals have been design. The major characteristics and major design outcomes are presented in Chapter 4. Based on the findings of the case studies, which are rather case specific, a more general vision will be elaborated in Chapter 5. First, in Chapter 5 a few very promising concepts are presented. Next, a vision is presented of a

Figure 1.1   Structure of the project

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                    ┌─────────────────────────────────┐
                    │         Background report         │
                    └─────────────────────────────────┘
          ┌──────────────────────┐  ┌──────────────────────┐
          │ WP 1                  │  │ WP 2                  │
          │ Inventory inno-       │  │ Inventory NG-         │
          │ vative bundling       │  │ terminals and         │
          │ concepts in Europe    │  │ node concepts in      │
          │                       │  │ Europe                │
          └──────────────────────┘  └──────────────────────┘

  ┌──────────────┐ ┌──────────────┐ ┌──────────────┐ ┌──────────────┐
  │ WP 3         │ │ WP 4         │ │ WP 5         │ │ WP 6         │
  │ Analysis of  │ │ Analysis of  │ │ Indicators   │ │ Standardisa- │
  │ innova-      │ │ NG-terminal  │ │ and cri-     │ │ tion and     │
  │ tive bundling│ │ and node     │ │ teria for    │ │ compatibi-   │
  │ con-cepts by │ │ concepts     │ │ innovati-    │ │ lity in NG-  │
  │ modelling    │ │              │ │ ve bundling  │ │ operations   │
  │ with GIS     │ │              │ │ and NG-      │ │              │
  │              │ │              │ │ terminals and│ │              │
  │              │ │              │ │ nodes        │ │              │
  └──────────────┘ └──────────────┘ └──────────────┘ └──────────────┘

          ┌──────────────────────────────────────────┐
          │ Integrative analysis of innovative bundling│
          │ and NG-terminal and node concepts          │
          ├──────────────────────────────────────────┤
          │ Choice of (terminal)nodes for case studies │
          │ in WP 7                                    │
          └──────────────────────────────────────────┘

          ┌──────────────────────┐
          │ WP 7                  │
          │ Analysing perfor-     │
          │ mance effects of      │
          │ terminal designs in   │
          │ five cases by disign  │
          │ and simulation        │
          └──────────────────────┘

          ┌──────────────────────┐
          │ WP 8                  │
          │ Business plans and    │
          │ analysis of the fea-  │
          │ sibility of terminal  │
          │ designs of WP 7       │
          └──────────────────────┘

  ┌──────────────────────────────────────────────────────────────────┐
  │ WP 9                                                               │
  │ Integral indentification of probable, worthwhile and missing       │
  │ innovation directions. Recommenda-tions of public and private      │
  │ measures to encourage and support the development and              │
  │ implementation of NG-terminals, -nodes and -bundling networks.     │
  └──────────────────────────────────────────────────────────────────┘
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NG = new-generation

feasible and promising future for intermodal transport with innovative networks and new-generation terminals. Chapter 6 investigates implementation barriers which still could hamper implementation of these promising networks and new-generation terminals. The economical feasibility of new-generation terminals is also discussed in Chapter 6. Finally, in Chapter 7 the conclusions of the Terminet project are presented and worthwhile recommendations are discussed.

2

INNOVATIVE NETWORKS AND THE ADVANTAGES OF NEW-GENERATION TERMINALS

2.1   Towards a better cost-quality ratio of intermodal transport

Intermodal transport is to play an important role in the development of a more sustainable freight transport. However, in practice the average intermodal rail transport is still not covering its costs. This is partly because intermodal transport has to compete with unimodal road transport, which offers relatively fast, door-to-door transport and in many cases has a better cost-quality ratio than intermodal transport (Wiegmans, Masurel and Nijkamp, 1998a). This is mainly due to transhipment times and costs. Also, intermodal rail transport still suffers from a lack of efficiency and market orientation of the train system, while it seems that road transport has become even more efficient in the past years. As a result, intermodal transport is hampered severely to gain a larger market share.

To improve the competitiveness of intermodal transport, a quality leap seems necessary, to make node and link operations substantially more efficient. This is not just a matter of a higher quality and lower costs; in fact improvement of quality may in some cases lead to higher costs. Most important however, is to achieve a substantial better *cost-quality ratio*.

As far as *quality* is concerned, improvement should focus on the following aspects:

a) a reduction of the integral *lead time* in the door-to-door transport chain. The shipper then has his products sooner at his disposal. Also, less transport equipment and load units are needed, due to the faster circulation time. In the third place, there is a potential enlargement of the market area, as the transport radius is increased due to shorter terminal times. Also, better opportunities exist to realise more favourable departures and arrival times of transport units at terminals;

b) higher transport *frequencies* imply that the intervals between transport services become smaller, thereby reducing the waiting time for freight. Higher frequencies in turn will have a positive effect on the required stack facilities at terminals, as well as on the rental cost savings of shippers;

c) in order to play a more important role in transport markets, intermodal transport must be able to provide services for *more destinations*, also on *relative short distances* and for *small flows*, also in the case of pre and end haulage;

d) higher *reliability* is vital for the necessary reduction of buffers and is therefore directly related to costs. The costs of unreliability have become of growing importance, mainly as a result of the emergence of just-in-time deliveries;
e) more *flexibility* is necessary, mainly for capacity adjustments, in time and space;
f) *more suitable operation times* are important to realise favourable interconnections between links in the transport chain and for the optimising of terminal efficiency;
g) more attention should be paid to *sustainability*, as this may become a competing quality dimension as well on the long term.

Because of the usual focus on costs as a competition factor, it is generally supposed that the *costs* of intermodal transport need to go down. On the other hand, for time sensitive freight it is imaginable that the costs may increase, if quality improvements compensate for this.

2.2   The need for network and terminal innovation

Improvement of the quality of intermodal transport has much to do with the intensification and expansion of services: *intensification in time*, by implementing higher transport frequencies, and *expansion in space*, by serving more destinations.

However, in current practice the fierce competition between intermodal and road transport has encouraged a strategy focused on minimising the costs of intermediate transhipment or shunting, leaving collection and distribution completely to the road sector. This has resulted in an increase of relatively large-scale, direct terminal-to-terminal shuttle services, which require a substantial threshold volume in transport services and in terminals. In the case of smaller flows, this can only be achieved by *bundling* of several flows. However, this requires *innovative bundling networks*, that are more complex than the shuttle concept and accordingly demand complex node operations. If executed by the present conventional terminals or shunting yards, these operations would increase the time and financial costs of intermodal transport and thus undermine its competitiveness. Therefore innovation of terminals is necessary.

2.3   Complex bundling networks

Bundling is the process of transporting cargo, which belongs to cargo flows with different origins and/or destinations in common transport and/or load units on common parts of their routes. Figure 2.1 shows conventional direct begin-end bundling, compared to the complex bundling as it is applied in innovative bundling networks. *Complex bundling concepts have intermediate nodes for bundling purposes.* There, load units are resorted or transport units are reassembled. Thus, trains or push barges are assembled, which are loaded with units that have in common that they all need to go to the following intermediate terminal in the chain, even though they may have different end terminals.

By complex bundling three main advantages can be achieved (see also Figure 2.1):
a) a higher load factor of transport units or load units;
b) a higher transport frequency;
c) a larger number of destinations from each begin terminal.

6

While a) refers to the reduction of *costs*, b) and c) refer to improving the *quality* of intermodal services. An alternative for increasing the transport frequency is the enlargement of economies of scale by using larger trains or barges.

Figure 2.1   Direct begin-end bundling versus complex bundling of cargo flows
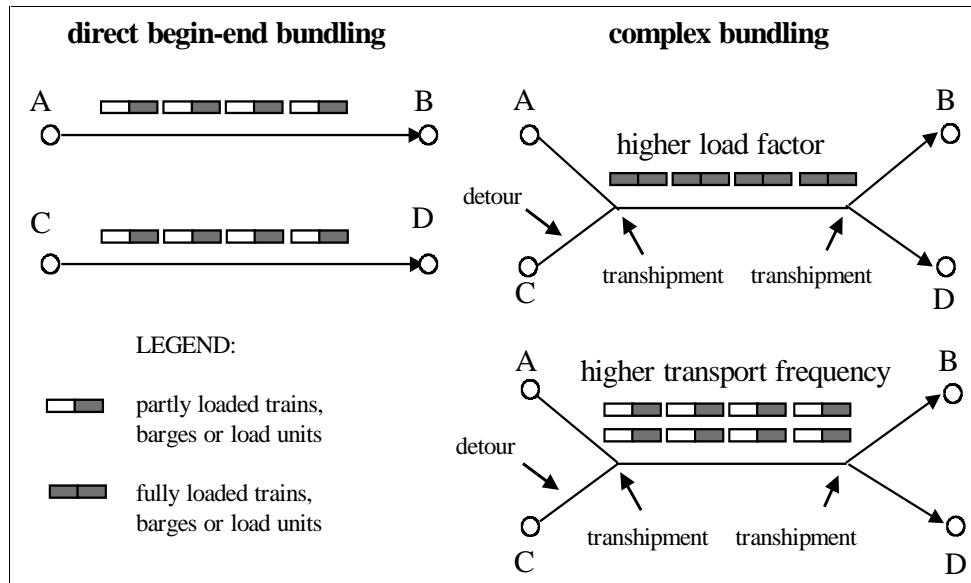
Source: Vleugel and Kreutzberger (2000).

Figure 2.1 also shows some disadvantages of complex bundling:
a) the additional transhipment or shunting costs time and money and is likely to reduce the door-to-door reliability of the transport chain;
b) the detours of routes for most transport services, compared to direct terminal-to-terminal services, increase time and costs.

The best bundling concept in each situation is the one that creates the optimum balance between the advantages and disadvantages mentioned above. The additional costs should be compensated by the advantaged of new-generation node operations.

Several basic concepts of complex bundling networks may be distinguished (Figure 2.2). Their main characteristics and typical nodes are:
1. the *begin-end network (BE-network)* is a network with *direct* transport services between two begin-and-end nodes. It has no intermediate nodes;
2. a *hub-and-spoke network (HS-network)* has one unimodal intermediate node, the *hub (H-node)*. The major difference between the one-directional (2a) and the all-directional hub-and-spoke network (2b) is the number of nodes involved in the exchange. In the latter case the number is higher and the hub-terminal has to perform on a higher level. The hub-and-spoke network can have continuous or broken chains. Continuous chains lead to less exchange at the hub, broken chains may allow better utilisation rates of trains or barges per spoke;
3. a *trunk-collection-and-distribution network (TCD-network)* has two unimodal intermediate nodes, the *collection-and-distribution nodes (CD-nodes)*, connecting the

trunk route and the CD-network. Trains or barges on the CD-network will be smaller or have lower frequencies than those on the trunk route;

4. the *line network (L-network)* has one or more multimodal intermediate *line* nodes *(L-nodes)*. In separated line networks (4a) load units are loaded *or* unloaded at line nodes; in diffuse line-networks (4b) loading *and* unloading takes place at the same line node;

5. the *trunk-feeder network (TF-network)* has several unimodal *feeder nodes (F-node)* on the trunk route. Feeder trains or barges are likely to have the same characteristics as CD-trains or barges. Separated (5a) and diffuse trunk-feeder networks (5b) may be distinguished.
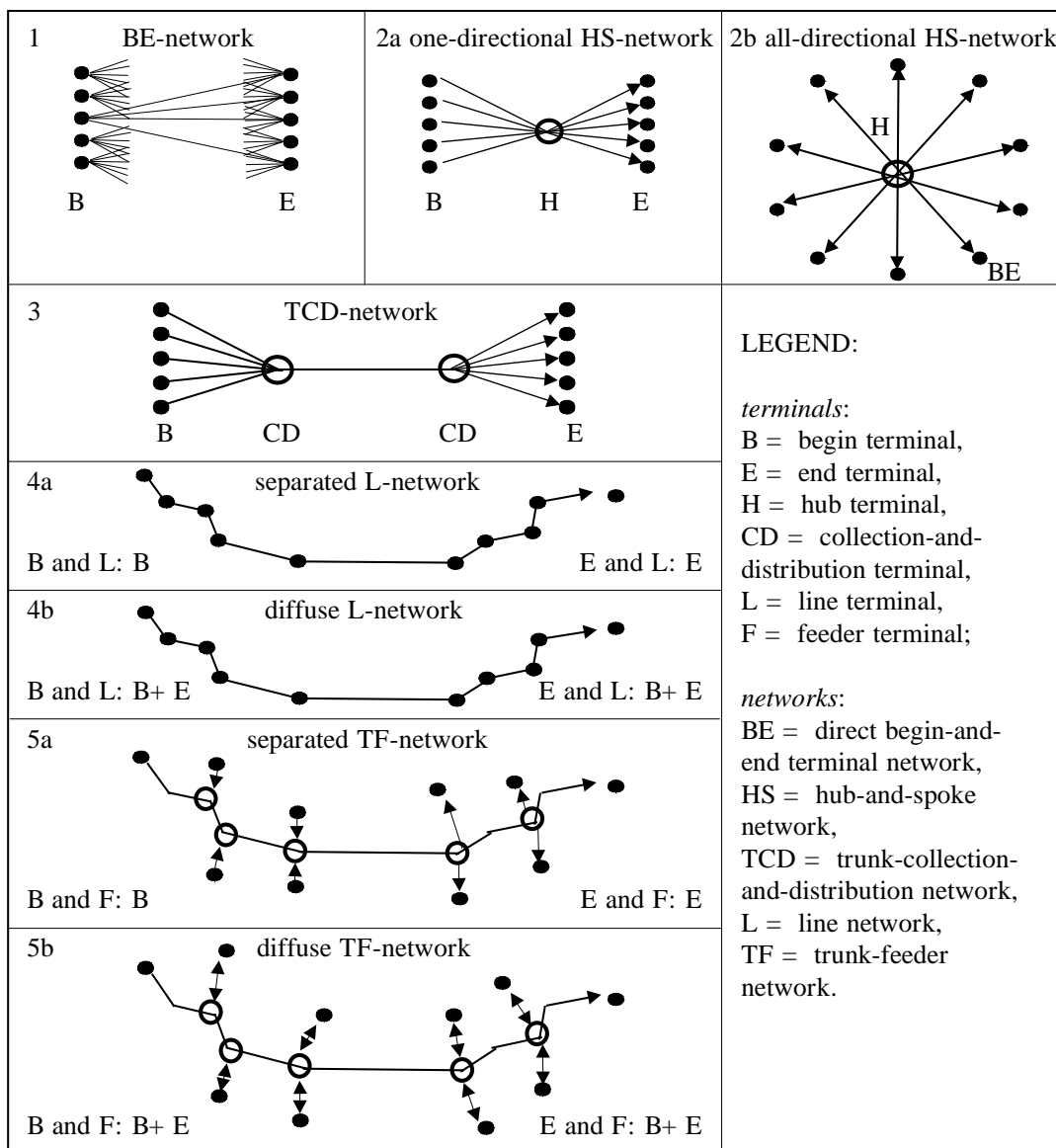
Figure 2.2 only shows the network for the *main modality*, without the pre- and end-haulage per truck and additional local or regional networks.

If the volumes of freight flows are not sufficient to fill a direct begin-end train or barge on the required frequency level, one of the *complex bundling concepts* will have to be applied. Alternatively, the freight can be transported directly by small transport units, such as trucks. As the costs and geographical factors are changing continuously, the search for the optimal bundling concepts and the adjustment of existing bundling concepts is a continuous activity of the transport sector.

A final aspect of complex bundling networks that should be explained is the difference between (network-)simultaneous and (network-)sequential transhipment.

Simultaneous or direct transhipment takes place from one train or barge to another, taking only one handling (i.e. one crane move). In contrast to this, in case of sequential or indirect transhipment, load units are moved between trains or barges indirectly, i.e. via a stack, which takes at least two handlings. This takes more time and is often more expensive than simultaneous transhipment. Therefore, simultaneous exchange at feeder, hub and CD-nodes, if possible, has quality and cost advantages. Sequential exchange is an option, if either the trunk or all feeder lines have several daily harmonised services.

Figure 2.2:   Bundling concepts as used in TERMINET.

1 BE-network	2a one-directional HS-network	2b all-directional HS-network
B E	B H E	H BE
3 TCD-network B CD CD E		LEGEND: *terminals*: B = begin terminal, E = end terminal, H = hub terminal, CD = collection-and-distribution terminal, L = line terminal, F = feeder terminal; *networks*: BE = direct begin-and-end terminal network, HS = hub-and-spoke network, TCD = trunk-collection-and-distribution network, L = line network, TF = trunk-feeder network.
4a separated L-network B and L: B E and L: E		
4b diffuse L-network B and L: B+ E E and L: B+ E		
5a separated TF-network B and F: B E and F: E		
5b diffuse TF-network B and F: B+ E E and F: B+ E		

Source: Terminet (1999).
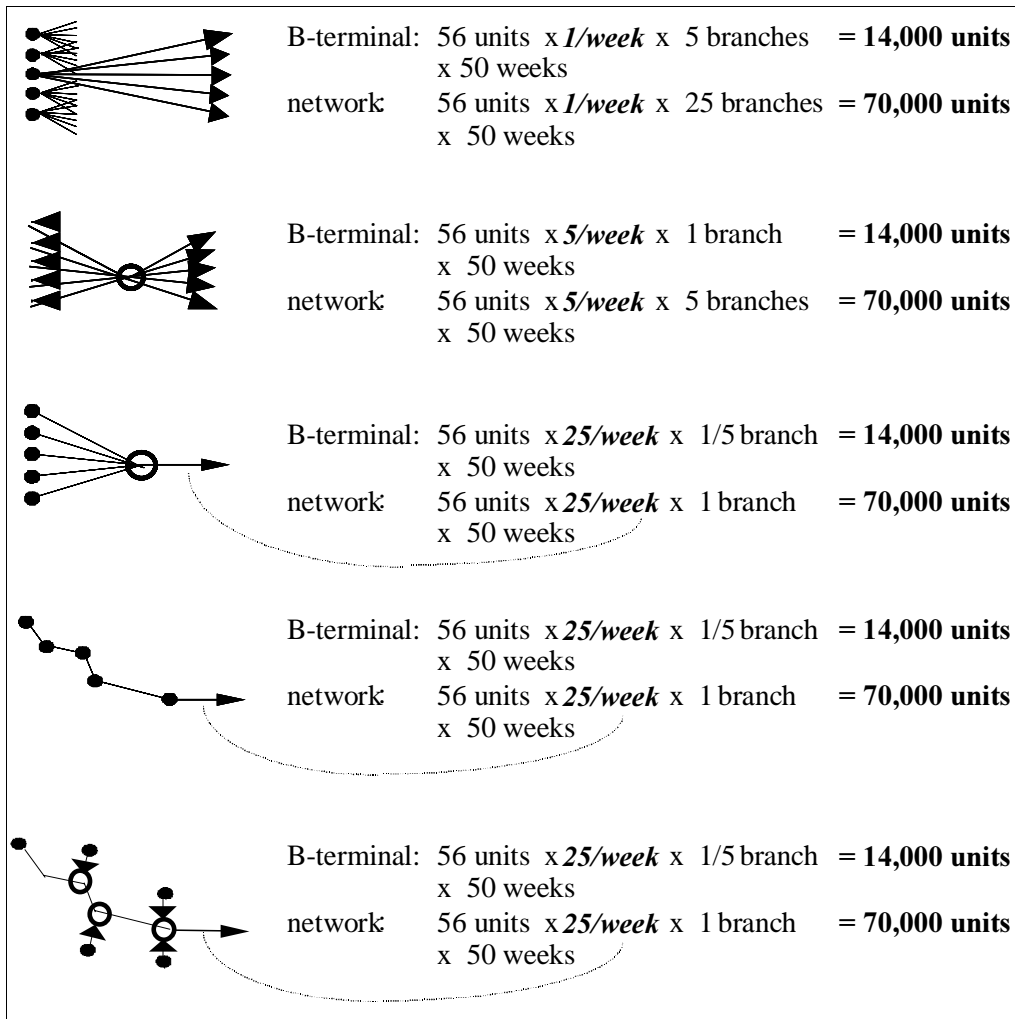

2.4   Frequencies and volumes: an example

An important step on the way to identify promising networks is to compare the networks, and to do this for different economic geographical situations. Of course the involved networks have to be comparable. This is the case if:

a) they have the same number of begin, end or begin-end node;
b) the distances between the nodes is the same;
c) they either have the same volume between all being and end nodes (volume approach) or have a comparable number of services per begin node (frequency approach).

9

A comparison between bundling concepts in terms of volumes and frequencies is made in Figure 2.3 and Figure 2.4. The example includes all networks of Figure 2.2, except all-directional hub-and-spoke networks and diffuse line and trunk-feeder networks, as these have different numbers of begin, end or begin-end nodes.

All trunk trains in the example are 400m. long, which, with a loading degree of 80%, means that it has 28 load units at an average (56 back and forth).

Figure 2.3: **Volumes and frequencies in the volume approach, i.e. volumes of each bundling concept are the same (bold), frequencies differ (italic).**

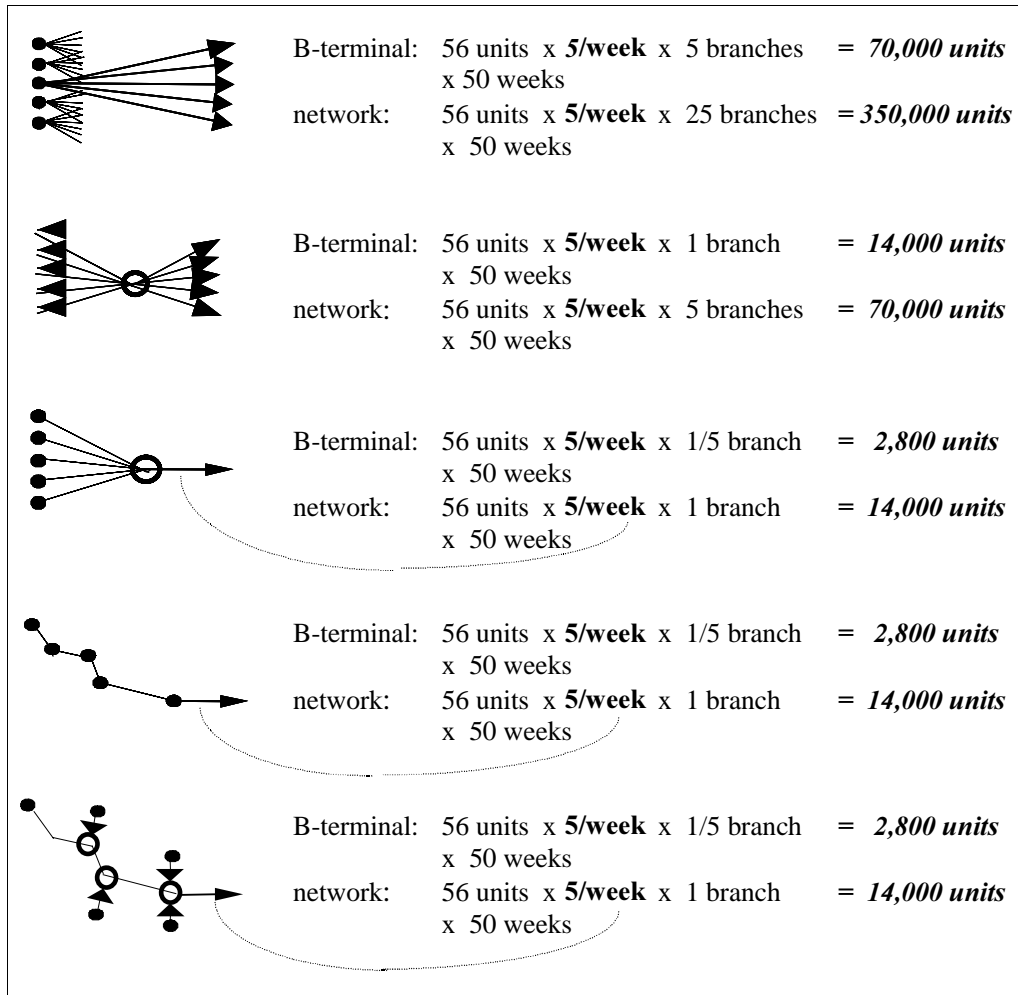|		
B-terminal:	56 units x *1/week* x 5 branches x 50 weeks	= **14,000 units**
network	56 units x *1/week* x 25 branches x 50 weeks	= **70,000 units**
B-terminal:	56 units x *5/week* x 1 branch x 50 weeks	= **14,000 units**
network	56 units x *5/week* x 5 branches x 50 weeks	= **70,000 units**
B-terminal:	56 units x *25/week* x 1/5 branch x 50 weeks	= **14,000 units**
network	56 units x *25/week* x 1 branch x 50 weeks	= **70,000 units**
B-terminal:	56 units x *25/week* x 1/5 branch x 50 weeks	= **14,000 units**
network	56 units x *25/week* x 1 branch x 50 weeks	= **70,000 units**
B-terminal:	56 units x *25/week* x 1/5 branch x 50 weeks	= **14,000 units**
network	56 units x *25/week* x 1 branch x 50 weeks	= **70,000 units**

Source: Terminet (1999).

With respect to the volume approach (Figure 2.3), an annual network volume is assumed of 70,000 load units. Each begin and end terminal therefore has an annual transhipment of 14,000 units. This amount allows the following frequencies:
a) once a week per begin-end terminal in a begin-end network;
b) 5 times a week from each begin-end terminal in a hub-and-spoke network;

c) 25 times a week from each begin-end terminal in a TCD-, line or trunk-feeder net-
   work;

The conclusion is that the complex bundling allows to offer much frequenter services,
compered to begin-end networks.

**Figure 2.4:   Volumes and frequencies in the frequency approach, i.e. frequencies
            of each bundling concept are the same (bold), volumes differ (italic).**

B-terminal:	56 units x **5/week** x 5 branches x 50 weeks	= *70,000 units*
network:	56 units x **5/week** x 25 branches x 50 weeks	= *350,000 units*
B-terminal:	56 units x **5/week** x 1 branch x 50 weeks	= *14,000 units*
network:	56 units x **5/week** x 5 branches x 50 weeks	= *70,000 units*
B-terminal:	56 units x **5/week** x 1/5 branch x 50 weeks	= *2,800 units*
network:	56 units x **5/week** x 1 branch x 50 weeks	= *14,000 units*
B-terminal:	56 units x **5/week** x 1/5 branch x 50 weeks	= *2,800 units*
network:	56 units x **5/week** x 1 branch x 50 weeks	= *14,000 units*
B-terminal:	56 units x **5/week** x 1/5 branch x 50 weeks	= *2,800 units*
network:	56 units x **5/week** x 1 branch x 50 weeks	= *14,000 units*

Source: Terminet (1999).

In case of the frequency approach (Figure 2.4), it is assumed that each begin terminal
has a weekly frequency of 5 trains to each end terminal. In a begin-end network each
destination has to be served separately (i.e. 25 branches), which means a network vol-
ume of 350,000 units is required, 70,000 per begin-end terminal. In a hub-and-spoke
network the destinations can be served together (i.e. 5 branches), which implies that the
required volume per begin-end terminal is 14,000 units per year. In a TCD-, line or
trunk-feeder network this would be 2,800 units. The conclusion is that a certain fre-

quency can be achieved by relative small BE-terminals in complex bundling concepts, compared to begin-end networks.

2.5   The advantages of new-generation terminals

For the performances of complex bundling networks the quality of the terminals is essential. Conventional terminals in most cases do not meet the performance requirements of complex bundling networks, because they do not have:
a) the capacity and speed;
b) an appropriate lay-out, especially for rail-rail or barge-barge exchange;
c) an internal transport system, which is required for larger amounts of direct rail-rail exchange.

If the terminals absorb too much time and costs, the integral lead times and costs become too unattractive. Therefore, a substantial improvement of the cost-quality ratio of node operations can often be effectuated only by the implementation of new-generation terminals, i.e. *terminals that are capable of executing the complex operations required by innovative networks*. New-generation terminals are characterised by intelligent, compact layouts and synergetic operations for transhipment, storage and internal transport. More important, however, than the choice of technology are the *function* of the terminal in the network and the innovative ideas behind it.

The expectation is that new-generation terminals and nodes could provide substantially better cost-quality ratios of terminal and node operations. Together with more efficient link operations, this should improve the technical, operational and economical feasibility of innovative bundling networks.

New-generation terminals may well contribute significantly to a more efficient intermodal transport. This may be expressed in costs and/or in time. Due to shorter transhipment times at intermediate or begin-end terminals, the distance covered in the 'Nachtsprung' may increase substantially. As Figure 2.5 shows, quick handling at begin-end terminals means that more time remains for trains to run on the network. This means a larger distance could be covered or an additional intermediate terminal could be included in the service. Figure 2.6 gives an indication of the time savings for different types of networks in case fast, new-generation terminals were introduced at intermediate nodes.

12

Figure 2.5: **Quick handling at the begin and end node A and B allows more time on the network (example with a direct begin-end service with a cycle time of 24 hours).**
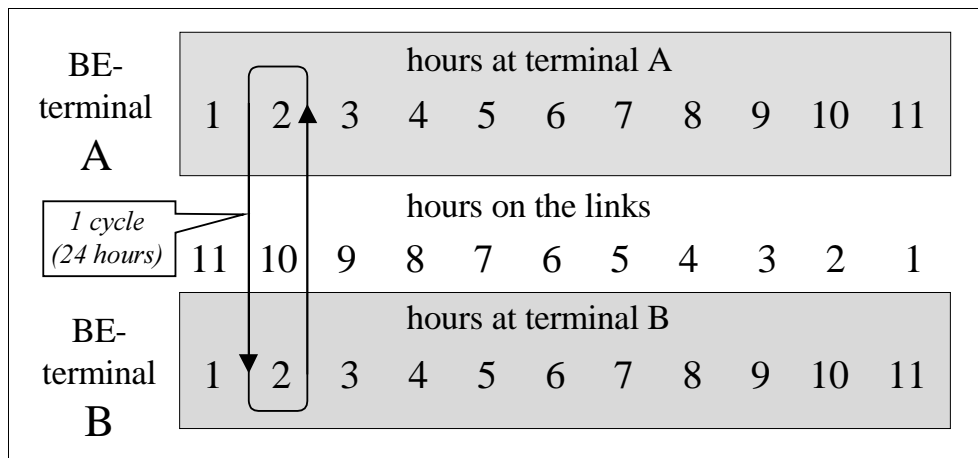
Figure 2.6: **Enlargement of maximal distances of rail transport services during the 'Nachtsprung' in bundling networks by introduction of new-generation terminals at intermediate exchange nodes (rail system time approximately 20:00-04:00 o'clock; figures are indicative).**
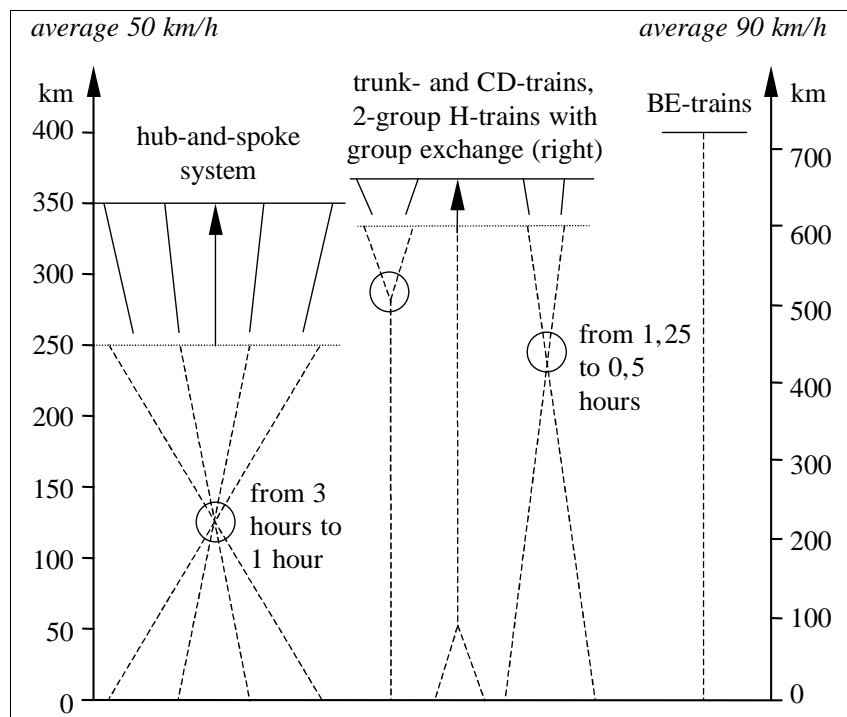
2.6   Synergy between networks and terminals

It must be emphasised that technical concepts can improve the competitiveness of intermodal transport only in combination with efficient operational strategies and other organisational measures. The synergy between technical and operational measures is important for both the terminals and the networks (Figure 2.7). The benefits of new-generation techniques cannot be fully exploited with conventional operations. Otherwise, new-generation operations need new-generation terminals for reasons of costs, speed and reliability.

In current practice this synergy is rare. There are on the one hand some rather theoretical complex bundling concepts and new-generation terminal designs, on the other hand there are several 'real', operational innovative bundling networks.
However, there are no operational new-generation inland terminals in existence, although a number of pilot plants has been built and tested. Also, there is little interaction between different groups of actors. At present, network operators seem more interested in the expansion and improvement of shunting yards, than in new-generation terminals. However, the expectation is that this will change when the optimisation of shunting yards has reached its limits and transport volumes continue to grow. At present, also network operators of existing innovative networks do not pay too much attention to bundling concepts or new-generation terminal designs. All operational innovative bundling networks that were identified in TERMINET use conventional transhipment or shunting techniques, which are in fact sub-optimal solutions for complex networks. The identified new-generation terminal concepts on the other hand, are at best designed with conceptual or projected bundling networks in mind, more than the innovative bundling networks that exist in reality.

Figure 2.7:   The synergy between technology and operational strategy.

Source: Terminet (1999).

14

3
METHODOLOGIES
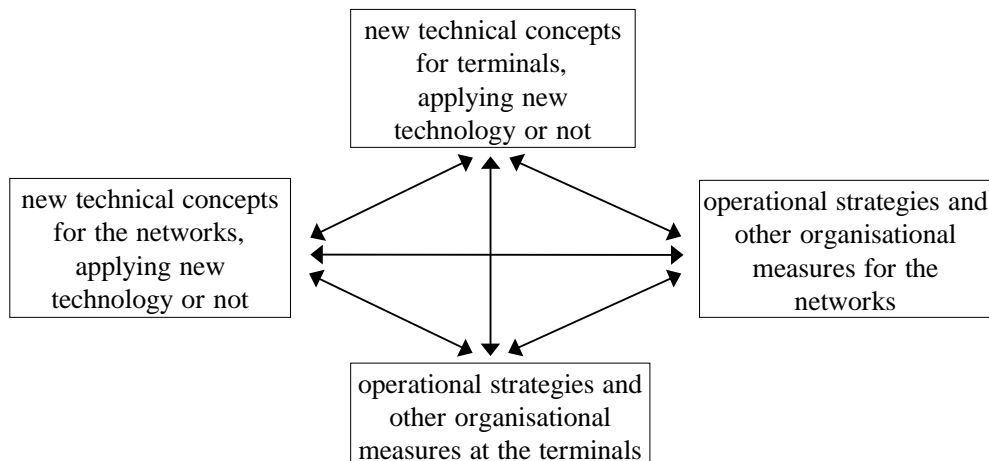
3.1   Introduction

In this Chapter we discuss the various methodologies which are applied in the work-packages of the TERMINET project. For the workpackages 1 to 6 we also discuss the major results, insofar as these are not dealt with in Chapter 2. The results of workpackages 7, 8 and 9 are integrally discussed in the Chapters 4, 5 and 6.

3.2   Investigation state of the art of new concepts (WP1 and WP2)

The first step in identifying promising innovative direction for bundling networks and new-generation terminals was to investigate and classify the state of the art of innovative projects and plans. The aim of the investigation was to obtain detailed descriptions of new generation terminals and innovative networks as proposed by actors in countries of the European Union, Switzerland and Norway.

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 investigation started with the preparation of two overviews of relevant concepts per geographic section: one related to innovative bundling (WP1) and one to new-generation terminals (WP2).
Concepts of innovative bundling have been marked relevant if bundling concepts have a certain level of complexity in order to achieve frequency and utilisation benefits, and, simultaneously one or more of the following criteria can be realised:
- reduction of the integral transport lead time;
- increase of transport reliability;
- increase of cost-quality ratios of operations and of the efficiency of investments;
- increase of the social acceptance;
- increase of the competitiveness of combined transport and/or of certain transport;
- establishment of corridors of terminals and terminal nodes.
Concepts of new-generation terminals have been marked relevant if one of the two following criteria could be met:
- the presence of automation or robotisation of transhipment or internal transport;

- the expectation of the necessity for automation or robotisation in the future.

In total 23 innovative network concepts and 99 concepts for new-generation terminals have been marked as relevant, however only 31 new-generation terminal concepts have been described (Appendix 3 and 4). Information for concept descriptions was provided by desk research, as well as by interviews with shippers, goods and equipment manufacturers, transport companies, railway companies, terminal operators, (semi)governmental authorities, consultants and research institutes.

3.3 A spatial model (GIS) for modelling freight bundling networks (WP3)

The methodology that is proposed to model and assess complex freight bundling networks is based on a general spatial model of multimodal freight transportation implemented in GIS software: NODUS. In this section, we shortly discuss the model that has been developed and applied in the Terminet project. Appendix 5 provides additional information about the modelling methodologies and the software technique.
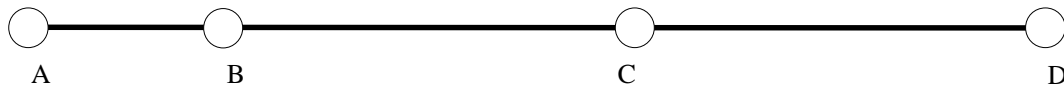
Virtual network
Transportation of goods on a real geographic network may be realised by various means on the same infrastructure. For instance, the same large canal can be used by small and large boats. Transportation also involves many different operations which do not appear in a normal geographic representation of the network, i.e. loading, moving, unloading, transhipping and transiting. In particular, the operations of transferring goods from one means or mode to another are not represented. However, in order to properly analyse a transportation problem with all its alternative solutions and operating dimensions, it is necessary to identify and separate each transport operation. This can be achieved by creating a virtual network, where a particular link is associated to every distinct transport operations which take place over the geographic network, thus linking in a systematic way all the possible successive operations in the geographic space. Three modes, with various means, are incorporated in the model: railways, roads and inland waterways.

NODUS generates automatically a virtual link for each possible mode t and means m on each real link. In some cases, this method of automatic and exhaustive generation of virtual nodes and links may create virtual links corresponding to operations which cannot be made at some nodes, like the handling of containers in some places without adequate facilities. This problem is handled by defining a list of exclusions for each real node, which is checked during the process of creating the virtual links and nodes.

Figure 3.1 illustrates a rail track going from city A to city D, via cities B and C. This track can be used by traditional trains, that may load or unload commodities not only at A and D, but also in the two other stations. If a shuttle train is to be modelled between A and D, it can be defined as a new transportation means, for which no loading, unloading or transhipment operations are possible in B and C.

16

Figure 3.1   Point-to point network (shuttle concept).

The corresponding virtual network is presented in Figure 3.2, in which, for clarity reasons, (un)loading and simple transit virtual links are both presented by means of dotted lines. Actually, the traditional train is allowed to stop for (un)loading in B and C, but the shuttle train doesn't have this possibility. To model this in NODUS, one just have to add an 'exclusion list' to B and C, in which loading, unloading and transhipping onto the 'shuttle' means is forbidden.

The same methodology can be applied to model a line network made of several links between dedicated terminals: it is just necessary to allow (un)loading and transhipment operations at each of the intermediate terminal-nodes.

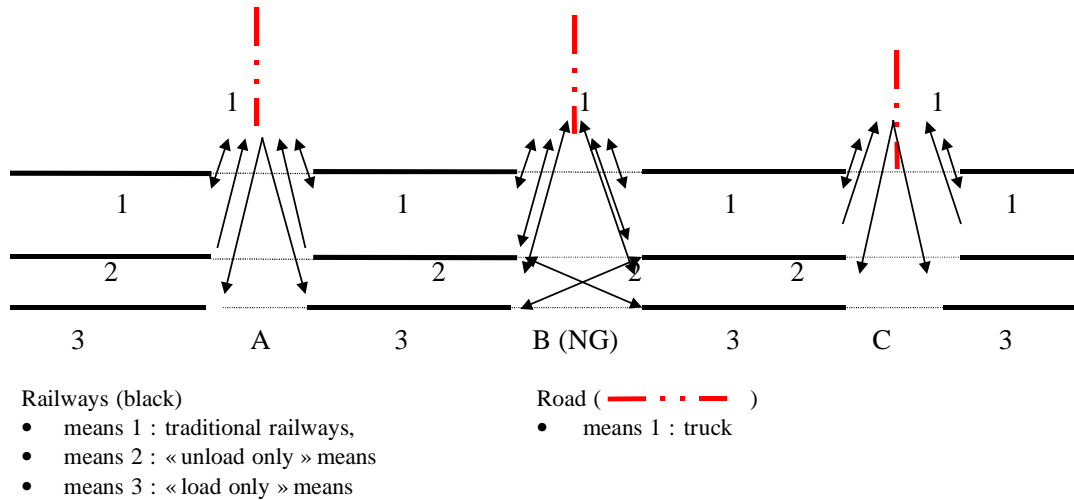**Figure 3.2   Corresponding virtual network point-to point network.**
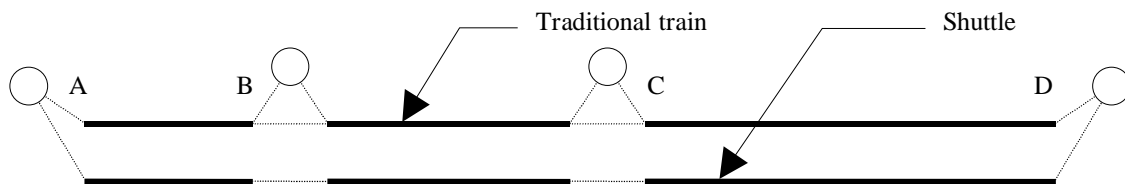
The methodology explained in the previous section can also be applied to model a bundling network made of a trunk line with collection/distribution forks, such as the one outlined in Figure 3.3. Its virtual network is represented in Figure 3.4, where the (un)loading virtual links are not drawn.

Figure 3.3 Collection Distribution network.
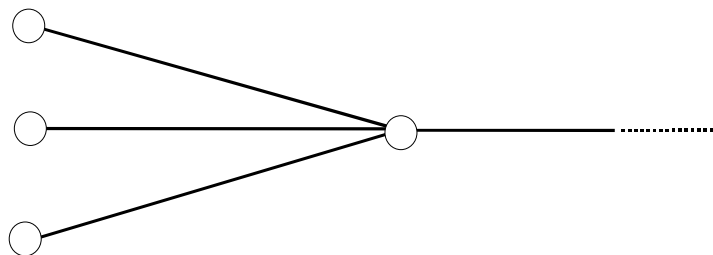
In Figure 3.4 the thin links represent traditional trains and the bold links represent the shuttle trains on the fork-lines and the main trunk line. All the dotted lines are « simple transit » virtual links. Normally, no cost is attached to those virtual links except if there is some shunting involved, but, in the case of a bundling fork, these (bold) dotted lines correspond necessarily to a transhipment between the main shuttle and the (often smaller) ones circulating on the fork lines. Thus, a transhipment cost function must be used to compute the weight of these particular « simple transit » virtual links.

Figure 3.4   Corresponding virtual network Collection Distribution.
Figure 3.5   NG terminal attraction model

Railways (black)
- means 1 : traditional railways,
- means 2 : « unload only » means
- means 3 : « load only » means

Road (—— · · ——)
- means 1 : truck

In order to properly model a collection distribution case, it is also important to avoid unwanted turns on the feeder forks. Indeed such turns could appear when the same railway track is used over some distance for different destinations. The way to avoid this is thoroughly discussed in deliverable D3 (Terminet, 1998)

The virtual network can also be used to measure the potential attraction of one or more new generation (NG) terminals introduced at precise locations on a multimodal network. Here, the basic idea is to create two additional transportation means for a particular mode, such as the railway for instance. The first « new » transportation means is linked only to loading operations and the second means linked only to unloading operations. The only nodes where transhipments are allowed between these two additional means are the NG terminals. It follows that the use of the new transportation means automatically implies that transhipment operations will be performed exclusively at the NG terminals. One or more such terminals can be introduced in the modelling according to the problem analysed. Then, different levels of transhipment costs can be set at the terminals in order to analyse their relative attractiveness when compared to other means. Figure 3.5 illustrates this modelling of a NG terminal.

In Figure 3.5 A and C represent traditional terminals and B the NG terminal. In terminal A and C, it is possible to load on transportation means 3 and to unload from means 2. Both loading and unloading operations are still possible for the « traditional » means 1. Transhipment from means 3 to means 2 is only possible at the NG terminal. This terminal will only be used if the loading cost at the origin, plus the transhipment cost at the NG terminal, plus the unloading cost at the destination, plus all other ship
ping costs is lower than the sum of the loading, unloading and shipping costs for means 1.

18

In this way, it is possible to analyse the impacts on transport flows of a particular localisation of a NG terminal or of a system of NG terminals. In a first stage, the NG terminals should be linked to all nodes where loading and unloading are possible. The result of that simulation would indicate the origins and destinations of the main flows transiting through the terminals. Then, in a second stage, by excluding a number of less interesting origins and destinations, a reduced configuration can be given to the bundling network which would result from the building of the NG terminals. Thus, this modelling approach provides a convenient technique to analyse the best localisation of NG terminals and the best configuration of networks organised around these terminals.

Cost function
It is clear that both shipping and transhipment costs play an important role for the attractiveness of NG terminals. Generalised shipping costs when using such bundling terminals could be reduced because a higher speed would be provided on the shuttle trains to and from the NG terminal and the NG terminal itself could propose faster handling than traditional terminals. In that case, NG terminals could be proved an efficient solution.
The relevant cost functions of each particular operation can be conveniently attached to the appropriate virtual link, so that it is possible to search for a minimum cost solution to a transportation task which must be performed on the network. In this model the cost functions are linear with respect to distance, but otherwise can be as complex as desired in terms of their parameters: time of the operations, crew wages, cost of fuel, capital cost, speed, insurance, rate of the time opportunity cost, relative value of a means' quality attribute, etc. Hence, with only limited available information, it is possible to define the cost functions in such a way that the total cost of a particular transport can be taken as the shippers' generalised cost, which determine his choice of a particular transport solution. Thus, the model is based on the minimisation of the shippers' generalised costs, and it is this minimisation which provides as solution assignments of the transportation task flows between modes, means and paths.

The main problem in this respect is to obtain information on all the elements which should be introduced in the cost functions in order to reach a complete estimation of a transport's generalised cost. This is extremely difficult to realise in most cases. However, a partial remedy to this problem can be found in the calibration of the cost functions which must be realised after a first assignment in order to obtain a good fit of the model to observed data on flows or market shares. Presumably, these adjustments are necessary because the cost functions have not taken into account some cost elements, like the quality differences between modes and means. For generating the necessary OD-matrixes with freight flows, a special stochastic procedure was developed to assign the global flows between countries onto specific points of origin and destination.

Application of the model
The software tool NODUS can be used for the evaluation of performances of new intermodal network concepts (new links or bundling strategies). With this software tool the user is able to generate figures and geographic maps which will provide him information about how freight will flow between transport modes, transport units and paths. The user is able to analysis and compare various scenarios, such as:

- the effect of the introduction a new intermodal link into the existing network;
- the effect of cost and/or tariff changes on links and in nodes;
- the effect of the introduction of new destinations on flows.

NODUS could be an interesting decision support tool for people involved in the organisation of multimodal transport routes and corridors. But also for terminal(-node) operators who would like to study the effects of network changes on demand of terminal capacity. The software is organised around a user-friendly graphic user interface that offers a lot of functionalities, i.e. editing digitised maps and the associated attributes, preparing and analysing different scenarios around a given network, visualising the details of what could happen not only on a given link but also 'inside' a node.

From the application of NODUS to four different bundling network concepts, it appears clearly that the value of a bundling network configuration depends above all on the general topology of the real network and the spread of demand through space. A proper assessment of a particular solution would require a thorough and detailed investigation of the relevant costs of the new generation terminals and of the newly developed transport vehicles; furthermore, up-to-date origin and destination matrixes only could determine accurate results in terms of flows for each mode and means as well as for the bundling networks.

3.4   Performance evaluation of bundling networks (WP3)

In WP1 innovative bundling networks have been investigated. The perception was that of the actor. In WP3 the innovative bundling networks are analysed from a researcher perspective in order to find preferable layout(s) of best performing networks The evaluation of the innovative bundling networks described in D1 (WP1) has been carried out through the following steps:

1. description of the basic structure and characteristics of the models for bundling the freight;
2. definition of the concept of 'the preferable network layout'. This definition has been designed from *the researcher's point of view*. It deals with the optimal network configuration (layout) defined for given circumstances (conditions);
3. definition of the indicators for estimation (quantification) the NG bundling network performances. This has appeared to be the most important and 'crucial' step. The performance indicators have been expected to satisfy the following requests: to transparently present physical, spatial and operational characteristics of the network, emphasise their diversity, quantify them in a unique way and be able to be easily converted into the evaluation criteria;
4. estimation (quantification) of the indicators for particular bundling networks. This estimation has been carried out for the concrete cases of bundling networks and related traffic scenarios presented in WP1 and WP2;
5. comparison and evaluation of the particular NG bundling networks with respect to the selected set of indicators and criteria (obtained by the indicators) with the aim to build the blocks for determining 'the preferable network layout(s)' under given circumstances.

20

In the present analysis elements of *'the overview table methods'* and *'multi-criteria methods'* have been applied to evaluation of the NG bundling networks. By application of the SAW (simple Additive Weighing) method the particular NG bundling networks have been ranked in preference order. The rank (1) denotes the most 'preferable' network (alternative), the rank (2) the second 'preferable' network, etc. The evaluation and comparison of the innovative bundling networks have provided a set of relevant criteria that have been applied for identification of the main characteristics of the promising innovative networks. Due to incompleteness of the relevant information (particularly those on the monetary characteristics of the networks) it is only possible to point the promising innovative bundling networks on a preliminary basis.

The identified most preferable concepts (per category) are: RoadRailer, ICF Quality Net with hub in Metz, RingZug Rhein-Rhur, Sogemar network, RO-RO Barge Transport, Container Exchange Point Barge and Floating Container Terminal.

Based on the analysis carried out in WP3, it has not been possible to make any general recommendation concerning 'the preferable layout(s)' of the innovative bundling networks. The main reason lies in the fact that each network, among the analysed cases, has been set up to serve to specific (local) markets. However, the analysis, classification, comparison and evaluation of similar networks with respect to dominant transport mode, general bundling model and set of relevant non-monetary criteria of their performances provided a basis for determining preferable bundling network layouts.

3.5   Performance evaluation of new-generation terminals (WP4)

In WP2 innovative new-generation terminals have been investigated. The perception was that of the actor. In WP4 the new-generation terminals are analysed from a researcher perspective in order to find preferable layout(s) (best performing) terminals.

From the discussion in §2.3, we can conclude that when evaluating a new-generation terminals we must consider its function and the type of bundling network it is part of.

The objective of WP4 is:
- to critically evaluate whether the performance of new-generation terminals as claimed by their manufacturers are realistic;
- to provide insight into terminal processes in different type of bundling networks;
- to compare the expected performance and characteristics of new-generation terminals with each other and with conventional terminals and shunting yards.

A central issue in our evaluation is the relationship between terminal layout and operations and network bundling demand, by means of a static process analysis. For this purpose we have defined specific network situations for each type of bundling network. Each new-generation terminal is confronted with these network situations, and four partial productivity measures are calculated: the number of train batches handled per hour, the handling time per train, land use efficiency ratio, and storage area utilisation ratio.

Every new-generation terminal is analysed for four types of bundling networks:
- collection-and-distribution (CD);

21

- hub-and-spoke;
- line (L);
- point-to-point or begin-end (BE).

For each type of network we assume a certain network situation which the new-generation terminal has to deal with.

The major results of the evaluation study are as follows:

1. *Hub-terminals:* for large exchange operations the Noell Megahub proves the best concept which meets the criterion of 1.5 hour exchange easily for batches with 6 long[5] trains at a reasonable level of investment. For medium exchange operations with batches of 3 long trains Tuchschmid CT3/350 proves the best concept which could also meet the 1.5 hour exchange time criterion. For small exchange operations with batches of 3 trains short trains the CCT Plus large proves the best concept which also meets the time criterion of 1.5 hours for exchange.

2. *CD terminals:* for Large scale CD operations Commutor, Noell Megahub, Krupp Megahub and Krupp Highrack are concepts which will suit very well in very dense networks with large streams, large trains and numerous destinations. Batch handling times are respectively 4, 11, 21 and 21 minutes. For medium scale CD operations Krupp Compact, CCT Plus Large, Tuchschmid CT 3/350 and Noell SUT 1200 will suit in medium dense networks. Batch handling times are respectively 73, 92, 69 and 84 minutes. For short trains batch handling times lay between 42 and 52 minutes. In small scale CD operations Krupp Small and Transmann TM-V2 are concepts which could function in a low dense CD network. The latter should only handle short trains in order to realise acceptable handling times for the feeders. Handling times for short trunk trains are respectively 28 and 55 minutes, for short feeders 19 and 110 minutes, for batches 111 and 110 minutes.

3. *Line terminals:* for large scale line operations Krupp Highrack and Krupp Compact will suit very well as line terminal in a dense network with many intermediate terminals and with a high frequency of line trains arriving at the terminal. The handling times are respectively 6 and 12 minutes. For medium scale line operations Tuchschmid CT 3/350, Noell SUT 1200 and 400, and CCT Plus Large will suit in a network with a medium frequency of line trains calling at the terminal and a medium number of stops in between begin and end terminal. Handling times are respectively 20, 24, 30 and 30 minutes for long trains and respectively 11, 14, 17 and 17 minutes for short trains. For small scale line operations Tuchschmid CT1/100, Transmann TM-V1 and Krupp Small will suit in small scale line networks, with short trains and only a few stops between begin and end terminal. The handling time of short trains are respectively 36, 40 and 45 minutes.

    The CCT Plus concept seems to be suitable for very small flows (several units per day), because of the low investment in equipment and terminal infrastructure. The generated low performances in this evaluation flatters this options.

A reference terminal has been used for a benchmark between new-generation terminals and conventional terminals. The reference terminal is 700m long, has 4 tracks, 2 truck

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[5] Long trains are 700 m, short trains 400 m. A long feeder train is 175 m, a short one 100 m. The utilisation rate of each train is 80%.

lanes and 3 storage lanes under the crane. There are 2 cranes, which carry out the rail, road and storage handlings. The four partial productivity measures have been generated for the reference terminal for all predefined network situations.

All new-generation terminals evaluated for hub-operations perform better than the reference terminal. For CD-operations the reference terminal ranks among terminals Tuchschmid CT3/600, Krupp Compact, Noell SUT 1200 and CCT Plus Large, which perform between 0.7 and 0.9 CD-batches per peak hour. The conventional terminal and the Tuchschmid terminal have the best investment/performance ratio. The Tuchschmid concept performs better than the conventional, but the conventional terminal is ranked one category lower for investment. For line-operations the conventional terminal is rather slow (a little more than 1 train per hour) and ranks among the smaller new-generation terminals. For small flows besides Tuchschmid CT1/100 and CCT Plus small could be very competitive with conventional solutions.

3.6   Integrated analysis of innovative bundling networks and new-generation terminals (WP4.2)

WP4.2 can be seen as a global forerunner of WP7, 8 and 9, as it is to *establish an integrated picture of probable, promising and innovative development directions of innovative bundling concepts and new-generation terminals and terminal node concepts.*

There is a hierarchy of networks in which the size of flows is the central factor. Wherever the flows are sufficient to allow large transport units to move with high loading degrees, on the desired frequency level, and to a large number of destination terminals, BE-operations deserve priority. They allow the largest distance and have the lowest lead times; of course, also the costs are the lowest.

However, the research results show what the potential of complex bundling concepts is. Given a certain departure frequency, complex bundling concepts allow integrating rather small rail-road or barge-road terminals into the network. And given a certain network and terminal volume, complex bundling concepts allow a relative high departure frequency from any BE-terminal, compared to BE-operations (see §2.4). In other words, the complex bundling concepts integrate small flows and allow operating with small BE-terminals and at the same time to generate the quality and cost features of large-scale operations.

Generally, HS-networks will be more suitable for medium-sized flows with medium to long distance. TCD-networks are rather suitable for small flows with long distances. L-networks with loading at BE- and L-terminals at the beginning of a journey and unloading at the end should have longer distances; the spatial concentration of L- and BE-terminals allows to restrict the route parts with low loading degrees. L-networks with (un)loading at any L-terminal may be suitable for smaller distances as well and therefore for regional networks. Similar conclusions can be drawn for TF-networks. A characteristic, which only refers to L-networks is that these do not cause additional transhipment costs in the chain; by implementing a L-terminal, the amount of (un)loading in the chain stays the same. Only the times costs of wagons, locomotives and load units increase.

The analysis of terminal performances shows that some new-generation terminal concepts are highly specialised and others are multifunctional, which means that they are suitable for more than one exchange function. Specialised terminals are very effective for the exchange type which they have been developed for, but if this types does not have sufficient freight flows, a low utilisation of the specialised terminal may be the consequence. Multifunctional terminals are likely to be more efficient, as they can serve different exchange types and flows at different times of a fortnight. Also, they are more flexible to changing exchange requirements on the longer term.

3.7 Selection of five case studies (WP4.3)

In WP7 five case studies with innovative network and new-generation terminal design have been carried out. The selection of the five case studies in WP4.3 has been based on the following criteria:

1. each case study is to comprise one of the following types of terminals:
   - a large maritime terminal (-node) for all modes of transport;
   - an inland terminal for all modes of transport (road, water, rail);
   - a large inland terminal for two modes of transport (road, rail);
   - a medium-sized inland terminal for two modes of transport (road, rail);
   - an inland terminal for one mode of transport (rail-rail);
2. there are not more than two cases per EU member state;
3. the cases cover a broad spectrum of bundling concept;
4. there are actors in the field which are interested in the research results and willing to participate;
5. some cases refer to new terminal developments, others to innovation inside existing terminal locations and installations.

The interest of actors was considered to be of special importance, as TERMINET, a research project in the tactical programme of the Fourth EC research programme, is to be of practical use on the short to medium term. The final choice is a compromise of what ought to be chosen according to the technical annex indications, according to the results of WP4.2 and the response of actors in the field.

The following case studies have been selected in the TERMINET project:

1. a large maritime terminal (-node) for all modes of transport. This was to become the node Rotterdam. But the actors at the Maasvlakte have other priorities. The central actor in the Eem-/Waalhaven, namely the operator of the rail terminal there, was rather interested in the options for the intermediate and hinterland rail terminal *Valburg (The Netherlands)*, which is located along the Rhine and the projected Betuwe route;
2. an inland terminal for all modes of transport (road, water, rail). *Duisburg (Germany)* has the ambition to develop into a major barge-rail hub. The integration of the existing and projected rail and barge terminals by technical means (terminal connections, terminal subsidiaries) and/or new bundling operations is the objective of this case study. The rail and barge terminal operators and the harbour authority are the central actors;
3. a large inland terminal for two modes of transport (road, rail). This case type has been adjusted to a large inland terminal for rail-rail exchange. The chosen case is

24

Metz (France). The objective is the substitution of the shunting yard by a Megahub like new-generation terminal. InterContainer is the central actor;

4. a medium-sized inland terminal for two modes of transport (road, rail) *Busto (Italy)*. This case type is slightly adjusted, as its objective is multifunctionality. Next to rail-road exchange also rail-rail exchange will be elaborated. The central actor is the intermodal and terminal operator HUPAC;

5. an inland terminal for one mode of transport (rail-rail) *Venlo (Netherlands)*. The central objective is to develop a medium-sized rail-rail terminal between the Dutch Belgium harbours and the inland terminals in the Ruhrgebiet/Cologne region and extended corridors. The projected hinterland route IIzeren Rijn is an important component for this exchange network. The development of a barge terminal along the Maas also makes the terminal of interest for rail-barge chains. The central actor is the rail terminal and intermodal operator ECT.

3.8 Indicators and criteria for innovative networks with new-generation bundling (WP5)

Because there are several actors in the chain, it is not possible to define a set of unambiguous indicators and criteria that would suit all actors. In fact, it is probable that there are some contradictions between the relevant indicators and used criteria of different actors. To illustrate this, in WP1 to WP4, different sets of indicators and criteria have been used order to select concepts, to classify them and evaluate their performances. These former WP's clearly show that different indicators are used innovative networks and for new-generation terminals. The aim of WP5 is to integrate these indicators and criteria into one set of overall indicators and criteria. This implies that a method had to be found to overcome contradictions in the chain.

In order to meet the objective the following methodology has been used:
1. investigation of used indicators and criteria (in literature on intermodal transport and within TERMINET);
2. development of the conceptual model of a virtual transport operator (system approach);
3. systematic selection of indicators.

The virtual transport operator is a functional player and does not exist in reality. He is above the organisational borders and is looking for the optimum of the whole intermodal transport system instead of sub optimum in each part of the transport chain.

The ideal solution fulfils the shippers' requirements at the same time as it produces the maximum profit for the transport operator. The purpose of the indicators is to help the virtual operator to evaluate his alternative solutions of providing the door to door service. His main concerns are time and money, but he needs also some additional quantitative and qualitative attributes of the service. We have concluded that there are five main categories of indicators:
- time;
- cost;

- destinations;
- volumes;
- quality.

Figure 3.6   System perspective of a virtual transport operator
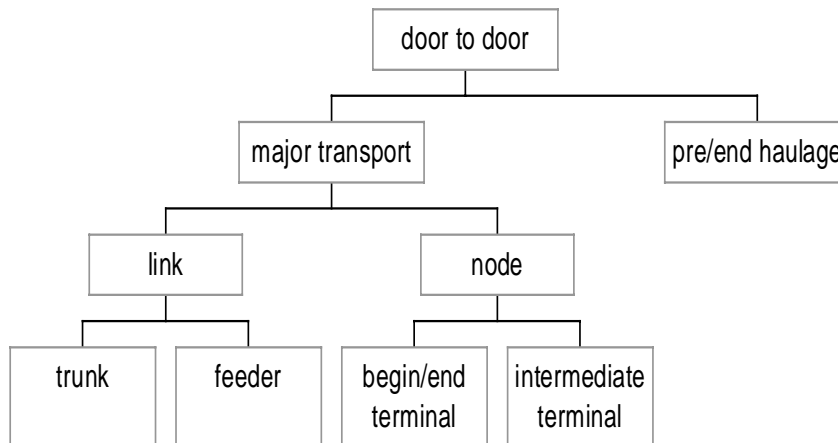
These indicators apply to all elements of Figure 3.6. For the virtual transport operator the 'final' value of each indicator counts. He is indifferent how these indicators score for the different parts of the chain. The different actors in the chain could us the same indicators, but will use different criteria because they only take into account their part of the chain. From the perspective of the virtual transport operator there is a continue trade off between the values of these indicators. A few examples of trade-offs are:
- faster terminal handling (time), higher costs;
- more intermediate destinations, more stops, longer chain time;
- higher frequencies, lower utilisation rate, thus higher costs.
The consequences of these trade-offs, quantitative terms have not been investigated yet.

3.9   Proposal for harmonisation (WP6)

In WP 6 a framework has been elaborated to evaluate measures harmonisation. The measures should aim at reducing development costs of new-generation terminals and innovative networks and at improving interoperability. Two levels have been distinguished: network and terminal.
    On the network level of harmonisation the elements of harmonisation are:
- trains/wagons;
- trucks;
- transport units;
- infrastrucutr (both for goods and information), and;
- information.
    On the terminal level of harmonisation the elements of harmonisation are:
26

- transport/transfer equipment and operations;
- handling equipment and operations;
- transport units;
- storage technologies and operations.

3.10 Five case studies (WP7)

In §3.7 we discussed which case studies have been selected and on which criteria. WP7 consists of innovative network and new-generation terminal design tasks for the cases Valburg, Metz, Venlo, Duisburg and Busto. Each case is elaborated with the following structure:

a) *Programme of requirements*
- description of the existing situation (location, operations, developments);
- problem description;
- objectives of new-generation solution;
- description of existing network and terminal operations related to the network;
- description of future flows and redesign of the network;
- presentation of an OD-matrix (origins-destinations);
- formulation of programme of requirements.

b) *Terminal design*
- choice of new-generation terminal concept(s);
- design of operations and terminal layout, including other terminals, secondary operations/sidings and the terminal environment;
- analysis of performances along a common set of indicators:
  - utilisation rate of equipment (cranes, storage facility, sorting systems);
  - peak performance of equipment;
  - handled volumes in terms of moves and paid transhipments;
  - terminal investments and operational costs;
  - extensions and other growth paths;
  - effects of growth paths for terminal investments and operational costs;
  - validation/verification with case stakeholders. Perspectives for implementation.

In Chapter 4 we discuss the major outcomes of the design task and performance analysis.

3.11 Simulation and animation (WP 7)

In WP 7 task 2 a simulation and animation tool for performance analyses of the case studies of WP 7 task 1 have been elaborated. Two simulation and animation tools have been developed and/or used for performance analysis of the case studies of WP 7. Both tools apply different simulation software:

1. A simulation and animation tool of Noell Machinebau, which has been particularly designed for the Noell Megahub[6]. The software is confidential.

   The program Simpro was selected as simulation tool as a result of an extensive market research. The basis for preparing a simulation model in this program are module libraries containing module types. Applied in any number into a simulation layout the simulation modules proper with individual parametering and statistic are than generated. The modelling of the module functions is carried out in Simpro with Petri networks and the programming language Modula 2. Apart from the standard library included in the supply exists the possibility to prepare user-defined module libraries on it's own. In the present case a module library was prepared for the terminal simulation.

   Among others methods of the structured analysis and the functional structure where applied when planning the new modules to be moduled. Hereby a case tool (computer aided software engineering tool) served as tool, in order to assure the consistence of hierarchic system description. The implementation of the Petri networks and the program text modules of the module types were based on this system description documented by diagrams.

2. A software tool which has especially been developed for the Tuchschmid Compactterminal. The tool of the Compactterminal at this stage is an animation tool, but could easily be further developed to a simulation tool. A demo of this animation tool is available.

   Each of the existing packages which were found had some of the functionality that was required to produce an operational simulation model. However, no simulation package was found that had the all the necessary functionality. Furthermore, no package was found that combined fast running times with good, three-dimensional, graphics capabilities. For the purposes of the research, it was considered that all these packages imposed significant limitations on the model design without offering major benefits in terms of the functionality over and above that which could be obtained with a high level programming language.

   In consequence, the use of high level language programming was considered as an alternative to the use of a special purpose simulation package. Modern high level programming languages such as C++ and Java are object orientated and allow for simulation models to be designed in a manner that reflects their natural construction. Thus, an Automated Guided Vehicle (AGV) object can be constructed which consists of a body, 4 wheels, and a container. It could then have assigned to it various attributes such as: width; length; maximum speed; acceleration; deceleration etc. Through the use of object orientated programming faster model development is possible as well as: increased model quality; easier maintenance of model code; enhanced ability to make model changes; greater reusability of model code; and the potential to develop more complex models.

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[6] Refer to Meyer (1998) and Alicke (1999), who wrote their theses about the development of the Noell simulation tool.

3.12 Business plans (WP8)

The economical feasibility of the terminal designs for the five case studies have been analysed by business modelling. For each case a business models has been built. A business model has the characteristics of a decision support system (DSS): it assists the user(s) in their decision-making tasks and it supports, rather than replaces, managerial judgement. With this model, several scenarios' can be simulated: from an optimistic to a pessimistic scenario.

The purpose of a business model is to calculate the ***economic feasibility*** of NG Terminals. The economic feasibility is measured in terms of profitability, growth and continuity. Therefor the main *objectives* are the following:
* *Profitability;* (e.g. profit in terms of net profit, cash flow and Return on Investment (ROI));
* *Growth;* (e.g. growth in terms of number of sales);
* *Continuity;* (e.g. continuity in terms of sales- and costs developments).

Besides these main objectives there are also some *secondary objectives*: the business model also contains price developments, the development of the rivalry amongst the competitors in the relevant market and the Net Present Value of initial investments.

Each case contains of a base model and a case specific model. The base model consists of *an environmental analysis* of the terminal in question and gives an overview of *the statement of results* and *the balance sheet*. With these two economic statements, other economic parameters are calculated. Besides, each case has terminal specific variables. These case specific variables have been integrated in the base model in order to be able to simulate with different scenarios.

The software which has been used is called *Powersim 2.5*[7]. This software is used for both building and simulating dynamic models. A dynamic model is a collection of variables that influence one another over time. Because of the dynamic character of Powersim models the development and behaviour of some variables can be precisely analysed over time. In Powersim it is possible to build the same interactions as they exist in reality. The main characteristic of a model is that it is a stylised reproduction of reality. Building models with the aid of computers is called *system dynamics*. There are three kinds of variables within Powersim: *level* variables, *constant* variables and *auxiliary* variables. With the level variables changes accumulate (e.g. bank account), auxiliary variables contain calculations based on other variables and constant variables contain fixed values that are used in calculations of auxiliary variables. With these three variables the dynamic models are build and simulated.

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[7] Except case Duisburg, which has been modelled in Excel.

3.13 Identification of implementation barriers (WP8.2)

Despite the mentioned benefits of new-generation terminals during the Terminet project none of the new-generations terminals have been implemented, nor are there any serious implementation projects of which we are aware off. However, some parties in Germany joined together in order to investigate an implementation plan of a Noell Megahub in Hannover-Lehrte. The question now is of course, *"why have not these promising terminals been implemented (yet)?* We could think of many reasons, but we believe that only with a structured analysis the most important implementation barriers can be assessed. For this purpose an analytical model has been developed and applied.

In order to set up a structured analysis we elaborated a conceptual model with a large number of potential implementation barriers. For the selection of potential barriers we based ourselves on the literature about *adoption and diffusion of technological innovations.* In respect to the adoption of innovations by individuals and organisations many empirical studies have been carried out. These studies always aim at identifying if, how and how much certain variables explain why a certain (technological) innovation is adopted or not. Due to these studies we know a lot about which variables are strongly related to the adoption of an innovation. We also know which variables are positively related to adoption and which negatively.

The technical innovation in our study is the new-generation terminal. This innovation is not implemented yet. In other words is not adopted. This implies that up till now the conditions for implementation have not been optimal. We elaborated a model based on the most important explaining variables. In this model the explaining variables are seen as potential implementation barriers. With the model we will identify implementation barriers for the five cases Valburg, Venlo, Duisburg, Metz and Busto

Starting points for our analysis were:
- The terminal and network designs of the case studies carried out in workpackage 7, and;
- Performance and cost data related to these case studies.

3.14 Final identification of promising innovative directions (WP 9)

WP 9 is the result of the concluding phase of TERMINET. The objectives of this final report are:
a) the final identification of promising innovative directions for bundling networks and new-generation terminals. TERMINET intends to support the recommendation of certain terminal concepts for certain types of nodes in certain bundling networks or, alternatively, to specify bundling networks with node types and locations suited to certain terminal concepts;

b) the evaluation of the feasibility of innovative concepts on the technical, operational and economical level and the description of the circumstances of a feasible course of development and implementation; the identification of institutional, as well as concept-specific barriers for implementation;

c) the formulation of public and private measures for supporting and encouraging the implementation of innovative operations;

d) the formulation of recommendations for further research.

4
CASE STUDIES

4.1   Introduction

The contents of the Chapters 4 and 5 moves from the concrete terminal design to the more abstract vision. In these chapters the results of WP 7, WP8 and WP 9 are integrated. First, this chapter focuses on the case studies that were carried out in TER-MINET WP7. Based on the analysis of OD-matrixes and actual network operations in five cases, five case specific terminal designs were made. These were the starting points of the calculation of the terminal costs and the analysis of the economic feasibility that were carried out in WP8. After this, in Chapter 5 the step is made to an integration of new-generation terminals and innovative networks, however on a somewhat more general level. Finally, a picture is presented of a feasible and promising future of intermodal transport that may be an inspiration for policy recommendations.

The aim of WP7 was to support the understanding of the value, which new-generation terminals add to node-effectivity and node-efficiency and thus the functioning of innovative networks. The specific aim of this chapter is to contribute to such understanding by comparing the operations, lay-outs, effects (and costs) of the different cases.
The conclusions show what can be achieved, if certain networks and terminals are implemented; networks and terminals, which the leaders and research members of each case have suggested, because they had expected them to lead to a best solution. But inside WP7 no further elaboration of alternatives and optimisation of solutions has taken place[8]. This means that:
- given a certain OD-matrix, only one network was designed[9];
- given a certain network, only one terminal was designed[10].

The absence of a larger number of alternative designs implicates that the conclusions are restricted. Nevertheless the comparison of these solutions allows drawing very inter-

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[8]   This would have exceeded the project budget substantially.

[9]   The only exception is Venlo, for which two OD-matrices were designed. But terminal designs and the analysis of investments and costs were restricted to one OD-matrix.

[10]   For the case Busto investment and cost projections were conducted for more than one NG-terminal concept, namely 3 Tuchschmid terminals, Dematics Transmann terminal and Noells Megahub concept.

esting conclusions, which contribute to the finding of promising directions of innovations.

All of this refers to the cases Metz, Busto, Venlo and Valburg. Duisburg is a separate matter, which is of great interest for TERMINET, but difficult to compare with the other cases.

The investment and transhipment costs of Metz and Duisburg will be dealt with in Chapter 5.

4.2   Case Metz

4.2.1   The functional main lines

Metz is the centre of the largest hub-and-spoke network of ICF. In the present operations (block) trains arrive at Metz, the wagons and wagon groups are reassembled to new trains, which run under new train numbers to the endterminals. Part of the exchange at Metz rather resembles a Trunk-collection-distribution than a hub-and spoke-network.

The central TERMINET idea for the case Metz is the substitution of the shunting yard by a new-generation terminal for rail-rail exchange. The major result is the time saving at the hub node. Trains can save up to 4 hours of time at Metz. This time advantage allows to optimise the network operations and makes intermodal transport more competitive. In the new network, (shuttle) trains stop at Metz, exchange load units amongst each other, and continue their journey (same train on both sides of the terminal).

The main bundling concept remains a hub-and-spoke-network. The optimal exchange type is that of network- and terminal-simultaneous exchange of load units between 6 trains, which are present at the terminal during the same period (= exchange-batch). The maximal batch size is six trains. There will be batches with smaller sizes. The exchange takes place during the night.

Next to the network-simultaneous exchange there is also the network-sequential one. This takes place between different exchange-batches, of course via the storage area.

Typical exchange operations are shown in Figure 4.1. The service area of the hub-terminal Metz covers a large part of Europe. The exchange volume is about 500 wagons a day (290,000 LUs/year; 7 days/week). As the Metz terminal only has rail-rail exchange during the night, it is possible in the future to let the cranes and sorting system run fully robotised. In the case study the cranes run semi-automated. Figure 4.1 focuses on the most important parts of the exchange operation and thus the simultaneous presence of exchanging trains at the terminal. In reality and in the OD-matrix such trains do not enter or leave the terminal at exactly the same time. There is a difference of arrival of about 8 minutes and the same for the departures, as the trains partly use the same link infrastructure. These slight differences in arrival and departure times are not shown in the figure.

34

Figure 4.1   Typical exchange operations at Metz.

4.2.2   Capacity and lay-out

The infrastructure is dimensioned for the exchange operations in the night period. In this period the average intensity is 75 crane moves per hour. The maximal intensity (i.e. capacity requirement) is 235 crane moves. The maximum storage requirement at any moment is about 226 LUs.

The terminal concept applied for this case is Noells Megahub concept. The terminal design for Metz is very similar to Noells Megahub concept for Hanover-Lehrte. It has 6 tracks, 6 semi-automated cranes, a sorting system with the length of the terminal and 15 shuttle cars. The capacity reserves during the night, especially in the peak periods, are restricted. This means that buffering of trains, break controls etc. need to take place outside the terminal.

4.3   The case Busto

4.3.1   The functional main lines

Busto is one of many terminals in the Milano region. A region, for which a large growth of the intermodal sector is expected and quite some restructuring of the terminals is projected. The TERMINET idea is to develop a new-generation terminal along one of the main tracks between Milano and the Alps, for instance near the existing terminal Busto 2. The exchange at this terminal could:

- be part of several bundling networks, serving the Milano region and/or also connecting northern Europe with whole Italy;
- be organised by different terminal or network operators (e.g. HUPAC, CEMAT, ICF), for which complex bundling is of great advantage. A possible configuration is that of each company having its own terminal for BE-operations, and one (or more) common terminal(s) for L-, HS- or other operations.

The growth potential in the Milano area for the period 2000-2020 is about 400,000 load units, of which approximately 180,000 LUs for a new-generation terminal Busto (Erni, 1999). These volumes mainly refer to flows from or to the Milano region. In this framework the following exchange levels were considered to be valid for the new-generation terminal Busto: 130,000 LUs (phase 1), 175,000 LUs (phase 2) and 300,000 LUs (phase 3). If complex bundling of flows between the Alps and northern Europe on the one hand and other Italian regions than the Milano one on the other hand would become of major importance, the exchange volumes would increase substantially beyond the mentioned levels. A new terminal Busto will not become larger by such a development, but the mix of bundling networks will change.

In such projections the new-generation terminal Busto can have several of the following functions:
- rail-road exchange. The involved bundling concepts are:
  – BE-networks. The trains end or begin at Busto;
  – L-networks. The trains stop at Busto and continue their journey, ending at a BE-terminal in the Milano region, northern or central Italy;
- rail-rail exchange. Trains stop at Busto, exchange load units amongst each other, and continue their journey to a BE-terminal in the Milano region, northern or central Italy. The involved bundling concepts could be HS-, TCD- or TF-networks.

The typical exchange operations are shown in Figure 4.2.

4.3.2 Capacity, lay-out and costs

The maximal intensity (= capacity requirement) is assumed to be around the 70 crane moves per hour (phase 1) and 90 (phase 2). This in combination with the annual volumes allows[11] to draw rough conclusions about the terminal types which could be implemented for the Busto location. Opposite to other cases, several terminal concepts have been evaluated for the Busto case. Most attention was paid to the Tuchschmid terminals, but also Transmodals Transmann concept and Noells Megahub concept have been investigated.

As far as the Tuchschmid terminals are concerned, the CT3/660 terminal is required for phase 2. This has 3 tracks, 2 rail cranes and 1 road crane. This terminal can be transformed to a CT3/1000. Such a change will be required before the level of 300.000 LUs (phase 3) is reached.

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[11] The terminal designs of the Busto case are based on a set of indicators instead of deriving performance requirements from an OD-matrix. In this approach the annual volume is an indication for the storage demand.

Figure 4.2   Typical exchange operations at the Busto new-generation terminal[12].

Alternatively, a terminal with 2 Transmann cranes could be of service in phase 1. The following phase would require 4 Transmann cranes. Because of the peak performances, these would not be sufficient for phase 3. The Transmann solution has the advantage that the exchange area is train-long. This implies that less sorting is required at the begin-terminals. But the application of a Transmann terminal requires a very exact operational design, as the maximum width of the terminal is 4 lanes. With three exchanging trains, one of the outer lanes will have to serve as truck lane and as lane for a transport system that moves between the cranes and the storage area. This internal transport system needs to be very effective, as there is hardly any buffer capacity on this lane. And it would be of great advantage, if the trucks and terminal-vehicles could commonly use the same lane across its total length.

Alternatively, a network-simultaneous batch of exchange trains can be handled sequentially on the terminal. But this increases the number of moves per transhipment and the required storage capacity.

Another alternative is the implementation of Noells Megahub with 4 cranes. This alternative is of interest for the exchange levels of the phases 2 and 3. The terminal is so

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[12]   As the calculations for the Busto case are based on a macro-approach, figure 8.2 is not based on an OD-matrix, but simply illustrates the global idea.

powerful that it could manage the volumes and peak performances even in 1 shift (8 hours).

The mix of rail-road and rail-rail operations in the same time implicates that fully robotised operations are not possible. This comment is not relevant for the Tuchschmid terminal, which always has (automation guided) manual handling.

The macro-approach of the performance analysis in this case does not allow deriving specific conclusions about capacity reserves. On the basis of indicators one may expect that the Busto terminals will need infrastructure outside the terminal for buffering, break controlling etc.

The total investments for the Tuchschmid CT 3/600 terminal are about 16 million euro (without siding), of which 3 for cranes and 2 for the sorting system. This leads:
- (in case of 130,000 LUs/year = phase 1) to capital costs of about 10 euro/LU. The operational costs are expected to be 22 euro/LU. The total in that case is 32 euro/LU;
- (in case of 175,000 LUs/year = phase 2) to capital costs of about 8 euro/LU. The operational costs are expected to be 17 euro/LU. The total in that case is 25 euro/LU.

The Transmann solution for phase 2 costs 5 million euro more investments, mainly caused by the crane equipment. If the exchange volume is slightly lower than that of phase 2, three Transmodal cranes are sufficient. Then the investments are on about the same level as of the Tuchschmid terminal.

The Noell Megahub belongs to a total different terminal class, not only according to the performances, but also to the investments required. Smaller versions of the terminal are of interest for phase 2, medium versions for phase 3.

4.4 The case Venlo

4.4.1 The functional main lines
Currently, there is a BE-terminal at Venlo serving the region around Venlo. Different public and private actors are busy to establish a barge terminal. The central TERMINET idea for the case Venlo is to establish a rail-rail terminal for exchanging load units between Belgian and Dutch trains to and from the (south- to north-) eastern hinterland.

The new terminal Venlo is a terminal for:
- rail-road exchange. The involved bundling concepts are BE-networks (the trains end or begin at Venlo; the other BE-terminal is a harbour terminal) or L-networks (the trains stop at Venlo and continue their journey);
- rail-rail exchange. The trains stop at Venlo, exchange load units amongst each other, and continue their journey. The exchange takes place between Belgian and Dutch trains, between Dutch and Dutch trains, and between Belgian and Belgian trains. Most of the involved bundling concepts are - according to the OD-matrix - HS-networks;
- rail-barge exchange. As there is some distance between the barge and rail terminal, this exchange at the rail terminal takes place between 3-TEU-trucks, which serve as inter-terminal-transport, and trains.

Typical exchange operations are shown in Figure 4.3.

Figure 4.3   Typical exchange operations at the Venlo terminal

Figure 4.3 focuses on the most important parts of the exchange operation and thus the simultaneous presence of exchanging trains at the terminal. In reality and in the OD-matrix such trains do not enter or leave the terminal at exactly the same time. There is a difference of arrival of ± 5 minutes and the same for the departures, as the trains use the same link infrastructure. These slight differences in arrival and departure times are not shown in the figure.

The exchange volume is expected to be about:
- 920 LUs a day (= 240,000 LUs a year; 5 days/week; = phase 1)[13];
- 1260 LUs a day (= 330,000 LUs a year; 5 days/week; = phase 2);
- 1560 LUs a day (= 405,000 LUs; 5 days/week; = phase 3).

The mix of exchange types in all phases is - when measured in load units - ca. 45% rail-rail, 30% rail-barge and 25% rail-road exchange.

The speed in which these volumes could be realised:

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[13]   The current volume of 60,000 LUs/year rail-road exchange is already included in this volume.

- (most rail-rail exchange) depends on the amount of organisation efforts. The OD-matrix is based in the idea that forecasted rail BE-operations are interlinked by an exchange at Venlo. Hereby the BE-operations turn into HS- and other complex networks;
- rail-barge exchange (and some rail-rail exchange) depends on the on attractiveness of services. The leading idea in the OD-matrix is a modal shift from road to rail;
- (rail-road exchange) on the growth of demand in the Venlo region.

Together phase 1 possibly could be achieved in 2005, phase 2 in 2010 and phase 3 in 2010+.

4.4.2   Capacity, lay-out and costs

The average intensity is 137 crane moves and 23 sortings per hour. The maximal intensity (capacity requirement) is 164 crane moves and 65 sortings per hour. The maximum storage requirement is about 226 LUs.

The terminal design is based on Noells Megahub concept. It is dimensioned in the following way: 3 tracks, 4 semi-automated cranes, a short sorting system with 19 shuttle cars.

This equipment is sufficient to run the exchange of:
- phase 1 in the time between 18.00 and 8 o'clock (14 hours)[14];
- phase 2 in 20 hours;
- phase 3 in 24 hours.

In all of these times about 20% of the capacity is reserved as buffer for non-punctual trains[15]. Nevertheless, these have to wait outside the terminal for handling.

The mix of rail-road and rail-rail operations in the time implicates that fully robotised operations are not possible (rail-road operations require manual positioning).

The total investments are about 38 million euro (without siding), of which 19 for cranes and 12 for the sorting system. This leads:
- (in case of 240,000 LUs/year) to capital costs of about 20 euro/LU. The operational costs are expected to be 14 euro/LU. The total in this case is 30 euro/ LU (3 shifts);
- (in case of 405,000 LUs/year) to capital costs of about 8 euro/LU. The operational costs are expected to be 12 euro/LU. The total in this case is 20 euro/ LU.

4.5   The case Valburg

4.5.1   The functional main lines

Valburg is a terminal for:
- rail-road exchange. The involved bundling concepts are BE-networks (the trains end or begin at Valburg) or L-networks (the trains stop at Valburg and continue their journey).

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[14]   Alternatively, the terminal could operate with 3 instead of 4 cranes in phase 1.

[15]   In this case non-punctual trains maximally have to wait 2 hours until they are handled.

- rail-rail exchange. The involved bundling concepts are TCD-networks or TF-networks (the OD-matrix does not express which of the two). In both cases the exchange takes place between trunk trains on the one hand and feeder trains on the other hand. There is no exchange between trunk trains.

The typical operations are shown in Figure 4.4 and Figure 4.5. The exchange volume is ca. 670 LUs a day (190,000 LUs/year).

Figure 4.4   The exchange operations at the Valburg terminal between feeder trains

Figure 4.5   Typical exchange operations at the Valburg terminal between trunk and feeder trains

4.5.2   Capacity, lay-out and costs

The average intensity is about 76 crane moves and 15 sortings per hour. The maximal intensity (capacity requirement) is 160 crane moves and 40 sortings per hour. The maximum storage requirement at any moment is about 91 LUs.

The terminal design is based on Noells Megahub concept. It is dimensioned in the following way: 6 tracks, 4 semi-automated cranes (each of them has a capacity of 30 LUs/hour), a short sorting system with 13 shuttle cars. Three tracks are normally occupied by trunk trains, the other three tracks by feeder trains. All parallel trains can stay at the terminal when they are at Valburg.

The terminal does not have particular buffer tracks. But track occupation and crane capacity reserves allow the handling of non-punctual trains at other than the planned periods. However, not in the peak periods, because the crane capacity is dimensioned on the peak demand. Such trains do not have to wait very long. Tracks for buffering of trains, break controls etc. are probably not required.

Figure 4.5 focuses on the most important parts of the exchange operation and thus the simultaneous presence of exchanging trains at the terminal. In reality and in the OD-matrix such trains do not enter or leave the terminal at exactly the same time. There is a difference of arrival of ± 5 minutes and the same for the departures, as the trains use the same link infrastructure. These slight differences of arrival and departure times are not shown in the figure.

The use of tracks implies that the feeder trains are diesel powered or - in case of electrical powering - that a change of locomotives is necessary at the terminal.

The total investments are about 42 million euro (without siding), of which 23 for cranes and 9 for the sorting system. This leads to:

- (in case of 190,000 LUs/year) to capital costs of about 20 euro/LU. The operational costs are expected to be 25 euro/LU. The total in this case is 44 euro/ LU;
- (in case of 430,000 LUs/year) to capital costs of about 9 euro/LU. The operational costs are expected to be 11 euro/LU. The total in this case is 20 euro/ LU.

4.6   The case Duisburg

4.6.1   The functional main lines

A major objective of the DeCeTe- and ECT barge terminals and the PKV-railterminal at Duisburg as well as the port authority, is to improve and develop intermodal transport in the Duisburg region. Since the potentials for a substantial increase of intermodal transport are not found in serving only the local market, an important strategy to realise this objective is to develop these terminals - which are located adjacent to each other - into a hub for barge/rail/road transport. The development of barge/rail services plays a major role in this strategy.

The development of barge/rail services implies that maritime barge flows are bundled with continental rail flows. In this way barge and rail transport at Duisburg can mutually

42

reinforce each other. On the one hand, potentials of barge transport will be enhanced, if barge services can be linked to rail services to dry inland destinations. On the other hand, rail services will profit from links with barge services. The mutual advantages are: higher loading degrees and higher transport frequencies. This will improve the price and quality of barge and rail services at Duisburg. Therefore, development of intermodal transport at Duisburg will be stimulated.

The barge services to/from Duisburg are focussed on serving the seaports (mainly Rotterdam and Antwerp). The rail services are focussed on inland destinations into many directions. Linking these services requires a matching of arrival times of barges with departure times of trains and solutions for minimising the additional terminal costs of exchanging units between vessels and trains.
The exchange volume between barge and rail, which is being envisaged for 2005, is about 75,000 units.
In the present operations vessels arrive in the morning and the trains leave in the evening and night. When the vessels are unloaded the barge containers are temporary stacked at the quay side awaiting for movement to the rail terminal by a Mafi vehicle, there they are temporary placed in a buffer stack awaiting for transhipment onto the train or are possibly directly transhipped onto the train, if the train is already present at the terminal. In addition to the inter terminal transport, in general, at least 3 handlings are necessary. The typical operations are shown in Figure 4.6. The ambition is to reduce the number of handlings and to save on the inter terminal transport costs.

Figure 4.6   Typical exchange operations at the barge and rail terminals in Duisburg.

4.6.2   Capacity and lay out
The required system capacity for the inter terminal transport has been determined on the basis of the handling capacity of the barge crane, which is about 30 moves or 45 TEU/hour. Assumed is that the barge crane should not have to wait, during unloading a vessel. Based on the vehicles' load capacity, their driving speed, the average travelling distance and the required time for handling the vehicles, a system capacity could be determined. The following system capacities were found:
- Mafi vehicle (present system): 10 TEU/hour. Optimisation of the present system would increase the capacity to 16 TEU/hour
- Mafi trailer trains: 48 TEU/hour
- AGV-system: 10 TEU/hour
- Linear motor system: 12 TEU/hour

The lay out of the terminal site will be an important element with respect to the attractiveness of the different systems. The average distance between the barge and rail terminal is about 600 meter.

Figure 4.7   The lay out of the terminal site.

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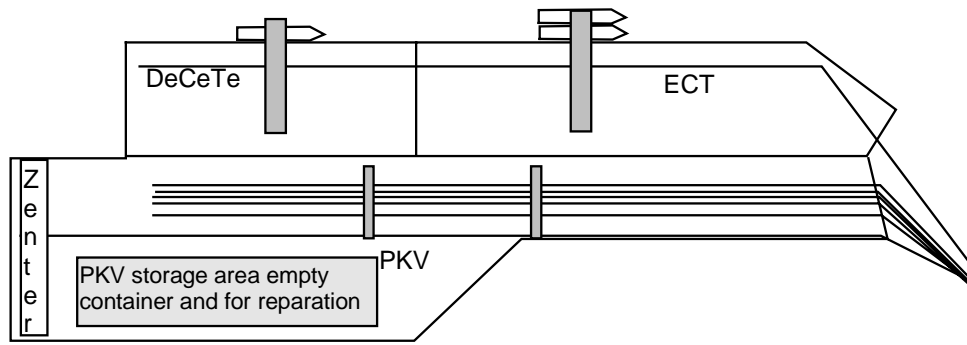
INTEGRATING NETWORKS AND TERMINALS: A FUTURE IMAGE OF INTERMODAL TRANSPORT

5.1   Introduction

In the preceding chapter five case studies have been elaborated, which focused mainly on the new-generation terminal. However, as accomplishing the integration of networks and terminals is one of the main objectives of TERMINET, in this chapter several promising *combinations* of networks and terminal concepts are evaluated. For this, two criteria have been decisive:

a) the combination of network and terminal is feasible on the technological, operational and economical level, within reasonable assumptions;
b) the relative advantages of using innovative concepts are substantial and undisputed.

As each situation is different, it is not possible to present a complete list of *the* most promising terminal-network combinations. Instead, three realistic cases have been studied. Each case represents different aspects of the intermodal transport, as well as different categories of terminal and network innovations. In the case of Metz, research focused on the replacement of a large shunting yard by a new-generation hub terminal. There was a relative strong focus on the advantages of modern technology. In the case of Duisburg, the main objective was to combine rail and barge terminals in the same network, using advanced, but not robotised technology, and to optimise the network by means of operational, rather than technological measures. The example of the Ringzug Rhein-Ruhr is somewhere in between, supposing the appliance of a system of semi-robotised compact terminals to an innovative regional network.

Finally, a more general image is presented of a possible future intermodal transport. Such a situation could serve as a policy objective.

5.2   Metz-Sablon as a hub in the ICF Quality Network

Currently, terminals play hardly any role in rail-rail exchange between intermodal flows. Shunting yards dominate this type of operations. Shunting allows the exchange of load units between a large number of trains (up to 30 per batch or night) and the bundling of intermodal and non-intermodal flows. This makes it possible *technically* to serve small intermodal flows.

However, shunting yards have some operational and economical disadvantages:

a) the relative long handling times reduce the time left for trains to run on the network and, accordingly, the maximum distance that can be covered;
b) the large amount of space that is required (about three times the train length);
c) the higher costs, compared to transhipment. The costs of shunting empty wagons increase the total costs per load unit;
d) the high noise level, compared to transhipment.

In the last decade, European railway companies have invested into large and modern 'new-generation' shunting yards that use robotised shunting locomotives and allow efficient operations. To take full advantage of these yards however, innovative wagons and automatic (un)coupling and brake reconnection are required.

Cost effects of robotising shunting yards were not investigated in TERMINET. Time advantages will rather be the consequence of operational strategies than of technological measures. Modern shunting yards require just as much space as conventional ones do.

The shunting yard Metz-Sablon is one of the main hubs in the ICF Qualitynet (Figure 5.1). The possibility of replacing this yard by a new-generation terminal was studied extensively in TERMINET. A case-specific terminal was designed (Figure 5.2)[16].

Franke and Vogtmann (2000) mention a reduction of the terminal time from 5:20 hours to 1:10 hours with the case-designed terminal Noell Megahub, a terminal suitable to replace large shunting yards as Metz. This means more possibilities with respect to different network operations, e.g. an increase of the maximum distance of 250 to 330km. – in this aspect intermodal transport then could beat unimodal road transport – or additional intermediate nodes.

The restriction to six tracks means trains would have to arrive and depart in batches, which means that some trains may not connect and load units would have to stay in the terminal until the next train. To reduce this disadvantage to a limited number of load units, network adjustments may be required. However, in case of Metz the time loss for consignees will be nil, compared to the present situation with long shunting times.

The reduction of the transhipment time means that with optimised network operations, it would be possible to handle all trains within an 8 hour time window each day. Even then, there would be a spare capacity within the time window, as well as during the night. Eventually it is possible to expand the terminal to 10 cranes or to enlarge the automatic sorting system.

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[16]   The functioning of this terminal is explained in §4.2.1 of Bontekoning and Kreutzberger (1999).

Figure 5.1:   Metz as a hub in the ICF network.
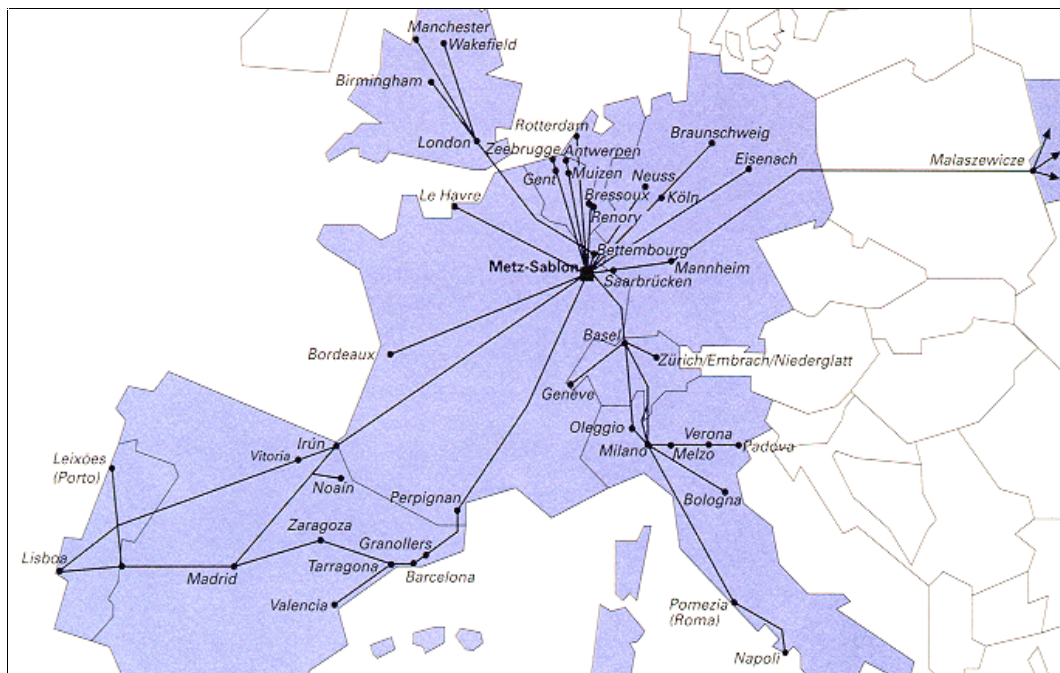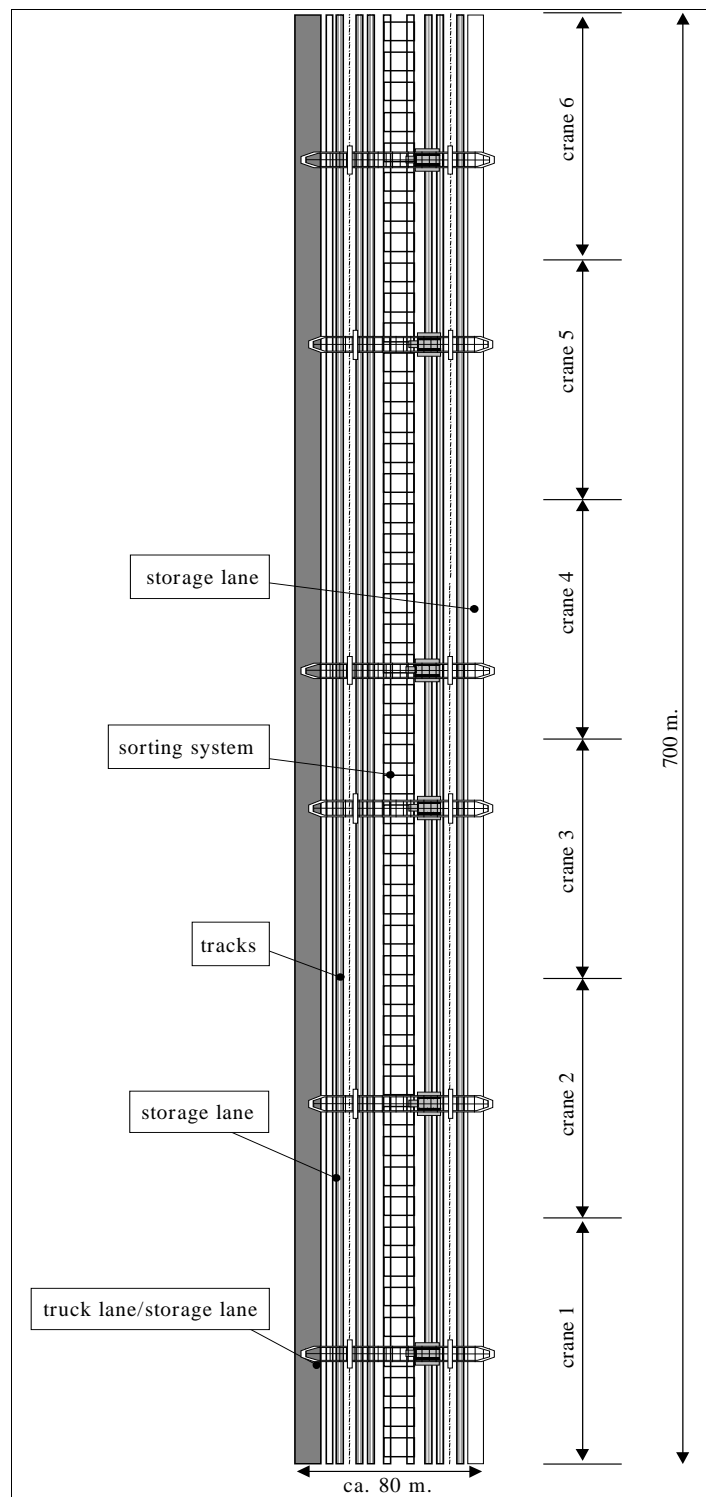

Source: ICF (1999).

Investment costs are approximately ε48 million[17]. Operating costs are expected to be about ε3 million per year, which would mean ε10.4 per load unit in case of the actual transhipment volume of 290,000 units per year. Overall, capital and operational costs are expected to be about ε27,6 per unit with an annual throughput of 290,000 units.
There are cost benefits too. The present yard in Metz-Sablon covers an area of 25ha., which with a Megahub could be reduced to circa 10ha. Also, a reduction of about 40 to 50% of the personnel is possible. In case of robotised cranes, an additional reduction of labour of 6 crane drivers per shift can be achieved.

It seems that the disadvantages of shunting with respect to intermodal transport still have not entirely been overcome by the introduction of modern shunting yards, especially when compared to modern terminals. However, shunting yards may be an interesting alternative if the batches of trains that must be exchanged simultaneously are larger than new-generation terminals can handle, i.e. larger than 6 to 11 trains. Nevertheless, the example of Metz shows that, at least in some cases, complex, large-scale operations may be executed more efficiently by new-generation technology.

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[17]   Without interest; based on the present transport volume and a depreciation period of 25 years (Francke and Vogtmann, 1999; Terminet D10, 2000).

Figure 5.2:   Noell Megahub for Metz.

storage lane

sorting system

tracks

storage lane

truck lane/storage lane

crane 1   crane 2   crane 3   crane 4   crane 5   crane 6

700 m.

ca. 80 m.

Source: Franke and Vogtmann (2000).

48

5.3   Rotterdam-Duisburg TCD barge network

Duisburg is an important transport node in the German Ruhr area, with good facilities for intermodal barge and rail transport. In Duisburg maritime containers from Rotterdam and Antwerp are transhipped from barges onto trains and bundled with continental flows.

The research in TERMINET focuses on the terminals in the Ruhrorter Hafen. Until recently these were the DeCeTe barge terminal, with a transhipment volume of about 90,000 load units in 1998, and the PKV rail terminal, with a volume of 130,000 units. The two terminals could be considered to operate at one site. The PKV terminal is the origin/destination terminal for many national and international train services. The terminal performs as a terminus. At present, mainly train-truck transhipment takes place. A new barge terminal has been constructed in 1999 by ECT. This will function as an outpost terminal, relieving storage capacity problems of ECT Rotterdam and improving its accessibility. The expected volume for this terminal is 120,000 units in 2005.

To increase the role of Duisburg in the national and international intermodal transport, these three terminals should be developed into a barge/rail/road hub. The focus is largely on the development of rail/barge services. Objectives are:

a) reduction of costs in the barge/rail transport chain, by improving the conditions for exchanging containers between barge and rail in a cost-effective way;

b) improving the connection time between barge and rail services.

The exchange of containers between barges and trains can take place via internal transport between the barge and rail terminal. At this moment exchange of load units between barge and train only takes place incidentally; in most cases (about 80%) this concerns empty containers. No barge/barge transhipment takes place; however, in the future this would be possible at the ECT terminal. The possible measures for improvement mentioned below are based on a forecasted internal barge/rail transhipment of 75,000 units in 2005.

Three options have been studied in TERMINET (Erni, 2000):

a) an extension of the current practice with MAFI-trucks and an identification system, from which MAFI drivers receive directions about the next unit they should pick up. The proposed system with 12 trailers and 3 operational MAFI-trucks has a capacity of 20 TEU/hour. The total technology costs of the system would be about ε830,000; there are no additional infrastructure costs. The yearly costs for operating, maintenance and staff would be circa ε430,000. Using a 'MAFI-train', figures would be somewhat better.

b) an AGV-system, guided by transponders beneath the road surface. Application of this system is hindered by the existence of a public road in the centre of the terminal area, that the AGV's will have to cross. Both for legal and practical reasons, automated vehicles cannot interfere with non-automated trucks. The current design does not yet provide a solution for this.
    For this system, the costs of technology and infrastructure are ε2,8 million. The total operational costs would be almost ε345,000, which is less than with the MAFI-system. However, this is more than compensated by higher capital costs. The overall difference is small.

c) a transport system with a linear induction motor, like the one used in the Noell Megahub. The system has 10 shuttles. However, also in this case the need for the shuttles to cross the public road is a barrier.

The costs of technology and infrastructure for this system are approximately ε13,7 million. Most of this (ε11,3 million) are costs for the specialised infrastructure. Due to the high investment costs, capital costs are much higher than for the other options. Total operational costs are ε1,2 million. Overall, this option is by far the most expensive.

The chances for the appliance of new-generation terminal technology in Duisburg seem to be limited. There are benefits, but the high investment costs are a severe problem. However, further progress could be found in improvements by applying innovative types of operations elsewhere in the network, e.g. by implementation of the CUB concept in the port of Rotterdam.

The Container Exchange Point for Barge Transport (CUB) is an exchange point for containers between barges, designed to function as a hub or CD-terminal between different terminals in the harbour of Rotterdam on the one hand and several inland barge terminals along the Rhine on the other hand. The concept is applicable to any other comparable situation.

The lay-out of the CUB focuses on direct barge-barge transhipment without interference of any storage area. The CUB handles standardised push-barges on the harbour side and non-standardised barges on the inland waterway side. Groups of 2 to 4 push-barges are moved from the CUB to Rotterdam, split there and distributed across different barge terminals (Figure 5.3). Later on, a same amount of push-barges is collected again, united to a convoy and moved to the CUB. The main objective of such operations is to delegate the time consuming harbour operations to specialised and relative cheap barge equipment (the push-barges can be handled at the terminals without any motor unit waiting).

The combination of a CUB near Rotterdam and the Duisburg network seems a very promising one, since the CUB could neutralise some disadvantages of the barge services on this route.

Currently, all barge services have more or less the same sailing schedule. The terminal time in Duisburg as well as in the port of Rotterdam is about 18 hours, making the total cycle time 72 hours. With organisational improvements, this could be reduced to approximately 44 hours for a 90 TEU vessel and 68 hours for a 398 TEU vessel. For regular services, a cycle time of (a multiple of) 24 hours is preferable, e.g. 48 hours for a 90 TEU vessel (Konings, 1999b).

A time reduction in the port of Rotterdam – where the barge calls at several terminals – could be achieved by implementation of the CUB. Also, this would enable a connection with more terminals in the same time.

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**Figure 5.3:   The Rotterdam-Duisburg barge network with a CUB.**
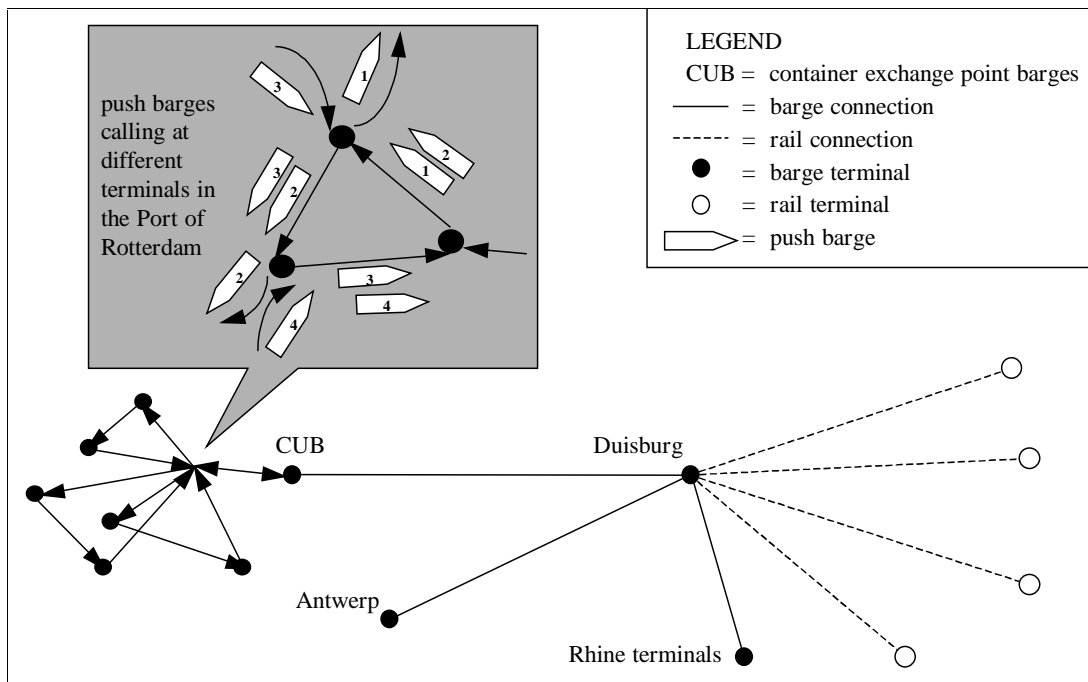
Source: adjusted from Vleugel and Kreutzberger (2000).

This is illustrated by an example for one vessel in Figure 5.4. Presently, the cycle time is 72 hours. In Rotterdam the vessel calls at two terminals, which in total takes more than one day. With the adjusted sailing schedule, the vessel only sails to the CUB where it exchanges units with the CUB barge. While the vessel is on its way to Duisburg and back to Rotterdam, the CUB barge delivers units at different terminals in the port of Rotterdam, at the same time picking up units for transport to Duisburg. In the example it is assumed that the terminal time in Duisburg could be reduced from circa 18 to 12 hours. Together with the CUB, this means that the present cycle time of 72 hours could be reduced to 48 hours, in other words each week an additional tour could be made. Also, the CUB barge calls at three terminals in the port, instead of two. This number could increase if several CUB barges are applied that call at different terminals in the port (as in Figure 5.3).

As this example shows, in some cases considerable cost and quality benefits may be gained by organisational improvements and innovative operations, rather than complex technology. In practice the most successful approach might well be the one that focuses on a certain mixture of all three elements.

Figure 5.4: **Example of the adjustment of the sailing schedule for one 90 TEU vessel by a reduction of terminal time in Duisburg and the implementation of a CUB in the port of Rotterdam.**
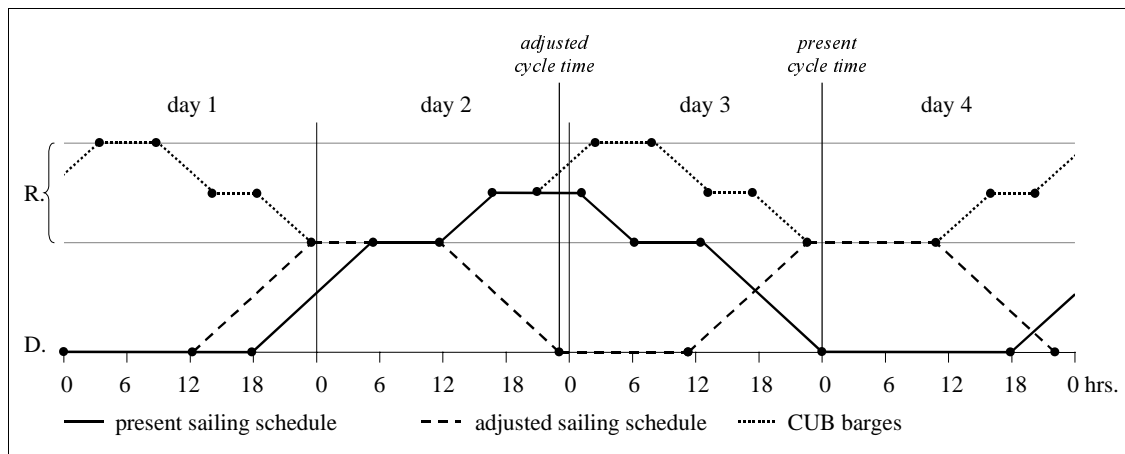
Source: Calculations partly based on Konings (2000c).


5.4   Ringzug Rhein-Ruhr

The Ringzug (i.e. ring train) Rhein-Ruhr is a prominent example for innovative line train concepts for combined transport on a regional level. Its major aims are:
a) to reduce the distance of road collection-and-distribution traffic;
b) to introduce more efficient network operations without shunting;
c) to turn more combined transport potential into demand;
d) to make combined transport more competing.

Due to doubts about the cost-effectiveness of the system, the Ringzug eventually has not been implemented. Nevertheless, it has been studied in TERMINET, as it is considered a promising example of the *type* of bundling networks that in future may increase the modal share of intermodal transport.

The Ringzug Rhein-Ruhr is about 300km. long and connects ten (in the long run eleven) terminals. Six of these are regular stops for (inter)national intermodal trains (Figure 5.5). Thus, the Ringzug has a double transport function as a trunk line for intra-regional transport and as a collection-and-distribution sub-system in the (inter)national network.
It is attractive to use the Ringzug instead of road transport for the collection and distribution of containers when the transport distance on the main route is at least 200 km. In case of regional transport, the Ringzug would be used when it could cover about two thirds of the total transport distance. In practice a figure of almost 2,000 units per day seems a realistic estimation, which allows 5 services per day in each direction. This would mean an expected transhipment volume of 100 to 570 units per day per terminal.

Figure 5.5: The Ringzug Rhein-Ruhr.
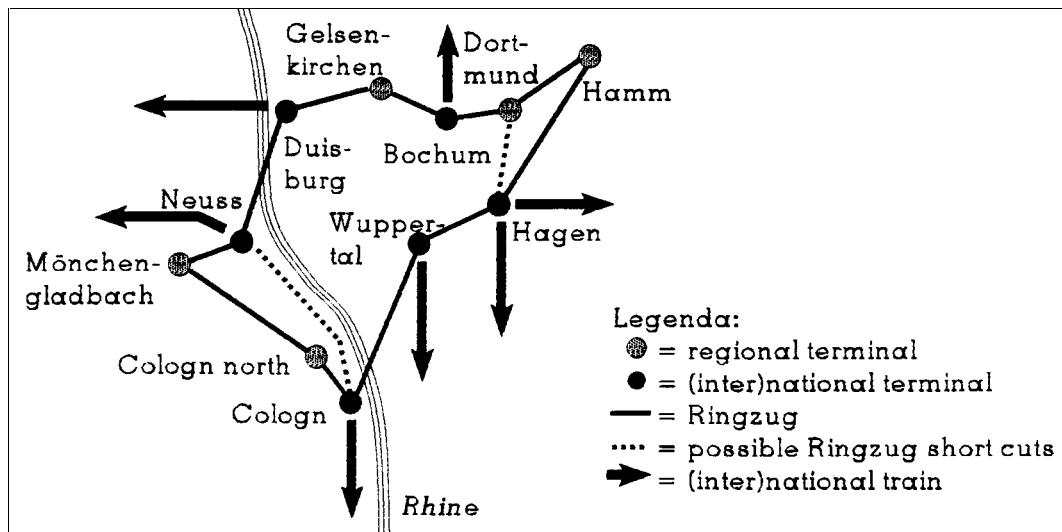
Source: Transcare, in: Vleugel and Kreutzberger (2000).

Although the concept terminals are equipped with reach stackers and gantry cranes, heavier, possibly new-generation, equipment could be justified (Sondermann and Zimek, in: Vleugel and Kreutzberger, 2000). Several regional Ringzug terminals are located on dead end rails, often because there is no space for 500m. long terminal pavements next to the main track. A more compact terminal could be located along a parallel track to the main track of the Ringzug. Thus, time losses could be avoided, as well as of investments for the long pavement.

In this situation the Tuchschmid Compact Terminal[18] seems a good option. This has an modular structure and could vary in capacity and number of tracks (with a maximum of four). At small regional nodes within the Ringzug, a CT1/100[19] may be sufficient, while for the largest (inter)national nodes a CT3/600 or CT3/1000 could be developed, as well as intermediate sizes for different nodes (Figure 5.6). This means it could be 'tailor made' for each of the Ringzug nodes. Also, an initial terminal could be enlarged in phases, when transhipment volumes increase.
A second advantage of all CT-types is the compact layout, with a length of only 240m. This implies trains pass through the terminal in three shifts. Dependent on the terminal size, the number of cranes and the length of the crane sections vary.

To estimate the total costs of Compact Terminals for all Ringzug nodes, it is assumed that at the (inter)national nodes 'on average' a CT3/350 is required (the transhipment volumes varies widely between nodes), while for regional nodes a CT1/350 is sufficient. Furthermore, it is assumed that at regional nodes no AGV- or sorting system is necessary. The complete Ringzug network then would require five regional CT1/350

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[18]   The functioning of this terminal is explained in §4.2.8. of Bontekoning and Kreutzberger (1999).

[19]   This means: one track and a maximum capacity of 100 units per day. Thus, a CT3/600 has three tracks and a capacity of 600 units per day etc.

terminals of circa ε8 million each and six (inter)national CT3/350 terminals of ε14.5 million each[20]. Together this would make a total of approximately ε130 million; however, this is a very roughly estimated figure, since no detailed node information. Also, these figures only include the costs of technology and infrastructure, not the cost of land requirement. The costs of transhipment could be estimated to lay between ε21 and 24 per unit for a CT3/350[21]; this may be less than ε20 per unit for a CT3/600 and ε16 to 17 per unit for a CT3/1000. These figures are indicative too.

Figure 5.6:   Tuchschmid CT 2/350.
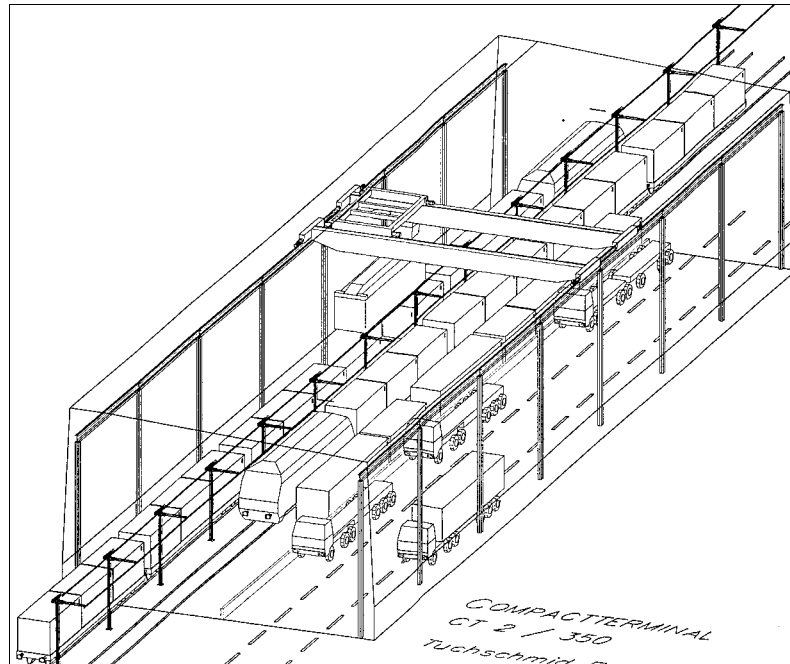
Source: Tuchschmid Engineering AG, in: Bontekoning and Kreutzberger (1999).

Although the Ringzug Rhein-Ruhr has not yet proven to be economical feasible, the concept as such seems promising. This type of services may add to the modal shift on medium distances. Also, the example shows that in cases like this there could be a use for new-generation terminals, since their main advantages, in this case a compact layout and a variable size within the concept, may match to the demands of the network.

5.5   A positive future image of intermodal transport

How could a possible future image of intermodal transport look like more in general in, let us say, 15 or 30 years, if we would extrapolate current trends, taking into account the demand of shippers and operators, as well as societal needs?

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[20]   Based on calculations (for TERMINET WP7) by Tuchschmid and OTB for Busto Arsizio.

[21]   Based on calculations (for TERMINET WP7) by Tuchschmid and OTB for Busto Arsizio.

Let us suppose that, in the period mentioned above, liberalisation of the railway sector has been completed. This allowed a speed-up of the development of integrated networks, more or less like the networks that were developed earlier in the airlines industry. Several large intermodal operators exploit own, extensive hub-and-spoke of CD networks, in many cases with own terminals, locomotives and wagons. Some them are former national railway companies that have been privatised, others have their roots in the private sector. Also, some ocean shipping lines own locomotives and operate several train services.

From the region, load units are transported by Cargosprinter or are trucked to the terminal. Other regions are serviced by feeder trains that run on line or begin-end networks, depending on the transport volume. Some of these feeder services, whether profitable or not, are provided by the terminal operator as a part of a package deal for exploitation of the terminal. Other feeder services are provided by truck companies which set up own rail services, in particular several regional line networks, and by trunk line operators. Thus, optimal adjustment of feeder trains to the national and international services is enabled and pre- and end haulage by truck is minimised.

At the main terminal, national and international line or shuttle trains make a quick stop and exchange load units with regional services and other long distance services. Most transhipment takes place semi-robotised and, if possible, simultaneously. Although new load units are slowly being standardised, the terminal cranes are also able to handle the many old units that are still in use.

At another part of the terminal, smaller numbers of priority units are loaded and unloaded. These are transhipped simultaneously or are delivered by direct feeder trains and trucks just before the train arrived; likewise, they will be the first to be picked up after the unloading. To ensure a high level of reliability and efficiency, this part of the terminal is fully robotised; for safety reasons no humans are allowed.

AGV's transport units to and from the barge terminal nearby. Train and barge networks are complementary and are fully integrated, although on routes where train and barge compete they serve different markets. In general, priority cargo may be transported by road or, occasionally, barge in case no rail service is available. The opposite is true for raw materials.

National and international trains arrive and depart at the terminal at all hours and, accordingly, so do feeder trains and trucks. There is no fixed relation between time schedules of trains and the business hours of consignees. Peak hours still exist in the morning and the evening however, though peaks are flattened out by the appliance of different tariffs during peak hours. Apart from this, additional charges are required for priority cargo, for which a maximum transport time is guaranteed, as well as a narrow time window for delivery. In fact this system of quality differentiation is very much like the system that has already been common for a long time in mail and courier services.

Although progress has been made in the harmonisation of railway systems, standardisation is not yet complete; still, there remain some problems concerning different track sizes. International trains in many cases run on dedicated tracks – especially in congested areas – and are adapted to different systems, so that no change of locomotives is needed. Also at the terminal the locomotive is not uncoupled. In most cases a small die-

sel engine is placed in front of it, to pull the train through the terminal. Thanks to electronic instead of hydraulic brakes, brake testing takes only a few seconds.

Since wagons are modified too, enabling automatic identification and pin setting, very short terminal times are possible and less labour is needed. Automatic train coupling is possible too, although it hardly ever happens at the terminal. Few operators still use conventional, non-modified equipment, since considerable surcharges are demanded at each terminal. Besides, most terminal operators allow the use of non-modified wagons only for feeder trains not transporting priority units. An ever-growing number of main tracks have been closed for conventional wagons, so that these do not disturb the automated processes at intermediate terminals.

The terminal operator co-operates extensively with the operators of the network services. This is a complicated task, as there are several of them, rather different in size and activities, and their services should connect. Some provide only a few services, while others exploit extensive networks that may include terminals or shipping lines. Time schedules of trunk and feeder trains and barges are optimised to enable short terminal times and a maximum rate of direct transhipment. Thus, a smooth and seamless door-to-door transport chain is ensured.

6
CONDITIONS FOR IMPLEMENTATION

6.1   Introduction

In the preceding chapters the main network and terminal concepts were discussed, as well as some promising combinations of the two. The advantages of new-generation terminals, and of their integration with innovative networks, are clear.
Nevertheless, new-generation terminals have not been successful so far. Therefore this chapter focuses on the conditions for their successful implementation and on possible barriers that block, or may block, their implementation.

First of all, economic feasibility of new-generation terminals seems to be a condition sine qua non for their implementation. Since it has appeared that part of the advantages of new-generation terminals occur in the network, economic feasibility should also be defined on the chain or even network level. In §6.3.1 the results of this approach are presented.
The occurrence of network profits implies that, for a capitalisation of the potential bene-fits of new-generation terminals, they should be integrated with the network. Preferably, this should be an innovative bundling network. Therefore, the economical feasibility of terminals indirectly puts certain demands on the technological and operational charac-teristics of both the terminal and the network. The most important of these are discussed in §6.4.
Finally, §6.5 briefly discusses what implementation strategy should be applied and what role government could play to stimulate the innovation of intermodal transport.

6.2   Factors of success and failure for implementation of innovations

6.2.1   The adoption process: phases of the innovation decision process
The innovation adoption process is defined by Rogers (in: Terminet, 2000c) as the pro-cess through which a potential adopter of an innovation – in case of new-generation terminals this typically is the terminal operator – passes from first knowledge of an in-novation, to forming an attitude towards the innovation, to a decision to adopt or reject, to implementation of the new idea and to confirmation of this decision (Figure 6.1). This process consists of a series of actions and choices over time, through which an ac-

tor evaluates a new idea or technique and decides whether or not to incorporate it into ongoing practice. This behaviour consists essentially of dealing with the uncertainty that is inherently involved in deciding about a new alternative to those previously in existence.

Figure 6.1:   Phases of the innovation decision process.
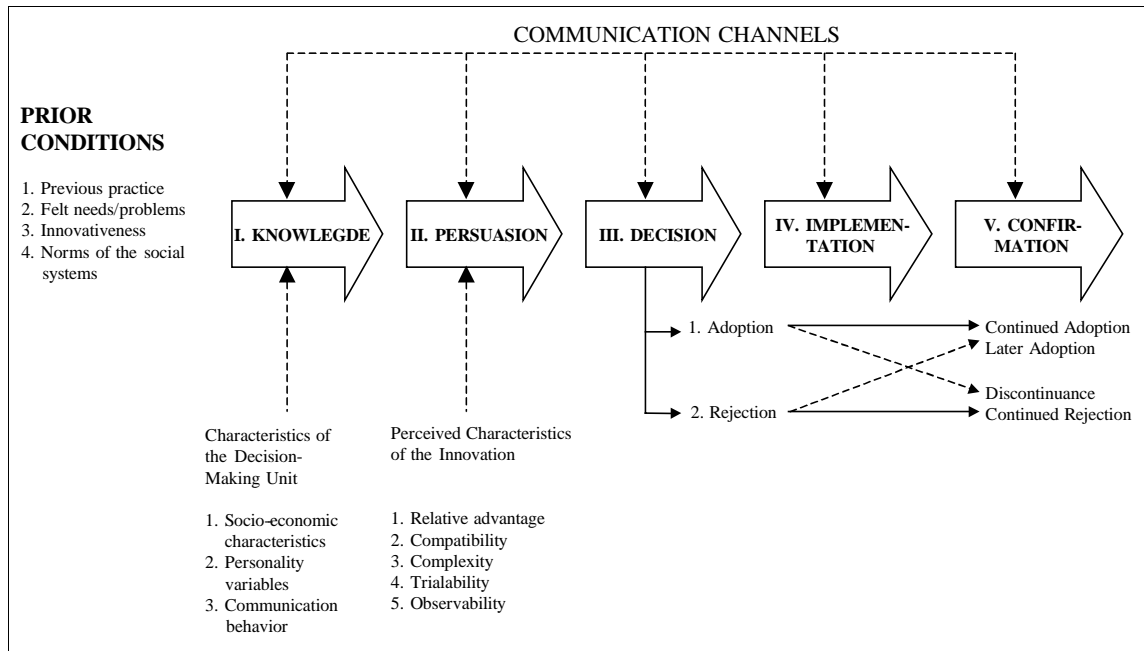
Source: Rogers, in: Terminet (2000c).

With respect to the implementation of new-generation terminals, it seems this process is somewhere between phases I and II. Research projects have generated a considerable amount of knowledge, but nevertheless potential adopters have not yet been persuaded to decide in favour of the innovation. It appears that certain barriers block the adoption and implementation of innovations in intermodal transport, in particular new-generation terminals.

6.2.2   Identifying barriers for implementation

According to Rogers (in: Terminet, 2000c), the variance in the speed of diffusion may be explained largely[22] by the following features of the innovation (also shown in Figure 6.1):

a) *relative advantage*: the degree to which an innovation is perceived as being better than the present situation;

b) *compatibility*: the degree to which an innovation is perceived as consistent with existing values, past experiences and demands of potential adopters;

c) *complexity*: the degree to which an innovation is perceived as relatively difficult to understand and to use;

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[22] According to Rogers the factors a) to e) may explain 49 to 87% of the variance in the speed of diffusion. The element of 'uncertainty' was added afterwards by Frambach (Bontekoning, 2000).

d) *trialability*: the degree to which limited experiments are possible with an innovation;
e) *observability*: the visibility of the results of an innovation for others;
f) *uncertainty*: the degree of uncertainty about the advantages of an innovation and the additional efforts that are required.

Table 6.1: **Impact of explaining variables on implementation of new-generation operations in 5 case studies.**

Explaining variable	Metz	Valburg	Busto	Duisburg	Venlo
Perception of innovation					
Relative advantage					
a) Performance/ service	++/n.a.	+/-	+/n.a.	+/n.a.	+/n.a.
b) Costs	+/-	-	+	-	n.a.
Compatibility	--	--	-	+/-	--
Complexity	-	-	+/-	+	-
Triability	+/-	+/-	+/-	+/-	+/-
Observability	+	+	+	+	+
Uncertainty	n.a.	-	n.a.	n.a.	n.a.
Potential adopter					
Size	+	n.a.	+	-	n.a.
Degree of specialisation	+	n.a.	+	n.a.	n.a.
Type of decision	n.k.	n.a.	n.a.	n.a.	n.a.
Information, communication and social system					
Availability	+	+	+	+/-	+
Quality	-	-	-	+	-
Value	n.a.	+/-	n.a.	n.a.	n.a.
Social system	+/-	-	+	+/-	+/-
Degree of competitiveness	+	++	++	++	++
Innovator/supplier					
Marketing strategy	++	-	n.a.	-	+
Government					
Active outreach programs	-	-	-	-	-
Subsidising R&D/ increasing information / reliable information	+	+	+	n.a.	+

++ strong positive relation to implementation;
+ normal positive effect;
+/- diffuse effect (both positive and negative);
- negative relation with implementation;
-- very negative relation.
A positive score means that the variable supports implementation. The variables with a score - and -- can be pointed out as implementation barriers that need to be overcome. Some variables we could not give a score due to a lack of information. This is indicated as n.a. (not available).
Source: Terminet (2000c).

Although the variables mentioned above are most important, other variables have been applied (Table 6.1) with respect to different actors in the diffusion process; these variables were derived from many former empirical studies which investigated the relation between certain variables and the adoption or rejection of an innovation. Each variable has been analysed for each of the TERMINET cases (Metz, Valburg, Busto Arsizio, Venlo and Duisburg).

In short, the six main barriers for implementation resulting from the analysis in TER-MINET are at the moment:

a) lack of clear statements about benefits and costs of new-generation terminals and complex networks;

b) large dependency on the development of complex networks, which hardly exists except for networks which use shunting yards;

c) practical and operational problems such as brake tests, pin setting, seal and damage checks, change of locomotives and train drivers at borders, change of locomotives at terminals and priority for passenger trains on congested rail infrastructure;

d) lack of clear fall-back procedures which are needed in case the new-generation terminal operations fail. This especially applies to operations with largely depend on automation and robotisation;

e) limitation of easy access of test facilities for potential adopters. However, Krupp, Noell and Transmann have a test site;

f) accessibility of information. Many actors in the transport field hardly know which information is available. And if they do, it is not easy to access this information, either because information is only disseminated among researchers and policy makers, publication of reports takes place one year or more after finishing a study or results are not public.

According to Rogers (in: Terminet, 2000c) large relative advantages could overcome variables with negative values. However, it still means that these other values are barriers which need to be solved.

6.3   Economic feasibility of new-generation terminals

6.3.1   Introduction

Economical feasibility of new-generation terminals seems to be a condition sine qua non for their implementation. Therefore, this section focuses on the costs and benefits of intermodal transport and, in particular, new-generation terminals.

In general, it can be said that comparison of costs between new-generation terminals and conventional terminals and shunting yard is very difficult. It requires very detailed information which, in case of future new-generation terminals, may not (yet) exist or, in case of actual terminals or shunting yards, is considered confidential or is not available for some other reasons. The main step that should be taken to improve the economical analysis in further research, is to improve the quality of the input. Therefore the focus in this section will be more on the general conclusions – that seem beyond doubt, even if the limitations mentioned above are taken into account – than on exact figures.

6.3.2   Costs of new-generation terminals

Table 6.2 shows the level of cost prices of transhipment for four out of five TERMINET case studies, compared with that of a conventional reference terminal, both at the actual transhipment volume and at the optimal utilisation rate of the terminal (i.e. 60%, as higher utilisation rates may go at the cost of the reliability level. Also, the cost prices of transhipment are given in case a) the costs of depreciation are fully subsidised, b) the

interest costs are fully subsidised and c) the costs of both depreciation and interest are subsidised, i.e. only operational costs are taken into account.

Table 6.2   Cost prices (ε) of transhipment per load unit.

Opening hours	2 shifts	3 shifts	1 shift	3 shifts	3 shifts
Actual cost price/transhipment	*Busto Compact*	*Valburg Megahub*	*Metz Megahub*	*Venlo Megahub*	*Conven-tional*
• actual volume (load units)	130,000	190,000	183,000	240,000	150,000
• actual cost price	32.7	44.4	43.5	34.2	40.0
• actual cost price if deprecia-tion cost are 100% subsidised	29.6	38.9	35.9	30.3	37.6
• actual cost price if interest costs are 100% subsidised	25.5	30.3	24.0	23.9	35.2
• actual operational cost price	22.4	24.7	16.5	20.0	32.8
Optimal cost price/transhipment					
• 60% capacity use volume (load units)	174,000	430,000	290,000	407,680	200,000
• optimal volume cost price	24.4	19.6	27.6	20.2	30.0
• optimal cost price if depre-ciation cost are 100% subsi-dised	22.1	17.2	22.8	17.8	28.2
• optimal cost price if interest costs are 100% subsidised	19.0	13.4	15.2	14.1	26.4
• optimal operational cost price	16.7	10.9	10.4	11.8	24.6

Source: TERMINET (2000a).

The current tariffs of inland terminals are ε16 to ε20 per transhipment. These are subsidised, as actual costs per transhipment of the conventional terminal are ε40. However, these are only indicative conclusions. Making a direct comparison between new-generation terminals and the reference terminal is somewhat tricky, as there is confusion about the actual costs and tariffs of inland terminals. For example, the ε16 to ε20 mentioned above refer to small terminals with a transhipment volume of 10,000 to 100,000 units, whereas the reference terminal is quite large. It is even more difficult to compare the costs of new-generation terminals with that of shunting yards, as the estimated costs of shunting differ between ε40 to ε100 per wagon (about ε25 to ε70 per load unit).
The subsidy on capital costs as used in the example is in fact in favour of new-generation terminals, which in general require much higher investment costs compared to conventional terminals. Nevertheless, it seems justified to conclude that while new-generation terminals also need subsidy to meet market prices, subsidy in many cases is less than it would be with a conventional terminal. (This is in particular the case with the Tuchschmid CT for Busto and the Noell Megahub for Venlo, which are less expensive than the terminals for Valburg and Metz.)

The picture is quite different in case the optimal utilisation rate of 60% is achieved. In that case new-generation terminals can utilise their large capacity, which results in considerable lower costs per unit. In some cases, especially Valburg and Venlo, it seems hardly necessary to subsidy at all. However, the assumed volumes that are necessary for this seem quite unrealistic for the foreseeable future.

6.3.3 Analysis of the economic feasibility of new-generation terminals[23]

Research on economic feasibility of new-generation terminals in TERMINET was focused mainly on the following objectives: profitability, growth and continuity. Economical calculations were made for the terminal case studies Metz, Valburg, Venlo, Duisburg and Busto Arsizio (TERMINET, 2000a), for which case-specific terminals were designed, based on actual network operations or on realistic assumptions of future network operations. A business economical model was used for this[24]. It is important to realise that the quality of the output from these calculations is determined by the quality of the input, provided by several TERMINET partners.

Main objective of the business models was to evaluate the economical feasibility of the five terminals, in order to gain insight in the feasibility of new-generation terminals in general. Since one of the main findings of TERMINET is the importance of the integration of terminal and network operations, also the possible additional gains were taken into account that could occur on the network, as a result of the new-generation operations at the terminal. When, due to these gains, the net profit was positive, taxes were also taken into account.

The difference between feasibility analysis and the cost price calculation in §6.3.2 is that not only costs but also profits were taken into account. Furthermore, a dynamic approach is chosen, taking into account a period of 6 years, while the cost price calculation is static.

Economical feasibility has been analysed both with and without government subsidies; in the public investment scenario government subsidies all investment costs, while in the private investment scenario there are no subsidies. Return on investment and net profits during a period of 6 years after the implementation of the new-generation terminal were analysed. Furthermore, the payback period of investments was estimated.

Public investment scenarios of most terminals lead to high positive net profits on the short term. Results for Valburg are the least positive. Therefore the feasibility of this terminal could be a cause of anxiety on the short term. However, the results could be somewhat more positive in case another – smaller – terminal would be designed. For example, with just a few minor adjustments of the terminal operations, a Megahub with only 4 tracks would be sufficient, instead of one with 6 tracks. Of course this could change the results of the feasibility analysis. Unfortunately however, it was not possible to analyse several terminals per case.

Calculation of the pay-back period[25] gives an indication of the expected number of years that the initial investment is paid off. In any case this should be within the depreciation period of the terminal, estimated at 20 years.

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[23]   This section is limited to the main – qualitative – conclusions of the feasibility analysis. For exact results we refer to TERMINET (2000b), on which this section has largely been based.

[24]   In case of Duisburg, Excel has been used for modelling, in the other cases Powersim.

[25]   The pay-back period is calculated as: the net present value in the last year of the analysis divided by the cash flow in that year.

Calculation of the pay-back period in the public investment scenario shows results of approximately 7 to 16 years. Therefore, we can conclude that investment in these cases, given the payback periods and the assumption of public investments, is very interesting. In the private investment scenario, no expected payback period is calculated; with negative cash flows no expectations of payback can be formulated. However, without government public investment the pay-back periods are expected to be higher then in public investment scenarios. How much is very difficult to predict because cash flows in some cases are negative.
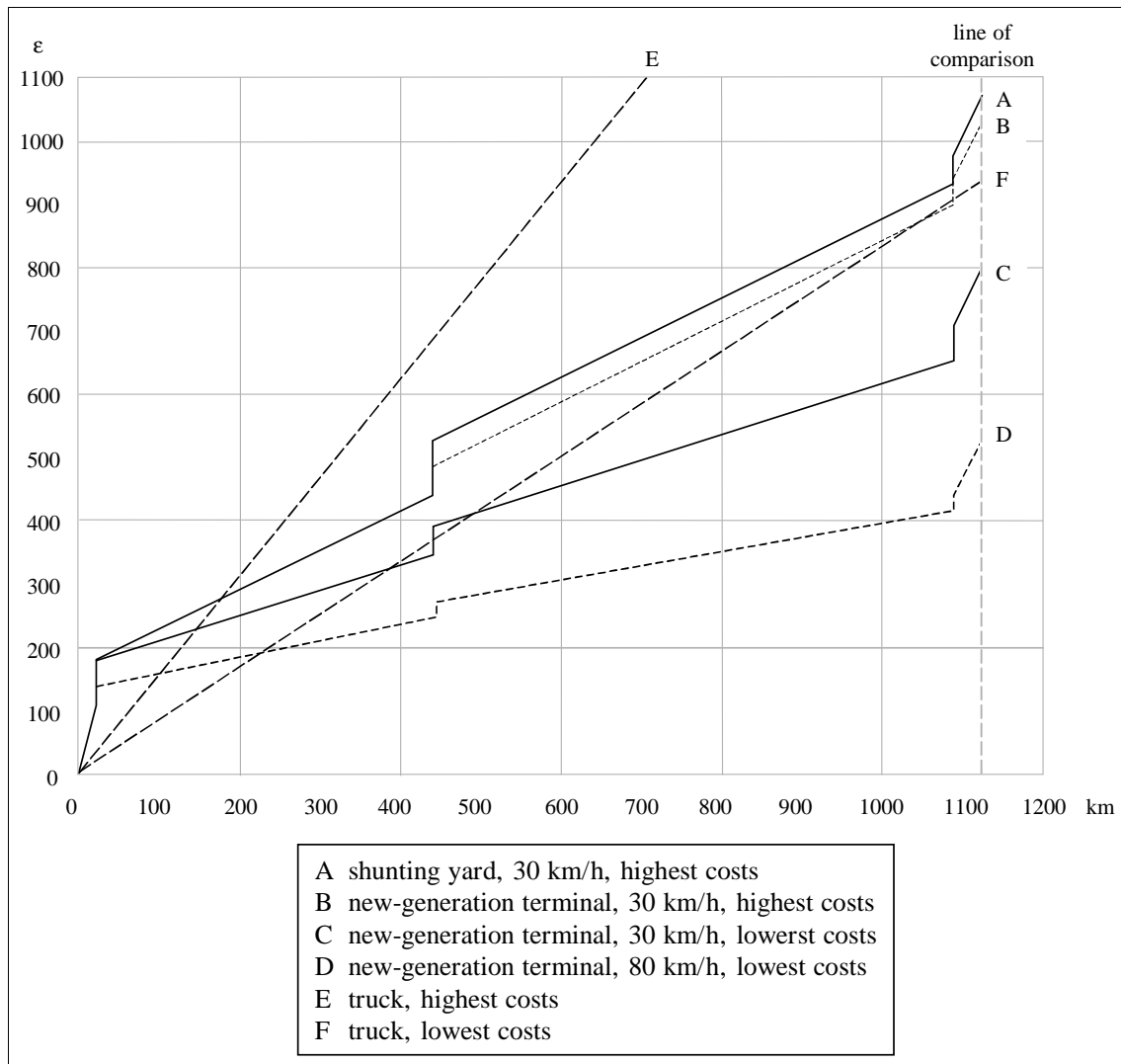
6.3.4 Costs of intermodal transport on the chain level

The cost structure of the intermodal transport chain, as well as that of unimodal road transport, are shown in Figure 6.2. This example concerns a distance of about 1150 km in the hub-and-spoke network, with Metz as a hub. It is important to realise that, due to the stepwise cost structure of intermodal transport, no break-even distance can be deduced from such figures, although this appears very tempting. Figures are indicative, as certain margins have been applied in the estimation of costs.

As the analysis in TERMINET shows, maritime intermodal chains are likely to be competitive with road transport in all distance classes, as they have pre and end haulage only on one end of the transport chain. Continental intermodal chains will be competitive for medium to long distances. On short distances the competitiveness depends on the availability and the use of network profits.

Figure 6.2 also shows that the effect of a higher speed of trains, i.e. 80 instead of 30 km/h in the example, is most promising. This will reduce the costs on the links substantially. However, an increase of the speed is difficult to realise, due to the limited capacity on the network.

Figure 6.2: **Cost structure of the intermodal chain with one intermediate tran-shipment and conventional times at begin and end terminals.**

|	
A	shunting yard, 30 km/h, highest costs
B	new-generation terminal, 30 km/h, highest costs
C	new-generation terminal, 30 km/h, lowerst costs
D	new-generation terminal, 80 km/h, lowest costs
E	truck, highest costs
F	truck, lowest costs

Source: presented by E. Kreutzberger (OTB), TERMINET meeting in Mons, 26-01-2000

Figure 6.3 shows schematically the effects of the implementation of new-generation terminals at the begin and end nodes and at the intermediate node (e.g. a hub). It appears that the profits made on the links more than compensate for the higher costs of tran-shipment at the nodes.

As appeared from the feasibility analysis (§6.3.3), it is necessary to take into account the possible profits that occur in the network, due to the implementation of new-generation terminals, when measuring their costs and benefits. Roughly, these profits could be the result of a) higher load factors, b) higher transport frequencies and c) shorter circulation time for both wagons/barges and load units, that become possible by the implementation of a new-generation terminal and new bundling concepts.

Figure 6.3: **Changes in the intermodal chain cost structure due to the implemen-tation of new-generation terminals (dotted line).**
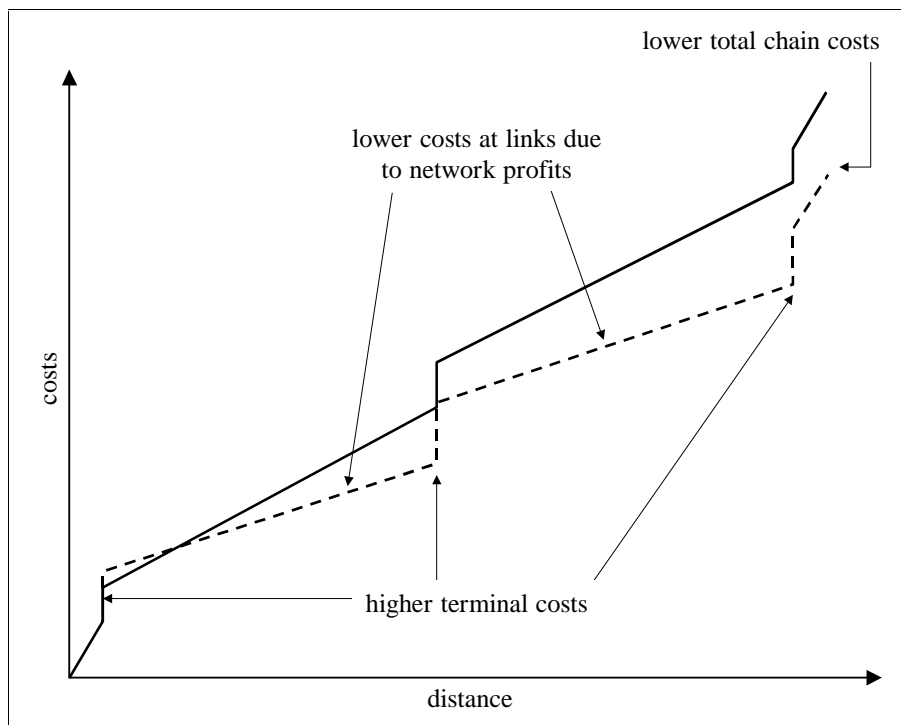
6.3.5 Allocation of costs and benefits within the transport chain

The economic feasibility of new-generation terminals depends very much on the terminal concept and design chosen in each situation; the results for the cases discussed in this chapter are therefore more of an indication, than a definitive answer. Nevertheless, they suggests that in most cases public investments are needed for the implementation of new-generation terminals – which is in fact not different with conventional terminals. Given this, the feasibility analysis shows that *an economic feasible implementation of new-generation terminals is possible*. However, a few comments should be made with respect to this.

The costs of the investment in a new-generation terminal are made by the terminal operator, while part of its benefits occur elsewhere at the network. This would imply that the network operator would reap the fruits that have been paid for by the terminal operator. Analysis in TERMINET of the economical feasibility of new-generation terminals indicates therefore that a) economical feasibility should be defined at the chain level, including both terminal costs and network profits, and b) cross subsidies within the chain, that is between the terminal and the network, are in many cases required for a feasible exploitation. This implies a (re)allocation of costs and profits within the transport chain.

In practice this could mean that profits from the network compensate the network operator for increased terminal tariffs, as long as the total results for both the terminal operator and the network operator – i.e. within the total transport chain – are positive.

This, in turn implies, that in many cases the materialisation of potential network profits is necessary for an economical feasible terminal exploitation. This, again, would require the integration of the terminal and the network[26].

Terminal and network operators should co-operate to achieve forms of chain management and agree on the necessary redistribution of the costs and profits of new-generation terminals. Government, in turn, should not focus only on the links or even the nodes, but at the combination of the two. If necessary, it should mobilise network and terminal operators, stimulating them to co-operate.

6.4 Technical and operational aspects of implementation

6.4.1 Implications of the integration of terminal and network

The preceding section stressed the economical importance of integrating the terminal and the network. However, especially with innovative network this has many technical and operational implications. These include the pros and contras of robotisation of terminal operations. Integration of terminals and innovative bundling networks is possible only to a limited extent with conventional technologies. On the other hand objections might be raised concerned the problems involved with robotisation, e.g. the reliability of robotised systems. Also, the compatibility of the network requirements made by new-generation terminals with the actual network operations deserves attention.

Most of the technical and operational issues discussed in this section are in fact not so much inevitable conditions for implementation of any new-generation terminal as such, as matters that should be dealt with in future, to make possible an innovation of the intermodal transport system on a larger scale. This is in particular true for future times operations.

6.4.2 Future time operations

The advantages of future time operations are more or less comparable with those of new-generation terminals. The mutual reinforcement of benefits that could be achieved by combining the two, is a powerful example of the synergy between networks and terminals. Therefore, the implementation of future terminal times seems to be an important condition for the improvement terminal operations. However, the problems involved with their implementation are considerable.

The intermodal trains presently have *conventional time* schedules. Trains run during the night, because at night the infrastructure is not occupied by passenger trains. Also, shippers demand arrivals of trains at rail-road terminals in the night or early morning and departures in the evening.

The consequences of conventional time operations are:
a) only a certain distance can be covered each night (the 'Nachtsprung');

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[26] Preferably, this should be an innovative bundling network, as this makes the best use of the advantages of new-generation terminals and offers the largest advantages in terms of economies of scale, fastness of transport etc.

b) the wagons of trains are present at a begin-end terminal all day, which is not very productive, except that the wagons can partly serve as storage facility;

c) the storage demand has two daily peaks, one in the morning and one in the evening, to which the terminals storage capacity must respond;

d) many trucks are only loaded in one direction.

In contrast to conventional times, with *future time* operations intermodal trains run at all hours of a day, with terminal arrival and departure times distributed more equally. Thus, it is possible to let the trains return to the network as quick as possible after transhipment. This implies shorter terminal times and more time to spend on the network, assuming the total terminal-network cycle time stays the same. This spare time means that larger distances may be covered or additional intermediate terminals may be included in the service, thus increasing the service area and making trains more productive. The result of this is a costs and efficiency advantage.

However, an important barrier for the large-scale implementation of future times operations is the rail capacity during the day, when the tracks are primarily occupied by passenger trains. This situation may improve by an increase of the speed of freight trains, which would easy the assignment of paths to intermodal trains. Also, the network capacity could be increased by implementation of advanced safety systems that allow trains to run at short intervals. Where these improvements are not sufficient, the implementation of future times operations would require the construction of new tracks or even dedicated rail tracks for freight transport. Expectations are however, that this will be limited largely to the replacement of single bottlenecks.

Another problem could be the way future times restrict the freedom of shippers and other clients of intermodal operators. Implementation of future times implies that shippers may have to call at the terminal on different hours to pick up or deliver load units. Consequently, consignees may receive load units at inconvenient hours.

However, there are compromise models in which operations services with conventional times are reduced, but not abolished. Every destination may still be reached by trains that depart at conventional times, but other trains depart at different times during the day. Thus, shippers can choose and those who choose for non-conventional times, can take advantage of the cost benefits, as soon as the intermodal operators pass these on to their clients. The use of future times services could be encouraged by tariff differentiation (Terminet, 1999). This might imply a partly uncoupling of train arrival and departure times and the time schedule for picking up and delivering of load units by shippers.

6.4.3 Barriers for robotisation

Of all new-generation technologies, robotisation of terminals attracts perhaps the most attention. Most new-generation terminal concepts are robotised or semi-robotised. In some cases robotisation is an option, rather than a central characteristic of the concept. It is still a matter of discussion to what degree, and in what circumstances, robotisation of terminal operations is preferable.

In general, much attention has been paid to the automation and robotisation of the transhipment process itself. However, for a successful implementation of robotisation it is necessary also to give some thoughts to secondary procedures that may seem insignifi-

cant, but in practise can hinder smooth terminal operations. These mainly have to do with the arrival and departure of trains, rather than with the actual transhipment of units:

a) pin setting: the pins on the rail wagons have to be set in the right position for different sizes of load units. This still has to be done manually. It should not take a long time to develop a technology to automate this, e.g. by using springs;

b) wagon identification: wagons must be identified, in order to place units on the right wagons. This is important because wagons may have different destinations. Also, some new-generation terminals require a specific loading order to reduce the internal transport. Presently, wagon identification is still done manually, although a technological system seems possible;

c) damage and seal check: arriving load units must be checked for damage. Also, their seals should be checked. It seems difficult to robotise this, although it could be done at a distance by video;

d) physical check: it must be checked physically if all load units stand on the pins properly. This also could be done by video or an 'electronic eye';

e) brake tests: wagons should have electronic brakes. When the locomotive has been uncoupled, brake tests are necessary. The hydraulic brakes that are still common at the moment means that these tests take too much time (up to half an hour). With electronic brakes they would take only a few seconds;

f) train coupling and sharing should be automated and, if possible, avoided. Also, the change of locomotives should be avoided.

Most of these procedures still have to be executed manually. This is a major barrier for robotisation, because it implies human beings should work in robitised areas, which is not allowed for safety reasons. Besides, manual procedures take too much time – insofar as they cannot be carried out parallel to the transhipment itself – thereby reducing the time advantages of new-generation terminals.

In fact however, most of these are not technological barriers. In most cases the technology for automation is already available or could be developed in the near future. However, this would imply that all wagons should be adapted or replaced by dedicated wagons, which would require a large investment. While the benefits of this are for the terminal operator, the network operators have to pay for it. Most realistic seems to be the replacement of depreciated wagons by dedicated wagons. However, as the average life cycle of a rail wagon is measured in tens of years, it may well take 30 to 40 years to replace all wagons. Nevertheless, this seems a necessary step in the innovation of intermodal transport, which should be a main point in intermodal transport policy. Furthermore, when replacing the old wagons, the standardisation of (new) wagons should be taken care of.

6.4.4 Reliability of innovative networks and new-generation terminals

Reliability of transport is probably the most important aspect of transport quality and certainly one of the most important competition factors in transport, nowadays even more than before. Therefore, a main condition for a successful implementation of new-generation terminals and innovative networks is their reliability.

If intermodal transport is to compete with road transport, it has to offer at least equal reliability. While it is true that trucks suffer more and more from traffic congestion, this may also be the case for pre- and end-haulage in the intermodal transport chain.

68

Delays, for whatever reason, are the most common type of reliability problems. Once there is a delay, it may easily spread over the network, especially when the network capacity is limited. Then, the problems of fitting in a delayed train in an already rather stringent time schedule may easily cause additional delays.

Delays in the transport chain may occur either during terminal operations or in the network. It seems reasonable to assume that the chance for delays increases with the number of intermediate transhipments in the transport chain. This means that complex bundling, since it is characterised by at least one intermediate transhipment, may increase the vulnerability of transport for delays compared to direct point-to-point transport.

Complex networks with short terminal times may be even more vulnerable for delays, because there is no buffer time to compensate for the loss of time (in contrast to the typical conventional terminal, where trains stay on the terminal all day). This is especially the case with future time operations, when trains should return to the network immediately after transhipment, so that there may be no buffer time at all.

As in many complex networks part of the transhipment is simultaneous (direct train-to-train), dependent on the policy of the operator trains may have to wait for each other (for example in a hub terminal). This could mean a delay spreads to all trains.

There are three ways to prevent delays or to compensate for them:

a) increasing the speed on the network, to make up for the loss of time. In practice this is difficult, since it requires a surplus of network capacity at any moment;

b) increasing the transport frequency. Thus, delayed load units can easily go with the next train, without the necessary for trains to wait for each other or for delayed trucks. However, this requires sufficient transport volumes to maintain frequent services and at the same time it requires some spare capacity on all trains;

c) anticipating for possible delays and include a certain buffer time in the time schedule. However, this will partly neutralise the benefits of fast transhipment at new-generation terminals, increase the transport time and make the transport less efficient. Also, it would require buffer tracks or yards for waiting trains.

As b) and c) show, the approaches focused on preventing delays, optimisation of transport reliability will often go at the cost of its efficiency and vice versa (Figure 6.4; see also Hamilton, Walker and Bennett (1996). A terminal in each given situation faces a certain level of reliability and efficiency. If the terminal operator focuses on reliability, efficiency will decrease because reliability requires buffer time and spare capacity, on trains or barges as well as on the terminal itself. Reliability seems to be optimal, when the terminal operates at between 60 and 70% of its maximum capacity. Efficiency, in contrast, requires optimisation of time schedules and the use of full capacity. This problem is most obvious in innovative networks with fast terminals and short terminal times, which mean less buffer time is available. In particular with future time operations the use of time could be optimised to such an extent, that there are hardly possibilities left to compensate for any delay.

Robotised processes are considered to be more reliable, productive and safe[27] than manual operations. This implies that efficiency could be increased if reliability is maintained

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[27] Although specific safety measures may be necessary in robotised areas. Apart from this, as Dhillon and Anude (1993) mention, an unreliable robot in many cases also means an unsafe robot.

on an equal level. As Figure 6.4 shows, whatever balance is found between reliability and efficiency, with technical and operational parameters unchanged the total reliability/efficiency level will be limited by the constraint line *a*. A higher level *b* could be achieved by optimisation of operations. The highest reliability/efficiency level *c* however can only be reached with robotisation of terminal operations. This implies that robotisation may be focused, depending on the operators' policy, on one of three objectives:

a) a moderate increase of both reliability and efficiency;
b) a large increase of reliability with efficiency unchanged;
c) a large increase of efficiency with reliability unchanged.

However, in case of robotisation the *operational* reliability is very much dependent on the *technical* reliability of the terminal. Unfortunately, it is difficult to test the technical reliability of robotic systems in advance, e.g. by simulation[28]. Therefore, there should be a fall-back system, to take over in case of a defect.

While the general reliability of operations may be expected to increase with robotisation, the few delays that do occur, tend to be severe. These may be caused by defects of e.g. the information system. Robots cannot improvise and deal with problems in a flexible way. To minimise the delay as much as possible in case there is a problem, robotic systems should have a certain built-in fault tolerance, enabling them to endure some amount of failure (Hamilton, Walker and Bennett, 1996). In fact the principle is similar to the built-in buffer time in the train schedule, which was mention above. Accordingly, any built-in fault tolerance will have some negative effect on the performance of the system, which is the price for reliability.

Robotisation may increase reliability, making possible highly optimised terminal operations. In general we may say that, if possible, highly efficient operations with short terminal times should be robotised.

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[28] Meyer, 1998, tested the effects of disturbances on the train handling time (e.g. reliability) for the Noell Megahub.

Figure 6.4:   The (schematic) relation between network efficiency and transport reliability.
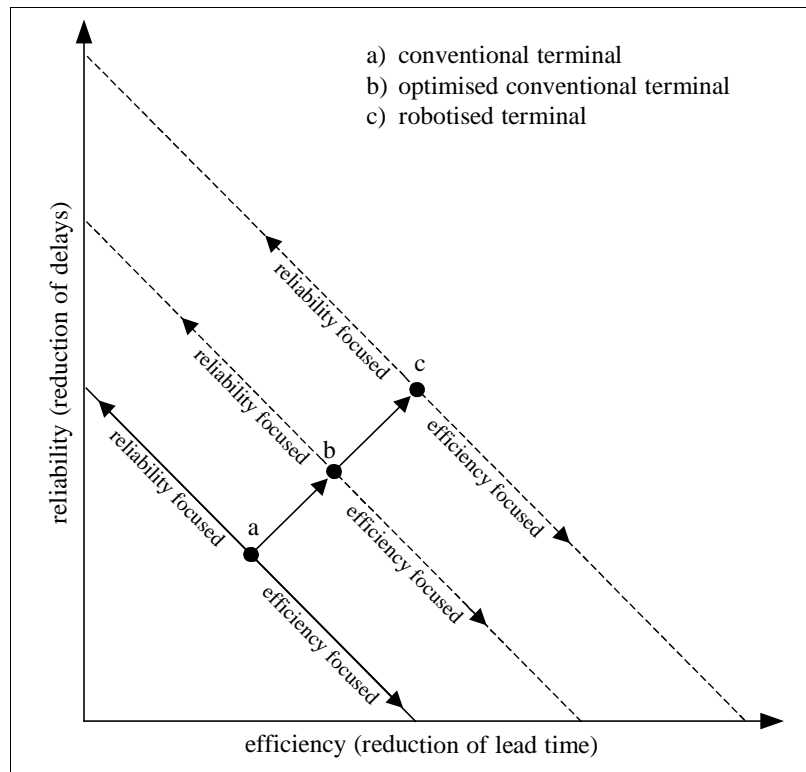
6.4.5   **Compatibility with existing operations**

In general we could say that there is a gap between existing operations and the type of operation required by new-generation terminals. This is true for both terminal and network operations.

The close relation between terminal and network operations implies that innovation of the terminal, i.e. a change of the terminal operations, will affect network operations in several ways. Also, operation at the terminal itself must in many cases be changed when a new-generation terminal is implemented, due to different transhipment times and capacity, number of tracks, yard capacity etc.

Adjustment of time schedules, train composition etc. may be a necessary condition for terminal innovation, in case the new-generation terminal is not compatible with actual network and terminal operations for t*echnical* or *operational* reasons.

On the other hand, adjustment of present operations may also be necessary for *economical* reasons after terminal innovation, to make possible the exploitation of potential benefits that occur on the network. Potential benefits are valuable only if they can be materialised indeed into economical benefits. This means time benefits, the result of terminal innovation, should be materialised by using the extra time to cover more distance or to make a call at an additional intermediate terminal. This implies adjustment of network operations, which in this case has not necessarily to do with a possible technical and operational incompatibility between terminal and network.

71

6.5   Implementation policy: the role of the government

It is widely believed that technological innovation is a main source of economic development and that technology is a public product, similar to physical infrastructure and a clean environment. 'Market failure' arguments are often applied to explain that a market economy underinvests in the production of knowledge and innovation (Leyden en Link, 1992, and Ronayne, 1984, in: Terminet, 2000c). Consequently, it is argued that government should play an active role in advancing basic science and technology development and supporting diffusion of innovation through direct funding of research, technology transfer, and commercialisation (Moon and Bretschneider, 1997, in: Terminet, 2000c).

With respect to the innovation of intermodal transport, government can – roughly spoken – choose between a laisser faire policy, in which innovation of intermodal transport is completely left to the market partners, and a more positive policy, in which government plays an active role in the innovation process. We think the latter is preferable. Government could accelerate diffusion by promoting active outreach programs, subsidising research and development costs, increasing information and enhancing reliability of information.

Evaluation in TERMINET of the current EU development and implementation policy with respect to new-generation terminals indicated two main weaknesses (Bontekoning, Hemelrijk and Trip, 2000).
First, a policy objective should be defined quite explicitly. It may consist of certain requirements or targets or of a positive future image of the desired situation in e.g. 2025. In our opinion the latter is preferable, since the future image may serve as a source of inspiration for defining requirements, while it seems more difficult the other way round. Also, no network operators participate in the current EU technology research projects, nor do any terminal operators, which are the potential adopters of innovation. A main finding of TERMINET and other research in this field is the necessity to relate terminal innovation to network operations. EU policy still focuses too strongly on technology development, which is in fact is no longer the main barrier for implementation.

72

7
CONCLUSIONS AND RECOMMENDATIONS

7.1   General conclusions

In this section, several general conclusions are formulated with respect to the results of TERMINET. These conclusions will recur in the recommendations, which are grouped thematically in the next sections.

1. The quality benefits which new-generation terminals and innovative networks could have in many cases are clear and undisputed. This is in particular the case when there is a certain synergetic effect of innovations both in the network and at the terminal. Therefore **terminal and network should in all cases be seen as one system and should be considered at the transport chain level, or even at the network level**

2. **The crucial problem of the feasibility of new-generation terminals is that high investment costs are located at the nodes, while most advantages occur in the network. Therefore a redistribution of income, from the links to the terminal, is necessary to make the implementation of new-generation terminals really feasible. Co-operation and chain management are needed to enable the introduction of new-generation terminals.**
    In most cases a large investment is necessary, which consequently lead to high capital costs. Total costs per unit at a new-generation terminal are often higher than at conventional terminals or shunting yards. However, operational costs of new-generation terminals are often lower than at conventional terminals or shunting yards. It appears that the costs of transhipment per unit cannot be competitive. However, a closer look at the cost structure shows, that in most cases large costs are made at the terminal, while possible benefits occur elsewhere in the network. It appears terminal innovation leads to network adjustment – and in most cases improvement – and, vice versa, network innovation generates demand for new-generation terminal technology. Materialising and redistribution of these network profits may bring operators to accept higher costs at the terminal itself.

3. **Policy and research should be less one-sidedly focused on technology:**
   a) Technology in itself should not be an aim. In many cases considerable benefits can be achieved by operational or organisational improvements, e.g. in the network, which are often much cheaper.
   b) Technology should no longer be seen as the main problem. Most technology that is required is already available, although in some cases it is still in the pilot phase. The main problem is the implementation, rather than the invention, of new technologies, which is as such an organisational and economical, more than a technological problem. Technological research should mainly focus on the flexibility and scalability of new technologies (see §7.2.8).

7.2   Recommendations

7.2.1   Relevant actors

Many actors are involved in intermodal transportation. However, a survey of the current EU policy and research projects shows, that relative little attention is paid to terminal operators – the potential adopters of terminal innovations – and network operators – who should bring forward demand for new-generation terminals by selling of network services instead of point-point services. **It is necessary to involve both terminal operators and network operators, as without them no policy for the implementation of new-generation terminals can be successful.**

A very important element in the constitution of an implementation policy – in fact one that recurs again and again in the following sections – is the need for co-operation between actors. It appears that co-operation is complicated because the relevant actors, such as terminal constructors and operators, network operators, rail agents, shippers and government bodies, are diverse and for a large part relative unorganised.
The European Commission should decide which policy she wants to carry out concerning the innovation of intermodal transport. She may leave it to the market, or she may chose a more active, stimulating role. However, there is at present no single strong actor in intermodal transport who is able to join forces. Therefore **we see a need for an active role for branch organisations and, if necessary, government, in stimulating and directing co-operation between market partners. Future implementation consortia should consist of a wider range of actors, which, especially with semi-permanent consortia, should have a more dynamic character and therefore should be adapted according to the different phases of the implementation process.**

With respect to the railway sector, a problem remains the insufficiently market-oriented, rather bureaucratic approach of many national railway companies, which de facto still are monopolists. In general, these companies have very limited resources. Altogether this is a major barrier for the implementation of new-generation terminals. In this aspect **liberalisation of the railway sector could help to create a climate more in favour of innovation.**

74

7.2.2 Policy objective
Actors should agree on a clear policy objective, based on their common interests in innovation of intermodal transport. Preferably, this should be a kind of positive image of future intermodal transport, which may serve as beacon for policy.
We think it is relevant for any implementation policy to specify its aims in a more inspiring way than only by means of a set of standards that must be met. The positive image may help to make partners conscious of their common interests, as these are important to stimulate mutual co-operation. Also, it could indeed be a source of inspiration for the defining of regulation and standards.

To enable government and other actors to define adequate and up-to-date policy measures, the positive image should reflect the state of the art, as well as certain ambitions. Therefore, it should be based on the latest insights and research results.

7.2.3 Pilot terminal
To show the benefits and possibilities of innovative intermodal transport in practice and to evaluate the conditions for economic feasibility, we recommend to build one or more pilot terminals. These should be most promising cases, since a failure of the pilot terminals would be a serious barrier for further implementation of new-generation terminals. On the other, hand a success would be a real powerful mean to persuade potential adopters and therefore a strong stimulus for further implementation.

With respect to the cases evaluated in TERMINET, the most promising are Venlo, Metz and Busto, mainly because of three reasons:
a) The pay-back period is reasonable. This is in particular true for Venlo, in which case the pay-back period is relatively short;
b) the terminal operator is also the network operator in two cases (ICF/SNCF in Metz; HUPAC in Busto). This is a major advantage with respect to the integration of terminal and network operations. Also, the fact that the terminal and the network are operated by the same actor will increase the awareness that costs and benefits should be considered at chain or network level;
c) the benefits of a new-generation terminal at the network level in these cases are clear. However, benefits are not the same. In Metz there are mainly performance improvements; a much faster handling compared to the present shunting results in considerable potential network benefits. A good comparison between costs of shunting and costs of a Megahub is difficult, because realistic figures of shunting are hardly available. In the case of Busto, benefits are mainly economical, i.e. costs per unit are less than in the present situation, with equal transhipment time.

The implementation of a pilot terminal requires the composition of a strategic consortium. It is important to involve all relevant actors in the implementation process. In any case terminal constructors, terminal operators and network operators should be involved, since they are respectively the suppliers, potential adopters and potential clients of terminal innovations. Also, it should be considered in many cases to involve road transport, rail schedulers/agents and trade unions.

75

Government should play an active role in composing and directing such a consortium. Therefore, if market partners do not proceed, government should take the initiative in bringing together the actors that should constitute the consortium.

Whether or not the government should subsidise the implementation of a pilot case is a political question. The answer could depend on the weight of societal policy objectives and the willingness of market partners to invest. Government could reduce financial risks e.g. by claw-back subsidies or yield management with respect to additional profits generated in the network. Some type of public-private partnership could be an option in this.

Activities of the implementation consortium should not end with the implementation of the terminal. They should also include exploitation of the terminal and the network for a certain period.
The implementation consortium should be allowed the exploitation of the terminals and the network together, e.g. by means of a concession. This will increase the interests of partners in the implementation process, since they have the opportunity to recover the investment costs also on possible network profits. Furthermore, it will stimulate the integration of network and terminal, since there exists already a co-operation between network and terminal operators. Integration may in turn increase possible network profits, which is important with respect to the first argument mentioned above.

Another possibility that deserves attention is to elaborate a line network. The importance of line networks and line terminals is underestimated and up to now little is known about their costs and performances. Nevertheless line networks are important, especially for intermodal transport of small flows and for regional feeder systems.
Special attention should be paid to the development and continuation of feeder services. This seems to be an important element for the increasing of the market share of intermodal transport. Also, it can add to reduce regional pre-and end haulage. However, in many cases feeder services are not profitable. Continuation of feeder services could nevertheless be guaranteed by making them part of a larger, more profitable 'package deal'. **We therefore suggest that – if possible – operation of a feeder network should be part of a major concession or licence,** whether for terminal or network (i.e. trunk line) exploitation. Also, exploitation of feeder lines could be combined with concessions for regional pre- and end haulage, in which case it is possible that regional train services are provided by road transport carriers.

7.2.4 Implementation of future time operations
A main element of the innovation of intermodal transport on the longer term is the implementation of future times operations, both at the terminal and on the network. Only with future time operations (i.e. trains running all day, instead on only in the night hours), it is possible to make an optimal use of the time advantages new-generation terminals offer.

Main problem is the capacity on the network, in particular in congested areas like the Netherlands and the Ruhr area. **Future times require a better use of network capacity**

and/or an expansion of the network capacity. This means clear regulation is needed with respect to the priority of trains, especially after liberalisation of the railway sector. Good co-operation between rail schedulers is necessary. Main question is how synchronised networks fit into the system (for example a network of feeder and trunk trains with simultaneous exchange).

Also, it may be necessary to expand the network capacity. This could be done by:

a) a more intensive use of the current network, e.g. with more advanced safety systems that allows less distance between trains;

b) the construction of new infrastructure trains to solve bottlenecks in the network;

c) the construction of dedicated tracks for freight transport on certain routes.

A second barrier for the implementation of future times is the preference of shippers and consignees for conventional peak times. This could be solved for a large part by demanding an extra charge for handling during peak hours. Therefore, **if future time operations are implemented, we recommend a system of tariff differentiation to stimulate spreading of operations over the day.**

7.2.5 Implementation of necessary additional innovations

A recurring theme in TERMINET, as well as other research on intermodal transport, is the importance of the implementation of several necessary additional innovations that would facilitate or support the implementation of new-generation terminals, e.g. automatic pin setting and wagon identification, automatic train coupling and electronic brakes.

In fact innovations like these are an important condition for large scale innovation of intermodal transport and implementation of future time operations, since otherwise the potential time benefits of innovation will largely be neutralised by time consuming activities such as manual pin setting and hydraulic brake tests. This is in particular the case with respect to automated or robotised terminals and operations with very short terminal times. Apart from efficiency reasons, manual pin setting is not possible in fully automated terminals, since safety regulations in general do not allow human activities in robotised areas.

Most of the items mentioned above are minor barriers from a technological view. Technology needed for automatic pin setting or electronic brakes is already available or could be available within a few years.

The main problem however, is its implementation. Potential solutions all are based on the use of dedicated rail wagons, which would imply either replacement or adaptation of old wagons on a large scale. Most of the costs of this operation are for the train operators, while its benefits occur at the terminal. On the chain or network level however, implementation would be beneficial. Therefore **a chain approach is required, which implies close co-operation between all actors in the transport chain – terminal operators, train operators etc. – and if necessary balancing of costs and benefits between actors. Government and branch organisations should play an active role in bringing actors together.**

Also, government and branch organisations should consider an active policy to stimulate renewal of rail wagons. This could be done by regulation to encourage scrapping and replacement of old equipment, for example by investment subsidies.

When a considerable part of the wagons has been replaced, it should be avoided that conventional wagons interfere and disturb the automation process. Therefore, **in the longer term certain main routes or parts of the network should be closed for conventional wagons.** This will enable fully automated handling at intermediate terminals.

7.2.6   Communication policy

One of the main barriers for implementation of new-generation terminals remains the uncertainty of actors about their costs and benefits. Therefore, a communication policy should be developed to inform actors such as network operators, terminal operators, shippers etc. **We recommend that the EU develops an active outreach program as a follow up of research projects, to spread the results.** Such an outreach program could be carried by innovation centres, consultants or branch organisations.

An outreach program could include the organisation of regular conferences. Nevertheless, in this way only a select audience will be found. A more active approach will be needed to reach all relevant actors.

Furthermore, information could be spread by means of articles in both academic and professional journals. The writing of these could be made a task for researchers participating in EU projects.

Terminal suppliers in turn, should develop an active communication and marketing strategy, aimed at a quite specific target group of potential clients. Even more than they already are doing, they should emphasise the potential network benefits of new-generation terminals, more than the technological features. Marketing should focus both on terminal operators and network operators. To start with, it should focus on organisations like ICF and HUPAC, which are already operating both a network and several terminals or shunting yards.

As a means to inform market partners, **software tools like the ones developed in TERMINET should be made easier to use and accessible for non-specialists.** This implies further development of simulation tools and network models and increasing the possibilities for users to compare different options. In this way they could serve as valuable management tools for interested parties.

7.2.7   Integration with other policy fields

1. **The integrated view of terminal and network as one entity should also be reflected in infrastructure policy.** This implies that the focus of the program for Trans-European Networks of transport infrastructure should be more on integration of nodes and links and – in particular – on services, rather than on physical infrastructure.
2. **Economic regulation should be applied in a wise, rather than a rigid way, to maintain possibilities for network integration.** If anti cartel regulation would cause the intermodal network to fall apart in too many small pieces, this may harm the integration of networks that is necessary for a successful development of inter-

modal transport. Also, economic regulation should not hinder co-operation between market partners with respect to e.g. the joint implementation of innovations, standardisation or research[29].

7.2.8   Recommendations for further research

1. **Further research should be conducted on the integration of terminals and complex networks.** This implies the integration of terminals in complex networks, as well as the integration of different networks. These may be networks for different modalities or networks of a different scale of function, e.g. the integration and synchronising of feeder networks and trunk train services.

2. **Methods should be developed for the calculation of costs and benefits on link or network level.** Cost calculations in TERMINET were mainly focused on link costs. However, further research will be necessary on the trade-off of costs and benefits a) between different links in the network and b) between links and terminals.

3. **Further evaluation should take place of costs and benefits of new-generation line terminals and line networks,** as these could play an important role in the transport of small intermodal flows and in the development of feeder systems. The latter appears to be an essential element for increasing the market share of intermodal transport. Research should include all types of new-generation line terminals, e.g. Tuchschmid CT, Transmann, CCT+ and Krupp, as well as conventional means.

4. In relation to the previous, **research should be conducted on the possibilities for the development of feeder services and regional networks.** An important element for increasing the market share of intermodal transport and the feasibility of innovative networks is the development of costs-effective feeder services and, if possible, relative dense regional feeder networks. Also, the continuity of services is important.

5. **Further research is necessary on the advantages and risks of automation and robotisation and the conditions for successful automation of terminal operations.** Reliable fall-back procedures should be developed, which enable continuation of terminal operations in case of a system defect. Also, attention should be paid to the safety aspects of robotisation and to the reliability of robotic systems.

6. **In order to develop an efficient and effective implementation strategy for new-generation terminals, further evaluation should take place of transport related barriers for implementation.** With respect to the research conducted in TERMINET WP8 (Terminet, 2000c), variables should be validated specifically for the transport sector. Also, the explanation power of each variable should be studied.

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[29]   See also the recommendations by the U.S Committee for Study of Policy Options To Address Intermodal Freight Transportation (1998).

7. **Research should be conducted on the scalability and flexibility of new technologies.** Most present new-generation terminal concepts require relative large transhipment volumes to be economically feasible. They will be introduced first of all in nodes with large freight volumes. Nevertheless, in most nodes volumes are smaller, nor will they grow sufficiently in foreseeable years. This is in particular the case in regional or feeder networks. It is therefore a barrier for the innovation of these networks that no small, cheap new-generation terminal concept is available for the transhipment of small volumes.

Furthermore, research should focus on the flexibility of terminal concepts in case trains do not arrive on schedule and load units that miss connection and have to go with the next train. At present it is not clear whether automated terminal systems are flexible enough to cope with, quite common, disruptions like these (all the same, the reliability of the railway system should also be improved).

8. **In order to assess good insight in the competitiveness between modes more research is needed to analyse costs of different modes including infrastructure and cost coverage by operators.** At present, cost calculations for road, rail and waterborne are carried out in quite different ways in different EU countries.

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APPENDIX 1
OBJECTIVES OF WORKPACKAGES

WP1   Inventory of innovative networks

In this part of the WP the present and future bundling concepts for integrating small freight flows as proposed by major actors in the European transport field has been investigated. The investigation focussed on the following issues.

How is freight (soon to be) bundled in intermodal transport (including the bundling of LCL-freight) in Europe by major actors in the transport field (e.g. shippers, including logistical or trade actors, and transport companies)?

Are the new bundling concepts attained by transforming existing bundling concepts ('retrofit') or by developing and implementing completely new concepts? To which extent are they based on new-generation processing (automation and robotisation) or is new-generation processing being considered only for a later phase? What is the time schedule of implementation schemes?

What are the implications of the new bundling concepts for the performance and characteristics of terminals, transport units, and load units?

Who are the actors (shippers, transport operators and other transport actors, semi-public and public authorities, freight sectors) and what is their role in developing and implementing new bundling concepts?

What are the conceptual (technological, operational, spatial dimension), institutional and political barriers when transforming networks to the requirements of new-generation bundling concepts - or when trying to do so?

WP2 INVENTORY OF TERMINALS

In this part of the WP the new-generation terminal concepts as proposed by major actors in the European transport field will be investigated. The investigation focussed on the following issues.

How will the concepts for and development of new-generation terminals and terminal-nodes for intermodal transport in Europe respond to the requirements of shippers and transport companies, especially the network operators occupied with the innovation of bundling concepts?

Who are the actors (shippers, transport companies, terminal operators, semi-public and public authorities, producers of transport equipment, consultants and research organisations) and what is their role in developing and implementing new bundling concepts?

What are the conceptual, institutional and political barriers when developing and implementing new-generation terminal or terminal-node concepts - or when trying to do so?

WP3 BUNDLING CONCEPTS: new generation networks

1. Select or elaborate a software tool directed towards the support of decision-making in the area of bundling freight flows and determining locations of (bundling) terminals.
2. In this WP an attempt was made to integrate and analyse:
   - the currently rather isolated bundling concept innovations;
   - the results of WP1 task 1 (state of art) and 2 (actors organisational barriers);
   - the possible gap between innovative bundling concepts and organisational barriers.
   in order to identify the missing, probable and most promising directions of innovative bundling concepts. The project's point of view was emphasised. This task will identify which transport markets (products, load units), regions, transport corridors, bundling types and terminal locations are involved and appear to be very effective in the sense of leading to higher growth rates of intermodal transport or diminishing barriers in the growing intermodal transport sector?
3. To formulate indicators/criteria for the performance of terminals and terminal-nodes which belong to certain bundling concepts.

WP4 NODE CONCEPTS: new generation terminals

1. In this WP an attempt was made to integrate and analyse:
   - the currently rather isolated existing terminal innovations;
   - to identify the missing, probable and most promising directions for terminals and terminal-nodes. Hereby the project's point of view was emphasised.
   - Which technical, process and spatial concepts for and developments of terminals and terminal-nodes:
     - appear to be very effective for different performance directions?
     - are set up in a manner that enables the gradual introduction/ implementation and/or combination of different concepts?
     - will function optimally in certain (new-generation) bundling concepts?

Identify - in an integrated approach of bundling and terminal concepts - promising innovative directions: which concepts are likely to develop rapidly, to effectively support intermodal transport, and to diminish barriers to the growth of intermodal transport? The answers will reflect differences between transport markets (products, modality and load units), regions, transport corridors and terminal locations (types).

Determine concrete terminals or terminal-nodes for the five case studies which will be examined in WP7. To be able to validate project operators of the selected terminal cases will be asked to participate in the project.

WP5   INDICATORS AND CRITERIA

In this WP, descriptive indicators and normative criteria concerning the performance of bundling and terminal concepts have been listed. The performance and costs of a node (and terminal) are therefore strongly related to the performance and costs in the links - and consequently the bundling type involved. This relation must be reflected in the listings of indicators and criteria, taking technological progress into account.

WP6   PROPOSAL FOR HARMONISATION

The innovation of network and terminal concepts implies that the interfaces in these will change. The most important changes are expected at interfaces between terminals and links and/or between different parts of the links and/or between different parts of terminals. Consequently, the interoperability and therefore the interconnectivity at the interfaces may fall below acceptable levels. The objective is to reduce these dangers by reducing the complexity of interfaces and increasing the constructional (i.e. building) and operational (i.e. handling) flexibility at interfaces.

The research, development and implementation costs of innovations are highly dependent on the number of software or hardware components or connections. The aim must be to reduce such costs and thus increase the feasibility of new-generation networks and terminals by promoting the collective use of the same constructions, vehicles, other handling equipment, infrastructure, load units, software, and components of these by different transport and transshipment equipment manufacturers. Collective use is impossible without harmonisation. The objective of this WP is to identify promising harmonisation measures that would support economies of scale in the areas of production, engineering, building and maintenance of terminal concepts and equipment for new-generation operations.

WP7 DESIGN OF TERMINALS
The objective of this WP is the of design terminals with new-generation attributes and to show the performance differences of alternative designs and concepts and - within these - of technical, process and spatial variations. The performance differences will contribute to the identification of promising terminal development directions.
In order to be able to determine performance effects a software tool will be applied and developed. This tool will assist in carrying out relevant experiments in the framework of the TERMINET project.

WP8 BUSINESS PLANS

The promising innovative directions for networks and terminals identified in the previous WP's of the TERMINET project must be assessed in terms of their feasibility. The business plans of actors (in particular terminal operators) is chosen as the level of and instrument for feasibility analysis, as this level brings together the offers/investments and effects/benefits for one and the same clearly defined system. The business plans are elaborated for the five selected terminal cases.

The business plans provided supplementary information in order to draw conclusions about:

a) promising innovative directions for bundling networks, terminals and terminal-nodes. The value added to WP4, task 2 and WP7 is that feasibility is included as an argument;

b) a more integrated view of the circumstances in which the arrangements, concepts and equipment can be implemented on the medium and longer term. This can be the basis for the adjustment of public frameworks for the development, implementation and operation of new-generation terminals and networks;

c) the amount of public financial support or private external cross-subsidising needed to implement new-generation concepts for intermodal transport.

WP9 CONCLUSIONS AND RECOMMENDATIONS

In this WP a final identification of promising innovative directions for bundling networks and new-generation terminals and terminal-nodes will take place. The conclusions go deeper than those in WP4 (task 2), and generalise the functional and economic arguments of WP7 and WP8 respectively. An important part of the final conclusions is the feedback to earlier WP's. The level of WP9 is free from inconsistencies between the conclusions of the previous WP's and therefore represents a solid basis from which to select and elaborate recommendations for public frameworks and other measures to support the development, implementation and transformation of new-generation concepts and equipment. The conclusions and recommendations aim to support and encourage the development and implementation of new-generation operations on networks, terminals and terminal-nodes, by public as well as private actors and further research.

APPENDIX 2
OVERVIEW OF DELIVERABLES

D1 Report on Inventory innovative bundling network developments *(WP1)*
D2 Report on Inventory new generation terminals-(nodes) developments *(WP2)*
D3 Tool: GIS-presentation innovative bundling concepts *(WP3)*
D4 Report on Preferable lay out of innovative networks *(WP3)*
D5 Tool: Decision support tool/model for bundling lay out *(WP3)*
D6 Report on Preferable new generation terminals(-nodes) *(WP4, task 1)*
D7 Report on Which bundling concept integrates freight flows
with which type of terminal and terminal-node concept? *(WP4, tasks 2 and 3)*
D8 Report on Indicators and criteria for new generation
bundling, terminals and terminal-nodes *(WP5)*
D9 Report on Proposals for harmonisation and flexibility *(WP6)*
D10 Report on Performances analyses for 5 terminal case studies *(WP7)*
D11 Tool: Performance animation 5 terminal case studies *(WP7)*
D12 Tool: Terminal and terminal-node simulation with animation module *(WP7)*
D13 Business plans for 5 selected terminal case studies *(WP8)*
D14 Report on Background to business plans *(WP8)*
D15 Report on Final conclusion and recommendations *(WP9)*

APPENDIX 3
INNOVATIVE NETWORK CONCEPTS

RAIL CONCEPTS
1. Container shipments Jämsänkoski Paper Mill
2. Voltri network
3. Sogemar multi-modal network
4. PiggyBack Consortium
5. Wembley European Freight Operating Centre
6. RingZug Rhein-Ruhr
7. Hub of Metz and the Quality Net
8. RailRoads
9. The 'Drehscheiben' concept
10. Bundling at a regional level: The 'Linienzug concept'
11. The NEN (North European Network*)*
12. Bahntrans
13. FlexNode

DEDICATED ROAD CONCEPTS
1. Metrofreight

RO_RO CONCEPTS
1. Irish-Italy Piggyback Service
2. Ro_Ro- Barge Transport

BARGE CONCEPTS
1. Container Exchange Point Barges
2. Randstad Network
3. Floating Container Terminal
4. Via Aqua Via
5. Waste Transport

NODE CONCEPTS
1. Node Born
2. Node Duisburg

APPENDIX 4
NEW-GENERATION TERMINAL CONCEPTS

RAIL TERMINAL CONCEPTS
1. Noell Megahub
2. Commutor
3. Krupp Fast Handling System
4. Transmann Handling Machine
5. Noell Fast Transhipment
6. CCT Plus
7. RoadRailer
8. Compact Terminal Tuchschmid
9. Gateway Terminal HUPAC
10. Lättkombi Terminal
11. Train Coupling Sharing/Cargo Sprinter
12. Nord East Terminal Paris
13. Irún Terminal
14. Rail Terminal Maasvlakte

BARGE TERMINAL CONCEPTS
1. Barge Express
2. Rollerbarge
3. Selfunloading vessels

RO-RO TERMINAL CONCEPTS
1. FlexiWaggon
2. G 2000 Ro-Ro
3. Shwople Train
4. Shwople Barge

SEA TERMINAL CONCEPTS
1. Container Pallet Transfer System
2. Thamesport
3. Coaster Express
4. Train Loader
5. River-Sea Push Barge System

6. Combined Traffic Carrier Ship/Barge

NODE TRANSPORT SYSTEMS
1. Combi-Road
2. Selbsttätiges Signalgeführtes Triebfahrzeug
3. Internal Transport Node Maasvlakte (MTS/AGV)

INNOVATIVE TRANSHIPMENT UNITS
1. Casettes

APPENDIX 5

TECHNICAL INFORMATION ABOUT THE NO-DUS SOFTWARE

NODUS is a graphic software developed for analysing multimodal networks of freight transportation. It
- includes an interactive digitised-maps editor;
- handles user-defined databases;
- solves multi-product models;
- automatically generates a 'virtual network' which can simultaneously handle several transportation modes and means;
- includes a cost-function editor;
- assigns the flows based on OD-matrixes and costs provided by the user;
- offers the basic functionality of a geographic information system (GIS) for displaying the obtained results;
- allows the user to make use of external programs to solve specific problems.

As the real geographic network is tabulated as G=(X, U), which enumerates the links U_j of the network graph and their associated end-nodes X_i and X_k, these virtual links are defined by their two virtual end-nodes X_i^{jtm} and X_k^{jtm}. But, because the cost of moving goods in one direction may well be different from the cost of moving in the other direction, two separate arrows must be generated for all the virtual links.

The next step is to create virtual links corresponding to transhipping operations. This is done by a systematic comparison of the virtual nodes that can be linked by such an operation: transhipping at a node i is possible between all virtual nodes pertaining to that node, if they relate to different real links. No transhipping can be allowed between nodes which relate to the same link j, since it would correspond to a transhipment between two means of the same mode before turning back on the same real link.

Besides these transhipment virtual links, it may be convenient to include transit virtual links for the simple passage through a real node without changing the mode or the means of transportation. These links will connect virtual nodes with same i, t and m but different j.

The last step deals with the operations of loading and unloading at the real nodes. This problem is handled by the creation of virtual nodes X_i^{000} for each real node X_i. It is then possible to create a set of virtual links for these operations between X_i^{000} and every virtual node X_i^{jtm}, with separate arrows for loading and unloading.

As an example, Figure 1 presents a very simple real network made of railways (R) and waterways (W). To illustrate the difference which exists between transportation modes and transportation means, link U_1 of this simple network represents a canal (W2) large enough for small (1) and large (2) boats, while links U2 and U5 correspond to smaller canals which can accept only small boats; links U_3 and U_4 are non-electrified rail lines.
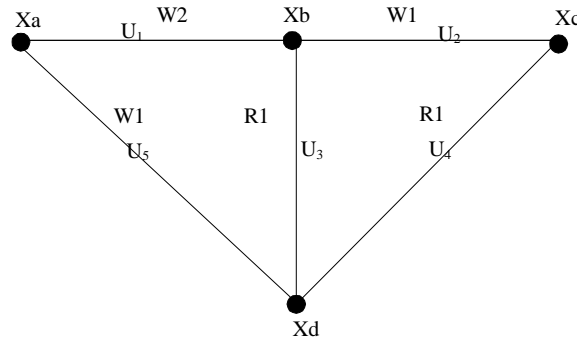
Figure 1   **Simple real network**

Figure presents the corresponding virtual network (where separate arrows are not represented in order not to clutter the diagram). At real node b, for instance, five virtual nodes are created:

- X_b^{000} represents the former real node where freight can be loaded or unloaded, while the other nodes correspond to the four possible combinations of j, t and m;
- An arrow from X_b^{000} to X_b^{2W1}, for example, would represent the loading of a small boat on link 2;
- An arrow on link U_2 from X_b^{2W1} to W_c^{2W1} would represent the moving of the (small) boat from b to c;
- An arrow on the dotted line between X_b^{1W1} and X_b^{2W1} would indicate a simple transit operation, while;
- An arrow on the line joining X_b^{1W2} to X_b^{3R1} would correspond to a transhipment operation from a large boat on link 1 to a train on link 3.

93

Figure 2   Corresponding virtual network
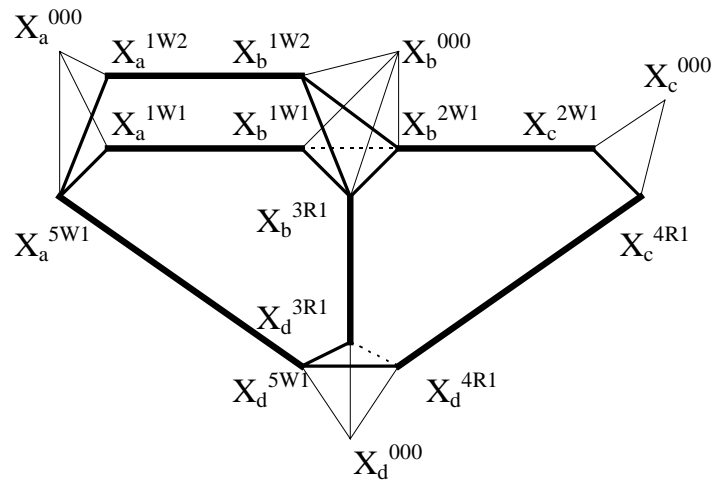
It is rather obvious that this approach can also be used for modelling and analysing a hub-and-spoke bundling network. From a technical point of view, the following rules must be followed in NODUS in order to properly model such a network:

- A second set of cost functions must be developed and used at the NG terminals so that the costs can be easily adapted. An alternative to this, is obviously, the introduction, in the user-defined database of NODUS of all the cost elements needed to compute specific node related costs, instead of « average » terminal costs.
- As NODUS always generates loading <u>and</u> unloading virtual links for a given mode/means combination, one has to introduce very high (dissuasive) unloading costs for the « load only » means, and very high loading costs on the « unload only » new transportation means.

The general objective of the multimodal transport model is to provide assignments of transport flows between modes means and routes on the basis of a minimisation of the shippers generalised cost of transport. The total generalised cost can be defined as $\mathrm{TC} = \sum_{l} \sum_{\theta} \mathrm{TC}_{l\theta}$, where $\mathrm{TC}_{l\theta}$ is the sub-total cost for the traffic on a particular route l with a vehicle of type θ. $\mathrm{TC}_{l\theta}$ is the sum of all the costs over the successive links (or operations) of the virtual network over route l, and it is supposed that all these costs are proportional to the total quantity transported $Q_{l\theta}$.

Defining a route l by a set l_i of « handling » virtual links and another set l_j of « moving » virtual links, if the cost per ton for any link is either constant or proportional to the distance s_j :

$$\mathrm{TC} = \sum_{l} \sum_{\theta} Q_{l\theta} \left(\sum_{i \in l_i} A^{\theta i} + \sum_{j \in l_j} B^{\theta} s_j \right)$$

This is the total cost which must be minimised with respect to the choices of mode/means combinations θ and routes l. After attaching the relevant cost functions to all the links,

94

this operation can be realised by applying a shortest-path algorithm on the virtual network.

The general set-up of the model allows flexible insertion in any simulated real network of a new transport infrastructure or a specific bundling network, either by modifying some of the cost function parameters or by the addition of new virtual links. Then, it is possible to assess their impacts on transport flows and their attractiveness through space by comparing the solutions obtained with and without the new terminals or bundling organisation.

The NODUS model is applied to four examples corresponding to the different bundling network concepts:

1. a railway line network from Muizen to Genova going through Bettembourg and Sibelin;
2. a hub-and spoke network based around a point North-East of Paris;
3. a barge shuttle service between Duisburg and Rotterdam, and;
4. a railway trunk line between Duisburg and Milano with forks to Antwerpen, Rotterdam and Hannover, on one side, and to Torino, La Spezia and Bologna on the other side.

These examples were based to a large extent on the information gathered in workpackages 1 and 2. In each case, a set of simulations with different values for the cost parameters were performed in order to assess the attractiveness of the assumed bundling networks.

NODUS 4.0 is a result of a series of developments started at FUCM-GTM in 1988:

- 1988, development of the KAST-software, intended for cost-benefit analyses of the Belgian waterways network;
- 1991, NODUS 1.0 : further development of the KAST-software for multi-modal freight transportation networks. This version, under MS-DOS, was in fact simply a digitised-maps editor;
- 1993, NODUS 2.0 : port of the software to MS-Windows. Definition of the concept of virtual network;
- 1994, NODUS 3.0 : integration of the concept of « virtual network » and of a cost calculation module in the software.
- 1995, Presentation of the Ph.D. thesis of B.JOURQUIN : 'Un outil d'analyse économique des transports de marchandises sur des réseaux multimodaux et multiproduits. Le Réseau Virtuel, concept, méthodes et applications.' NODUS 3.1 had been developed;
- 1996, Application of NODUS within the framework of several studies and publications. Evolution to version 3.12. Beginning of the development of version 4.0;
- 1997, NODUS 4.0 : Major evolution of the software that has been completely rewritten.

NODUS 4.0;
- is available for different operating systems and graphic environments;
- maintains a complete compatibility of the projects between the different platforms

- is optimised to offer maximum computation performances;
- is no longer limited in the size of the projects except by the available computer memory;
- includes an assignment module;
- is able to solve multi-product models in a specific way;
- offers the possibility of a highly detailed visual analysis of what is happening at the level of the virtual network;
- offers a more user friendly graphic interface;
- offers the possibility to take the size of the shipments into account.

NODUS 4.0 has been rewritten in C++ and can be used on the following systems:
- Windows 3.x (16 bits);
- Windows 3.x + Win32s, Windows95, Windows NT (32 bits);
- Unix[30] Xview, Motif or Xt (32 and 64 bits);
- Open VMS with Motif (64 bits).

All the functions of the software are present in all versions. The projects can be freely interchanged between the different versions.

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[30] Binaries are available at FUCAM for Sun Solaris with OpenLook, CDE-MOTIF and Xt, Digital OSF with Motif, Linux with Xview and Xt.

APPENDIX 6
LIST OF PUBLICATIONS, CONFERENCES AND PRESENTATIONS

Bontekoning, Y.M., **Multimodale bedrijfslocatieplanning vanuit dynamisch goede-renstroom perspectief,** in: R.H.J. Rodenburg and A.L. Kruse (editors) **Proceedings of Vervoerslogistieke Werkdagen**, 13 and 14 November, Vaals, 20pp, paper presented at the Vervoerslogistieke Werkdagen, November 1997.

Bontekoning, Y.M., December 1998, **Competitive intermodal transport: conditions for new-generation rail terminals**, paper presented at the 4th trail PhD-congress, Scheveningen , The Netherlands.

Bontekoning, Y.M., 1999, **New-Generation Intermodal Terminals**, TRAIL Research-school lunch Colloquium, Delft, March

Bontekoning, Y.M., 1999, **Towards new-generation intermodal operations: imple-mentation strategies for new-generation terminals**, paper presented at the NECTAR Conference 20 –23 October, Delft, 32pp.

Bontekoning, Y.M. 1999, The importance of new-generation terminals for intermodal transport, in: R.H.J. Rodenburg and A.L. Kruse (editors) **Proceedings of Vervoerslo-gistieke Werkdagen**, 11 and 12 November, Vaals, pp59-80, paper presented at the con-ference.

Bontekoning, Y.M., December 1999, **Implementation strategies for new-generation inland terminals: using the concept of classification of sub-markets**, paper presented at the 5th trail PhD-congress and part of Conference Proceedings, Scheveningen De-cember 1999, 26pp.

Bontekoning, Y.M., 1999, Market analysis of new-generation terminals, in: **Freight Transport Automation and Multimodality,** A Trail Research Programme brochure, pp18-19

Bontekoning, Y. and Kreutzberger, E., **The innovation of bundling concepts for combined uni- and multimodal transport on the basis of the introduction of new**

98

generation operations on terminals and terminal nodes. Paper presented at the 8th World Conference on Transportation Research, July 1998, Antwerp, Belgium.

Bontekoning, Y.M., and Kreutzberger, E., 1999**, Concepts of new-generation terminals and nodes**, TRAIL/OTB (was deliverable D2), Delft University Press.

Bontekoning, Y.M., and Kreutzberger, E., 2000**, Performance evaluation study of new-generation terminals and nodes**, TRAIL/OTB (was deliverable D6), Delft University Press.

Clark, M, and D. Erni, demonstration by animation of The Tuchschmid Compact Terminal at the Intermodal 99 Exhibition held in London.

L. Demilie, **Trans-European freight network model and its application to transport between Spain and Northern Europe** paper presented at COST 328 meeting in Lugano 11-15 January 1997

Demilie, L., B.Jourquin and M. Beuthe**, "Impacts on Modal Choice of New Generation Terminals : Performance Analysis of a Hub-and-Spoke Network"** paper presented at the conference of the European Regional Science Association in Vienna, 28/08 to 01/09/98.

Demilie, L., B.Jourquin and M. Beuthe**, "Impacts on Modal Choice of New Generation Terminals : Performance Analysis of a Hub-and-Spoke Network"** paper presented at the conference of the Association de Langue Francaise de Science Regionale à Puebla, 03/09 to 05/09/98.

Franke, K.-P., 1999, **Mega hub for intermodal traffic – the planning of the most advanced container terminal in the world**, presentation at the Wordcongress on railresearch, Tokio, 10.1999.

Franke, K.-P., 1999, **Der Containerhafen der Zukunft – eine High-Tech-Anlage - Anforderungen an die Suprastruktur,** presentation for the seminar „Worldseetransport for the turn of the century (Weltseeverkehr vor der Jahrtausendwende) of the Deutschen Verkehrswissenschaftlichen Gesellschaft (German Scientific Transport Organisation), Kiel, 10.1999.

Franke, K.-P., and M. Vogtmann, 1999, **Umschlagen statt Rangieren – Mega Hub Metz-Sablon. Präsentation im Hause Intercontainer-Interfrigo,** presentation about case study Metz for Intercontainer-Interfrigo**,** Basel, 12.1999.

Franke, K.-P., 2000, **Innovative Mega-Drehscheibe für den Kombinierten Verkehr,** presentation in an expertmeeting about future perspectives of intermodal freight transport – Technical innovations and systems**,** for members of the SPD-Bundestagsfraktion (political party). Berlin, 01.2000.

Gröhn, Jari, 1998, Intermodal transport research - is there any added value?, **Nordic Road & Transport Research,** pages 17-19. No 2.

Gröhn, Jari, **Indicators and criteria for intermodal transport**. Nofoma´98, Opening Markets for Logistics. Proceeding of Annual Conference for Nordic Researchers in Logistics. Pages 377-391. Publication by the Finnish Association of Logistics 11/1988.

Janic M, Reggiani A, Nijkamp P., **'Sustainability of the European Freight Transport System: New Generation Bundling Networks'**, paper presented at the 4th NECTAR Conference, 19-23 April 1998.

Janic M, Reggiani A, Spicciarelli T, '**Theoretical Background of the Innovative Bundling Networks in Europe'**, paper presented at the WCTR (World Conference on Transport Research), Antwerp, Belgium, 11-18 July 1998.

Janic M, Reggiani A, Spicciarelli T., **"The European Freight Transport System: Analysis, Modelling and Evaluation of the New Bundling Networks"**, paper presented at the European Regional Science Association in Vienna in August 1998.

Jourquin, B., **Trans-European freight network model and its application to crossing of Switzerland** at NECTAR Conference in Bertinoro, Italy, 13-14 March 1997

Jourquin, Bart A.M**, Freight Network Bundling Models; a methodological note,** NECTAR Cluster 2 meeting, held at Odense (Denmark) on 3-4 October 1997.

Jourquin, B., M. Beuthe and L. Demilie, 1998, **Freight Bundling Networks Models: Methodology and Application,** paper presented at the World Conference on Transportation Research, July 1998, Antwerp (forthcoming in Transportation Planning and Technology in 2000)

Jourquin, B., M. Beuthe and L. Demilie, **Impacts on Modal Choice of New generation Terminals: Performance Analysis of a Hub-and-Spoke Network**, presented at the ERSA Conference in Vienna, August 1998.

Konings, J.W., and M.W. Ludema, 1999, **Competitive River-sea Transport**, paper presented at the 5th trail PhD-congress and part of Conference Proceedings, Scheveningen December 1999, 21pp.
Kreutzberger, E., December 1998, **The performance of new-generation terminal concepts for hub terminals and collection and distribution terminals: balancing between effectivity and feasibility,** paper presented at the 4th trail PhD-congress, Scheveningen, The Netherlands.

Kreutzberger, E., 1999, Veelbelovende innovatieve intermodale netwerken met een nieuwe generatie terminals. Bouwstenen en concepten voor de zuidoost-corridor (Promising innovative intermodal networks with a new-generation terminals. Building

100

blocks for the south-east corridor), in: R.H.J. Rodenburg and A.L. Kruse (editors) **Proceedings of Vervoerslogistieke Werkdagen**, 11 and 12 November, Vaals, pp.81-96, paper presented at the conference.

Kreutzberger, E., 1999**, Innovative networks and new-generation terminals for intermodal transport**, paper presented at the 5th trail PhD-congress and part of Conference Proceedings, Scheveningen December 1999, 21pp.

Kreutzberger, E. and Y. Bontekoning, **New Generation intermodal networks and nodes: patrons and dynamics** paper presented at Research School NETHUR seminar "Cities of the Future" (Steden van Morgen), 31 May 1997.

Kreutzberger, E. and Bontekoning, Y., **Innovative bundling concepts and new generation terminal and terminal node concepts in the transport corridor Rotterdam-Rhine,** Paper presented at the 8th World Conference on Transportation Research, July 1998, Antwerp, Belgium.

Priemus, Hugo, **Terminals and networks of freight transport: a technological and organisational breakthrough towards multimodality**, paper presented at the NECTAR Conference in Tel Aviv (19-23 April 1998), Israel.

Schulze,G. and K.-P Franke, 1999, **Ein innovatives Produktsystem für den Kombinierten Verkehr. Weserlotse Logistik,** Nr. 11/12 1999. Sauermilch PR, Bremen.

Trip, J.J., 1999, Possibilities for the integration of continental and maritime intermodal transport flows in Valburg, in: R.H.J. Rodenburg and A.L. Kruse (editors) **Proceedings of Vervoerslogistieke Werkdagen**, 11 and 12 November, Vaals, pp27-42, paper presented at the conference.

Vogtmann, M. and K.-P Franke, 2000, **Planung eines innovativen Hub-and-Spoke - Terminals für Venlo**, presentation for representatives of the Province Limburg and the municipal of Venlo, Venlo, 02.2000

Wiegmans, Bart W., Enno Masurel, Peter Nijkamp, **Intermodal freight terminals: an analysis of the terminal market,** paper presented at the NECTAR Conference, 19-23 April 1998, Israel.

Remark:
The papers presented at the NECTAR Conference in Israel have been submitted to a special issue of the International journal *Transportation Planning and Technology* (UK).

Other activities

Beuthe, M.
- quoted some of the work by the TERMINET consortium in a report on intermodality submitted to the CEMT for its next Symposium.
- presented new work on network analysis at the Conference of the European Association of Regional Science in Rome (end of August 1997), and
- presented new work on network analysis at the Conference of the French Association of Regional Science in Lille (beginning of September 1997).
- followed the researches of the CODE-TEN European project as a "Quality controller ". He had the opportunity to inform the partners of the work realised in TERMINET (1998).
- Informed the Region Wallonne where we FUCAM was working on a Belgian model of freight transport about the Terminet project (1999).

M. Beuthe and B. Jourquin have had the opportunity to present some results of the TER-MINET work at the EFS/NFS SCAST conference in Berkeley (10-13 March 1999).

Bontekoning, Y.M.
- drew up 4 Terminet newsletters during the period 1997-1998
- presentation at Dutch railcluster "Setting the agenda for rail research", 1999
- presentation about performances of new-generation terminals in Trail research-school research programme Freight Transport Automation and Multimodality, cluster meeting 1998
- presentation about organisational implementation barriers of new-generation terminals in Trail researchschool research programme Freight Transport Automation and Multimodality, cluster meeting 1999

Bontekoning, and Trip, presentation of Terminet results in the PhD-course Technological Innovation in Transport, 2000
Demilie, L.
- participated in the Euro Session on GIS modelling., 17-22 May 1997

Jourquin, B.
- presented some elements of the NODUS work in Lille (23-24 April 1999) at the NECTAR meeting of the Environment Cluster,
- presented Terminet work at the EURESCO meeting on Socio-Economic Analysis and Geographic Information Systems, in Espinho (22-27 May 1999).
- presented the new work on network analysis (WP 3) at The Conference of the Western Regional Science Association at Kamuela, Hawaii, USA, 1997.
- made the *guide book* for the Software NODUS available on the site www.fucam.ac.be/~gtm.

Kreutzberger, E.,
- presentation at final conference IMPULSE 1998, Brussels

- gave lecture at PhD-course Automation of freight transport: difficulties of intermodal transport, 1999.
- presentation about innovative networks in Trail researchschool research programme Freight Transport Automation and Multimodality, cluster meeting 1998
- presentation about innovative networks in Trail researchschool research programme Freight Transport Automation and Multimodality, cluster meeting 1999

Priemus, H.,
- gave a lecture on new European networks of multimodal freight transport during the conference 'Transportation: A challenge for the FUTURE' (Delft University of Technology). 1997,
- courseleader of the 2-day PhD-course Automation of freight transport: difficulties of intermodal transport, 1999.

Wiegmans, B.
- gave lecture at PhD-course Automation of freight transport: difficulties of intermodal transport, 1999.