Rolling Shelf

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Final Report

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Summary:

This report contains major results of the project. The objectives of the project ranged from research on demand for palletised goods and parcels for 1999 and 2005 to studies of a promising rail transport technology concept with the opportunity to capture a significant share of the market within a foreseeable time horizon.

The types of goods considered (LTL, palletised goods and parcels) are showing the highest growth rates of all transport segments. The characteristics of these types of goods led to technology concepts featuring train speeds of 160kmph maximum and fast transhipment methods, supported by internet-based information technology. Design studies for new rail wagons were made. A set of four terminals was developed in detail for an in-depth cost and operations analysis. Operation concepts for running a transport network were developed and applied as a basis for cost models.

A business study on using small containers for specific depot-depot transport has shown very promising results. Results were turned into practice for truck transports, however it is equally valid for train transport. Another business study has shown promising break-even figures on train utilisation: a profitable operation is possible in most cases when train utilisation is above 50%.

Key elements and findings of this project are transferred already into new projects: CO-ACT being the first, further projects will follow.

Contents

1. Introduction

The background of the Rolling Shelf project is summarised in this chapter. First, some of the freight transport trends and their external impacts are introduced (see sections 1.1.1 and 1.1.2). Second, the transport policy objectives are discussed (see section 1.1.3). This discussion reveals that transport policy goals are currently not achieved and that modal shift policies (supported by innovations in rail technology) form a promising way of solving the problems at hand. The Rolling Shelf project goals are explained against this background (see section 1.2.1).

1.1 Background of the Rolling Shelf project

1.1.1 Freight transport trends

The European market for freight transport has undergone structural changes in the last decennia. These changes in the demand for freight transport have occurred due to far-reaching logistics trends such as the general *rationalisation of distribution networks* (a reduction of the number of distribution centres), *increased outsourcing of logistics services* (production companies concentrating on their core business), *supply chain integration* (e.g. inventory reduction schemes), and *time compression* (e.g. just-in-time, efficient consumer response). All of these shifts in the logistics focus of companies ultimately had a number of impacts on the demand for freight transport.

First, a general trend is the *decrease of average shipment sizes*. Smaller shipment sizes are a consequence of the need for shorter lead times and the need to deliver exactly the right amount of goods at the prescribed time. Inventory levels are consistently reduced, which causes a need for fast and frequent transport. This in turn creates additional traffic.

Second, *faster modes of transportation* (i.e. road haulage and air transport) have become more popular compared to rail and inland waterways. Over the past ten years, the shortening of order lead times and an increase in the amount of sub-contracting have begun to make a significant contribution to traffic growth [McKinnon, 1994]. Garreau *et al*. [1991] for instance showed that, as a result of the implementation of just-in-time concepts, 75 per cent of American companies appeared to have changed their use of transportation modes for both inbound and outbound shipments. The railways were the biggest losers in this respect, with road and air transport winning. Timeliness and responsiveness were found to be the most important criteria for modal choice.

1.1.2 Externalities caused by freight transport trends

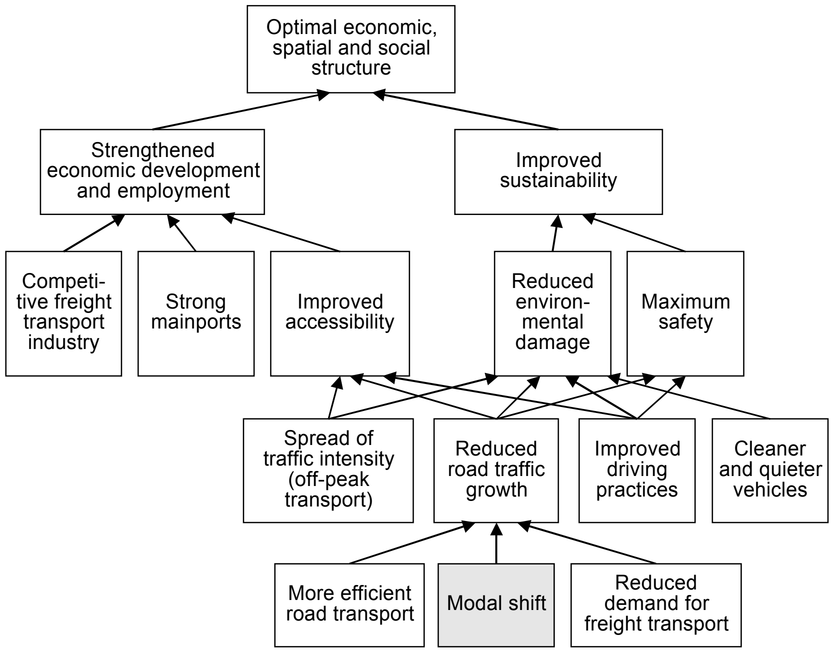
It goes without saying that transport activities are of strategic importance to the functioning of a modern society. Transport and logistics activities not only account for considerable shares of the working population, they also can be considered a lubricant of the economy as a whole. Freight transport can therefore be considered as a basic good. Nevertheless, there is a dark side to these positive externalities of freight transport operations. The following negative externalities can be mentioned:

- *Emissions*: air and water pollution caused by exhausts.
- *Disruption*: noise from engines and tyres, vibration, partition of landscape and wildlife habitats, visual intrusion by infrastructures and vehicles.
- *Depletion of energy resources*: vehicle operation contributes to the depletion of fossil fuels.
- *Congestion*: adding an extra vehicle reduces traffic speeds if infrastructure capacity is limited.
- *Safety concerns*: road accidents cause deaths, injuries and property damage.

One of the most challenging problems is the reduction of emissions (mainly CO_2). Emissions of CO_2 contribute to the greenhouse effect, NO_x and SO_2 lead to acidification, while C_xH_y cause smell. Both NO_x and SO_2 have actually been reduced since the late 1980s, but CO_2 emissions are still increasing.

1.1.3 Freight transport policy objectives

Faced with the challenges described above, different transport policy objectives have been formulated by the European Union (see Figure 1-1). The prime objective of (freight) transport policy is to create a so-called optimal economic, spatial and social structure. This broad objective is split into two parts. When we look at the negative externalities, improved sustainability of freight transport is the relevant sub-objective. Aspects of sustainability are improved accessibility (i.e. reduced congestion), reduced environmental damage (i.e. reduced emissions, disruption and depletion) and maximum safety. These sustainability objectives can be achieved by a shift to off-peak operations, reduced road traffic growth, improved driving practices and cleaner/quieter vehicles. A reduction in the growth of road transport can in turn be obtained by more efficient road transport, a modal shift to rail and waterway transport, and a reduction in the demand for freight transport.



Source: Muilerman [2001]

Figure 1-1 Freight transport policy objectives

1.2 Objectives of the Rolling Shelf project

The Rolling Shelf project is aimed at reducing road traffic growth (and its negative externalities) by developing an attractive alternative mode of transportation and thereby realising a *modal shift* from road to rail transport. Through this modal shift a decoupling of economic growth and road transport externalities can be achieved. As wil be shown in the following sub-sections, such a modal shift can be materialised through a series of technological innovations in the rail transport sector.

1.2.1 Project goals

Rolling Shelf is aimed at regaining considerable parts of the market share that rail companies have lost since the early 1970s. Rolling Shelf's strategy of handling this research challenge is one of technological and organisational innovation. Rolling Shelf aims at eliminating some of the disadvantages of current rail transport, by offering a fast and economically attractive alternative to road and even air transport. Especially the segments of part shipments, where road transport has dominated over the years form the target market of the Rolling Shelf concept. The overall objective of the Rolling Shelf project can be formulated as:

Enable a considerable increase of the rail transport share in high-value and time-sensitive palletised goods markets, even on short distance relations (about 100 km).

The Rolling Shelf system should be suited for parcels, pallet-packed cargo units or pallet-related containers, as today only a small part of this market is transported by rail.

This translates into following sub-goals:

- Improve transhipment through **automated goods transfer**, thus ensuring that transfer costs can be reduced, while efficiency of the overall system can be increased.
- Propose a **network of terminals** suited for the needs of the Rolling Shelf system.
- Design a **new type of goods wagon** that allows fast and easy loading and unloading of palletised goods in conjunction with a suitable transhipment concept.
- Evaluate the **economic aspects** of the Rolling Shelf system. To this end, investments for goods wagons, terminals and logistics telematic system, as well as operational costs are taken into consideration.

1.2.2 Main technological innovations

The main target of the Rolling Shelf project is to provide an alternative mode of transportation for parcels, pallets and small containers, that is able to serve high-value and time-critical consignments. This means that the feasibility of the Rolling Shelf system requires following technological innovations:

- *Wagons and trains*
    - Wagons for fast and automated transhipment
    - Trains for high utilisation and high dynamic loading operations
    - Operations for timetable and passenger-like operations between specific terminals
- *Transhipment facilities*
    - Facilities for dynamic and flexible loading and unloading of pallets and small containers
    - Terminal designs for small, medium and high volume goods transhipment
- *Load units*
    - Pallets grouped onto systems pallets and equipped with tags; Transport inside specially designed Rolling Shelf wagons.
    - Small containers serving as pre-consolidated shipments; Transport on flat wagons.

1.2.3 Project consortium

In order to cover all of the issues described above, the Rolling Shelf project involved partners from different disciplines and countries:

- *Adtranz (D)*: Wagon designs
- *Alcatel Austria AG (A)*: Transport telematics solutions
- *EveCo Software GmbH (A)*: Project management and scientific coordination
- *Integral Verkehrstechnik AG (A)*: Wagon development
- *Kessel + Partner (D)*: Pallets flow matrix and prognosis, transport models
- *Logotrans GmbH (A)* : Insurance consultation
- *Schäfer Noell GmbH (D)*: Transhipment and terminal designs
- *Railion Benelux (NL)*: Rail distribution process development
- *Österreichische Bundesbahnen (A)*: Wagons designs, terminal and track developments
- *United Parcel Service Transport (D)*: Rail transport network development
- *Versteijnen Logistics (NL)*: Logistics and cost consultation
- *vr-architects (D)*: Developing and producing models for visualisation

1.3 Outline

This report is divided in three parts. Part I includes an estimation of the market potential of the Rolling Shelf concept, by calculating current and future freight flow matrices for European destinations. This is done for palletised freight and for parcels (see Chapter 2). Based on these freight demand estimations, a possible network of Rolling Shelf terminals is deduced. Subsequently, train operations are simulated in order to estimate the required transhipment capacities at the various terminals.

Part II deals with the technical concept that is defined within the restictions of the discussed market potential. Various terminal concepts are developed in chapter 5, while concrete concepts for wagons and trains (including load units) are covered by chapter 4.

Part III encompasses an evaluation of the market potential and the technical concept in terms of economic benefits. The feasibilty of the technical concept is therefore elaborated in chapter 6. Dissemination strategies and future intiatives with direct links to the Rolling Shelf concepts are discussed in chapter 8.

PART I
MARKET POTENTIAL AND MARKET REQUIREMENTS

2. Potential market for the Rolling Shelf concept

The target market of the Rolling Shelf concept has been briefly indicated in the previous chapter: the market of palletised part shipments and parcels even for shorter distance relations. In this second chapter, the potential market is further specified. Subsequently, the market potential of the Rolling Shelf concept is estimated on the basis of transport models developed by Kessel+Partner. The results of these freight flow analyses are used to design a complete Rolling Shelf terminal network including required terminal capacities. Additionally, based on the previously discussed transport demand forecasts, a simulation of the train operations on the deduced network is performed.

2.1 Target market

The focus of the Rolling Shelf concept is defined as follows:

- *Emphasis on transportation of palletised goods and parcels*: these freight types form a class of commodities that have shown relatively strong growth figures in the past and will continue to do so in the future. A modal shift from road to rail in these segments would therefore be highly efficient in light of the transport policy objectives mentioned in the previous chapter.
- *Concentration on less-than-truckload shipments (LTL, also part shipments)*: a rail concept will only be attractive when it is capable of efficiently combining part shipments into one larger consignments. Full truckloads are efficient from the consignors' perspective, and therefore 'out of reach' for rail alternatives, unless consignors possess a direct connection to the rail network.
- *Minimal distance*: the distance within which the Rolling Shelf concept will prove to be an attractive alternative approximately lies around 100 km and higher. Freight that is transported over more than 100 km is considered potential freight for the Rolling Shelf concept.
- *Logistics requirements*: the logistics characteristics of the Rolling Shelf concept (e.g. transit time, on-time reliability) must be competitive when compared with road-only concepts. The logistics performance of the Rolling Shelf alternative should consistently be matched with the performance of this benchmark.

The rail-based Rolling Shelf concept (for technical details see Part II) aims at capturing a larger market share for palletised goods and parcels. In order to determine the potential market of the Rolling Shelf concept, existing data on freight flows of palletised freight and parcels were reviewed. Detailed data on both these commodity types however appeared to be lacking. Therefore, these data were estimated on the basis of secondary market data and transport models.

2.2 Estimation procedure

The data on palletised freight flows are basically determined by estimating an origin-destination (OD) matrix for 248 European traffic zones. The estimation is based on the traditional four-stage matrix estimation procedure. Kessel+Partner executed three stages in order to calibrate an OD-matrix for the 248 European zones.

- *Generation*: how much traffic does a particular zone produce and attract? Data for these estimations are provided by structural data such as traffic counts. Transport statistics are complemented by socio-economic data of the zones and other additional information.
- *Distribution*: what traffic flows exist between which zones? This phase results in an OD-matrix. An OD-marix can be estimated on the basis of a so-called generalised transport cost function (also cost-deterrence function), in which cost elements such as transhipment and transit time (time costs) and transport costs are integrated. This function represents the disincentive to carry freight as distance (time) and costs increases.
- *Modal split*: which mode of transportation is used for which traffic flow? The input data for the modal split estimation are models of networks for road, rail and barge, as well as transport characteristics of each mode (e.g. transit time, on-time reliability).

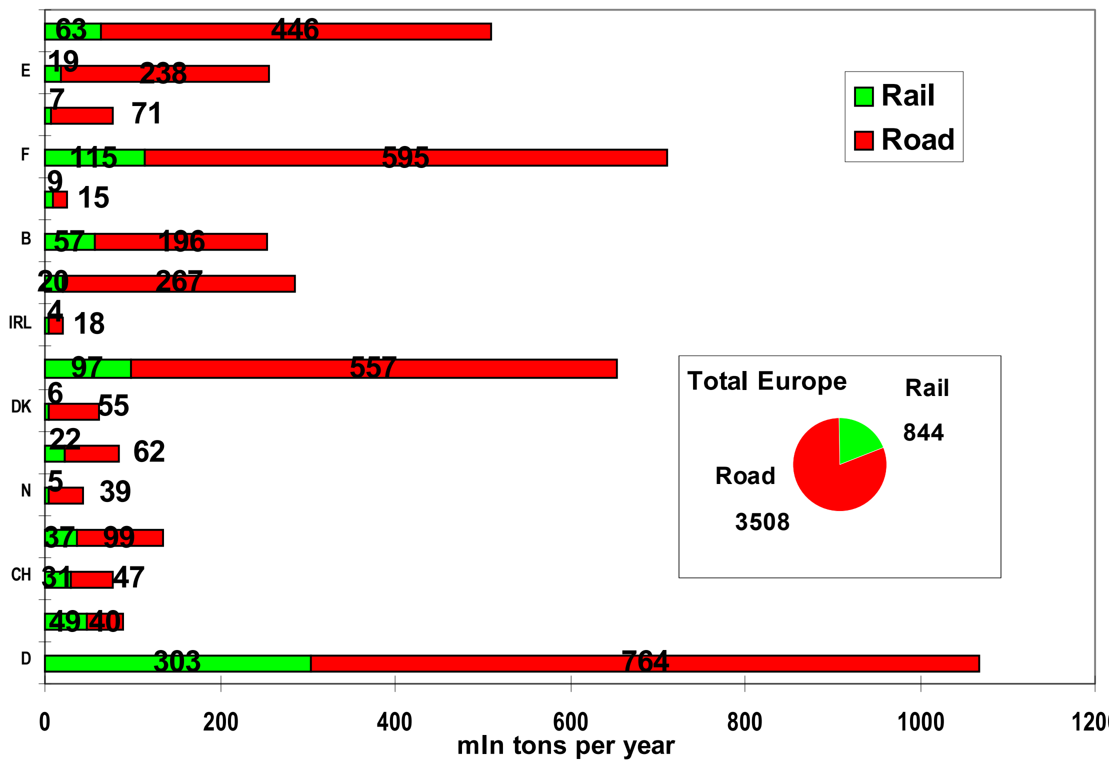
The underlying models are based on probability and mathematical theory (regression, gravity-models, logic-models). Empiricals data originate from surveys, while data sources from other projects are used for model calibration. Concerning the contents, freight volume generation is assumed to be a function of regional economic activity; the generalised costs as input for the gravity-models have impacts on the spatial distribution of the freight transport volume and the characteristics of modes (transportation time and cost, reliability, safety) determine the modal split, estimated with the logic-transport-models.

In order to deduce the *pallet* flows between traffic zones, the final step included the application of information on the average weight of pallets per commodity. These data were obtained from literature and expert interviews. This leads to the final result, which is a OD-matrix of transport flows on pallets per commodity and mode of transportation.

2.3 *Estimation results: European pallet matrix*

2.3.1 Total freight volumes

The volumes of total freight flows and the modal share of rail and road of the respective European countries are shown in Figure 2-1. The total of long-distance transports within Europe and neighbouring countries comes out at about 4400 mln tons per year in 1996. European rail transport usually has a share of less than 20 per cent of the total transport flows. The only exceptions to this rule are Germany, Austria and Switzerland. The modal share of rail transport is higher in these countries due to the relatively good rail infrastructure and the rail affinity of good structures. Figure 2-1 gives an aggragated overview of the national and international transport flows. In addition to the transport volumes of the European countries, the modal split of the whole of Europe is shown by the small pie chart.



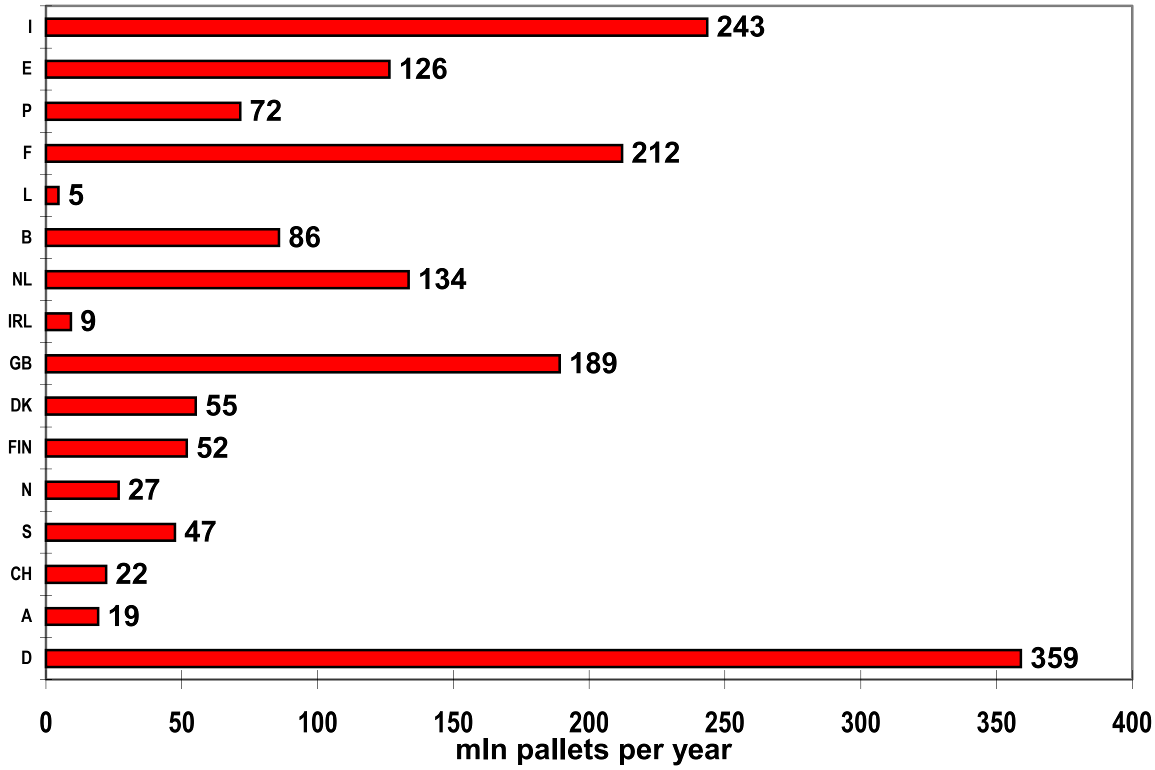
Source: Kessel+Partner [1999]

Figure 2-1 Total long-distance freight flows by road and rail (mln tons per year in 1996)

2.3.2 Pallet flows in Europe

The data on pallet flows and part shipments were deduced on the basis of the above figures. Filtering out part shipments and pallet shipments per commodity produces the volumes of pallet flows per country (see Figure 2-2). These pallet flows represent the potential market for the Rolling Shelf concept.

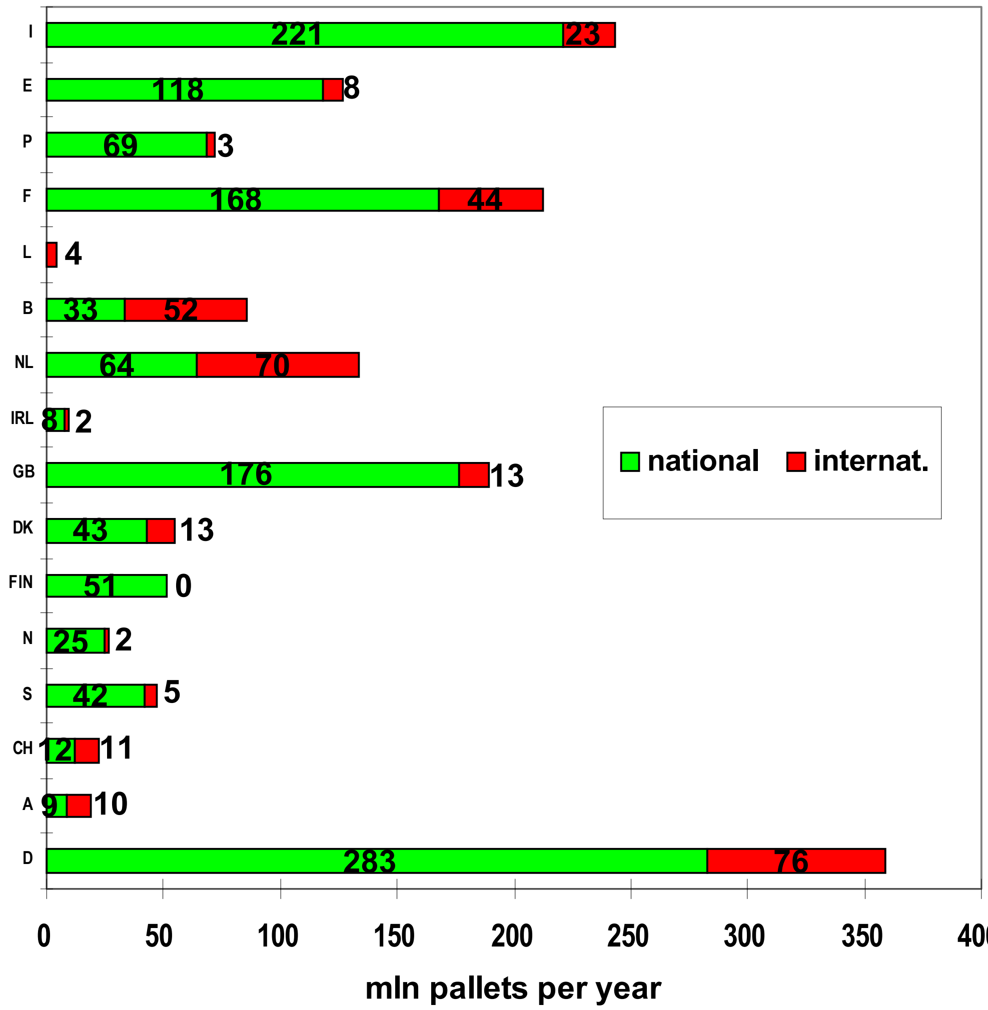
The rather low amount of pallet flows by road in Austria and Switzerland (22 mln and 19 mln pallet shipments per year) is explained by the relatively low modal share of road transport in these countries.



Source: Kessel+Partner [1999]

Figure 2-2 Pallet flows (only part shipments) by road in 1996 (mln tons per year)

Figure 2-3 gives the same pallet flows as shown in Figure 2-2, but now differentiated for national and international flows. As Figure 2-3 reveals, relatively large differences exist between the share of international pallets in the different European countries. These differences are caused by characteristics of road transport as well as by the decreasing share of part shipments on long transport distances. Austria and Switzerland have a high share of international pallet flows (54 and 36 per cent) due to the relatively strong dependence on international freight. Due to their international position as a mainport for Europe, the international flows are significant for Belgium and the Netherlands (shares of 48 and 44 per cent). All the other countries display international shares in a range of 6 to 21 per cent, except for Portugal and Norway.



Source: Kessel+Partner [1999]

Figure 2-3 National and international pallet flows by road 1996 (mln pallets per year)

2.4 Estimation results: European parcel matrix

In addition to pallet flows, parcels are considered a potential market for the Rolling Shelf concept. On relations where the parcel volume is not sufficient to fill a normal swap body or a whole truck, parcels can be collected in small containers. As will be discussed in later sections, the Fiftybox (half a standard swap body) is assumed to transport parcels within the Rolling Shelf project.

To specify the market potential for parcel transports, an analysis (including forecasts) of European parcel flows has been carried out. Since there are no detailed statistics available on parcel flows for any European country, not to mention the whole of Europe, an estimation of the flows of parcels has been exectuted. With the help of different secondary data the plausibility of the estimations was checked. Among others, an integrator evaluated the firms' own statistics of parcel flows between their terminals and – in a more disaggregated form – between origin and destination of the parcels. These data were used to estimate a European parcel matrix.

In total some 10.5 mln parcels are transported within Europe on an average day. The overall average distance for a parcel is 221 km. A look at the parcel transport volume per country reveals the following values (see Table 2.1).

Table 2.1 Total parcel transport volumes for selected countries (# parcels per day)

Country	Estimates of total package volumes (mln parcels per day)	Information from publications
Germany	3.40	3.60
Sweden	0.25	
Norway	0.08	
Finland	0.08	
Denmark	0.09	
UK	1.38	
Ireland	0.08	
The Netherlands	0.45	
Belgium	0.19	
Luxembourg	0.006	
France	1.52	1.56
Portugal	0.07	
Spain	0.23	
Italy	0.33	
Switzerland	0.42	0.60
Austria	0.38	0.24

A comparison of the estimated volumes with the published numbers shows that these data correspond quite well. With the construction and estimation of parcel flows a Europe-wide parcel matrix for 1996 is made available. Since the parcel market is expected to achieve two digit growth rates in future, this matrix is an important element for the assessment of the future transport potential of the Rolling Shelf concept. The strong growth of the parcel market is related to the trend of ever-smaller shipment sizes and reliance on fast transport modes (see Chapter 1).

2.5 Forecast of the potential market for Rolling Shelf

Table 2.2 shows that an overall increase of the goods transport volume in Europe of about 41 per cent is expected. This increase is mainly caused by a 52 per cent increase of general cargo flows. Bulk transport only contributes 22 per cent to this increase.

Table 2.2 Transport volume in Europe in 1996 and 2015 (mln tons per year)

				1996	**2015**	**Change (per cent)**
Bulk				1461	1789	+22
General cargo	Non-palletised			1329	2089	+57
	Palletised	Palletised rail		94	138	+47
		Palletised road	Full-truckload	463	560	+21
			Less-than-truckload	**368**	**645**	**+75**
Sum				2254	3431	+52
Total transport volume				3715	5220	+41
Daily number of parcels in Europe				**8.26 mln**	**14.34 mln**	**+73**

Source: Kessel+Partner [1999]

Palletised freight

Within the segment of general cargo, palletised and non-palletised goods are discerned. Within these segments the highest increase of transport volume can be observed in the groups of less-than-truckload shipments of palletised goods. The current estimated transport volume in this segment is 368 mln tons per year. It is expected that in the year 2015 this volume will increase up to 645 mln tons. This represents a rise of 75%. This projected development can be expained by several factors:

- European industrial production will increase dramatically;
- the production of high-value products will increase more than proportionally;
- internationalisation and the international division of labour will increase in the coming years;

- the trend towards modular production and increasing outsourcing causes more shipments of semi-finished products;
- the trend towards inventory reduction and just-in-time production cause the occurrence of smaller consignments and higher shipment frequencies.

The mentioned transport potential of 368 mln tons in 1996 and 645 mln tons in 2015 is composed of the transport potential within different business industries. The largest volumes thereby stem from food products, transport equipment & machinery, clothing and other manufactured articles, and miscellaneous articles.

The average load per pallet varies between 150 and 550 kilograms (depending on the business industry). These average loads are used to calculate the estimated number of pallets per day in various European countries for 1996 and 2015 (see Table 2.3).

Table 2.3 Number of less-than-truckload pallets per day in Europe, 1996 to 2015 (x1,000 pallets/day) (Source: Kessel+Partner [1999])

Number of pallets per day in LTL shipments (x 1,000 pallets)						
Country	**1996**		**2015**		**Increase (per cent)**	
	Dispatch	**Receipt**	**Dispatch**	**Receipt**	**Dispatch**	**Receipt**
Germany	1403	1424	2556	2582	82	81
Netherlands	441	421	792	769	80	83
Belgium	271	245	456	412	68	68
Luxemburg	11	11	22	24	100	118
France	832	851	1648	1740	98	104
Italy	978	960	1889	1827	93	90
Spain	468	472	822	838	76	78
Portugal	265	269	465	463	75	72
Austria	58	62	102	123	76	98
UK	702	708	1129	1155	61	63
Ireland	26	26	39	40	50	54
Denmark	189	193	304	318	61	65
Finland	195	195	343	313	76	61
Sweden	190	184	348	316	83	72
Greece	95	97	158	163	66	68
Sum	**6121**	**6119**	**11073**	**11083**	**81**	**81**

In the market segment "less-than-truckload" a volume of about 11 mln pallets per day are expected for the year 2015. This corresponds with more than 300,000 truckloads or 27,500 Rolling Shelf trains per day. It should be stressed however that many of these pallets are transported on medium and short distances and are therefore not actually within the scope of this project's potential.

Parcels

A volume of about 14 mln European daily parcel transports are expected for the year 2015. This represents a growth of about 74 per cent compared to the parcel volume of 1996 (see Table 2.4).

Table 2.4 Number of parcels per day in Europe, 1996 to 2015 (x 1,000 parcels/day)

Number of parcels per day 1996 and 2015 (x 1,000 parcels)						
Country	**1996**		**2015**		**Increase (per cent)**	
	Dispatch	**Receipt**	**Dispatch**	**Receipt**	**Dispatch**	**Receipt**
Germany	3237	3240	5678	5908	75	82
Netherlands	381	374	619	610	63	63
Belgium	156	138	287	258	84	87
Luxemburg	4	3	9	6	116	122
France	1450	1455	2402	2357	66	62
Italy	303	302	557	577	84	91
Spain	209	219	433	449	107	105
Portugal	66	57	130	114	96	100
Austria	315	330	508	490	61	48
UK	1320	1320	2311	2232	75	69
Ireland	45	45	78	72	74	61
Denmark	75	77	113	122	50	59
Finland	74	80	118	129	60	60
Sweden	230	236	417	374	81	59
Greece	55	60	107	115	92	91
Sum	**7922**	**7936**	**13767**	**13812**	**74**	**74**

Source: Kessel+Partner [1999]

The largest current and future volume of parcels is and will be located in Germany, followed by France, and the United Kingdom. If 265 working days per year and an average weight of 6 kg per parcel are assumed, the projected transport volume of parcels will amount to 22.8 mln tons in the year 2015. The factors that boost the high growth rates of parcel volumes are the trend towards smaller consignment sizes, an upgrade of the average value-density of freight and changes in production processes (just-in-time, outsourcing of semi-products).

To summarise the forecasting of the Rolling Shelf potential, it can be said that the expected development indicates sufficient potential for the Rolling Shelf concept. There is every indication that the target market for the Rolling Shelf concept – LTL palletised goods and the parcel transport – will increase more than proportionally.

2.6 Network of terminals

The results of the freight flow analyses of the previous sections are used to design a complete Rolling Shelf network, i.e. the terminal network including required terminal capacities. Additionally, a simulation of the train operations on the deduced network has been performed by Kessel+Partner [2000].

In summary, this section includes an overview of the following issues:

- Development of a European transport network for Rolling Shelf;
- Simulation of trains and timetables;
- Interaction between train operation and terminal efficiency.

2.6.1 Business Study: Development of a European transport network

Starting point are the potential freight volumes for the Rolling Shelf concept, as discussed in the previous sections (pallets and parcels). The next step is the determination of optimal terminal locations and their catchment area. The terminal locations and the transport potential form the basis of the simulation of the train operations.

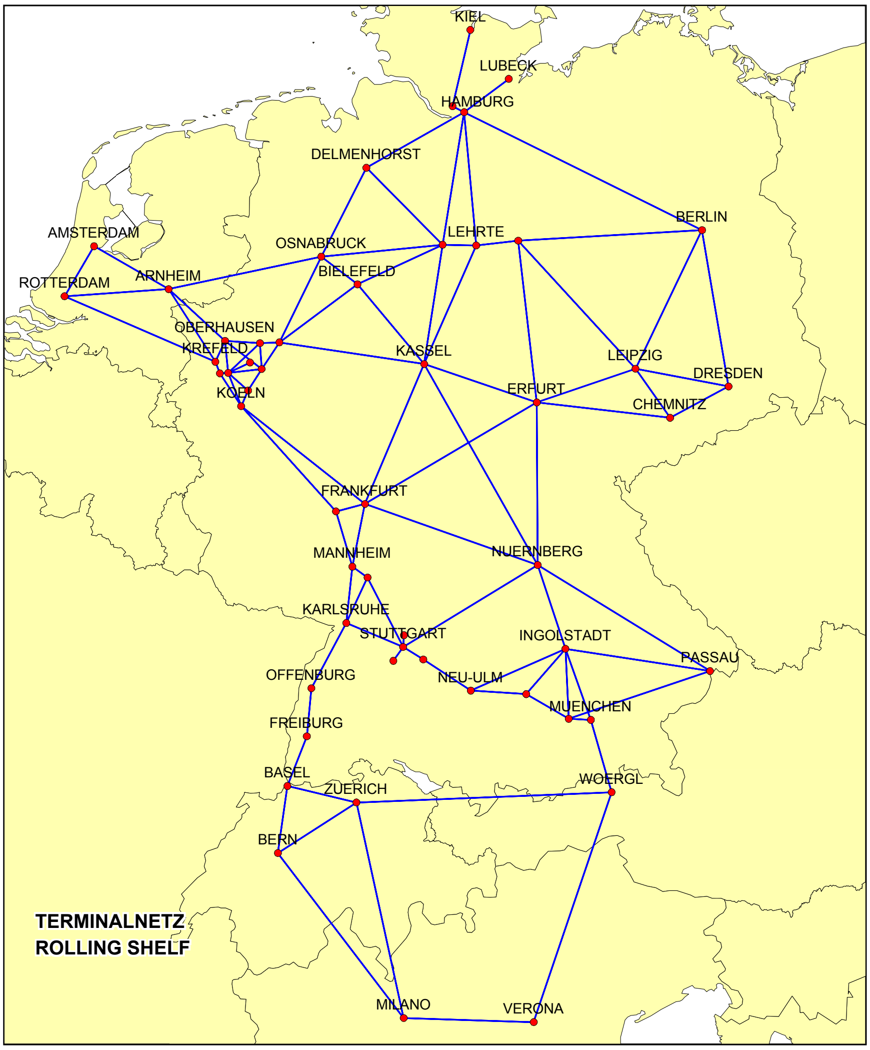
The estimated transport flows and a so-called terminal location model were used to determine the optimal terminal network for the Rolling Shelf system. To determine the Rolling Shelf network the following iterative steps were applied:

- Identification of a set of all available terminals for intermodal transport in all of the relevant regions;
- Assignment of traffic flows to all terminals and calculation of the distances;
- Extraction of flows with a transport distance of more than 200 km from the flow matrix;

- Usage of the suitable potential utilisation for each flow.

The terminal location model, which is an iterative algorithm, selects the most suitable terminals for each transport flow based on the above mentioned restrictions. During the iteration process the assignment of traffic flows to terminals can change, because the terminals with less than 500 transhipments per day are removed from the network.

The result of this procedure is twofold. First, a set of 53 terminal locations are selected. The complete Rolling Shelf network is displayed in Figure 2-4. This network represents the basic and optimised terminal network. Second, the basic transport demand, which is assigned to the optimised network is estimated. The terminal model revealed that 27,000 pallets per day can be counted upon.



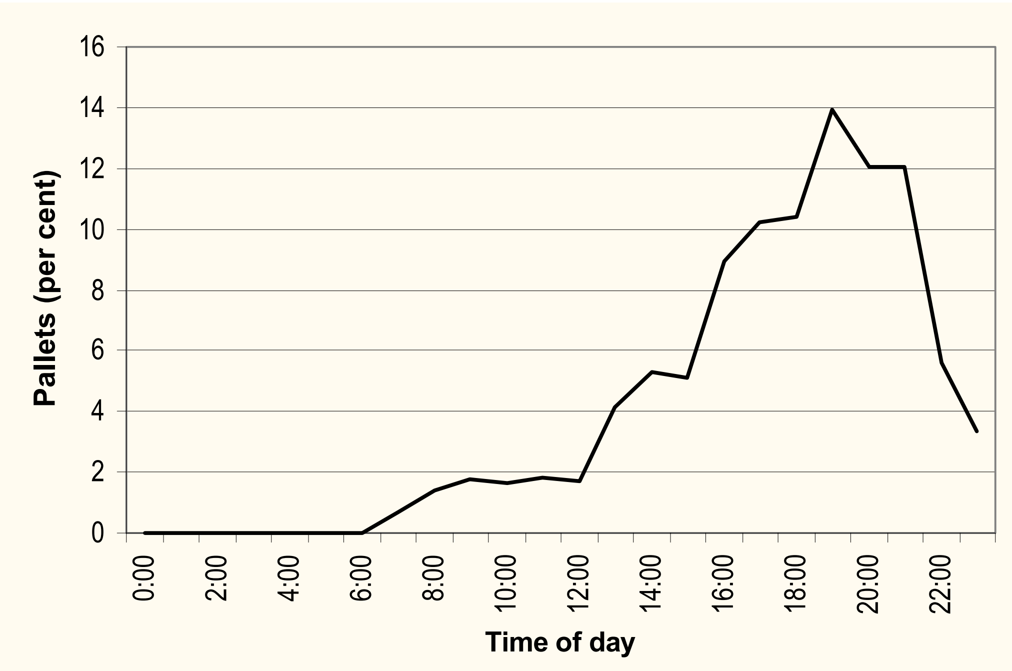
Source: Kessel+Partner [1999]

Figure 2-4 Rolling Shelf terminal network

2.6.2 Simulation of trains and timetables

The application of the simulation system in the Rolling Shelf network produces an optimised system of trains and their timetables. 48 trains are found optimal to manage the transport demand of 27,000 pallets.

The starting point of the simulation of trains and timetables are the 27,000 pallets, assigned to the 53 terminals. The consignments have different arrival times at the terminals, as is shown in Figure 2-5.



Source: Kessel+Partner [2000]

Figure 2-5 Daily distribution of consignment arrival in terminals

The figure reveals that most of the consignments arrive in the late evening (until 22:00h). This has major impacts on the train composition process. Because most of the pallets have to arrive at their destination early in the morning (before 05:00h), the train operations have to be organised in a way that most of the pallet-transports (ideally all pallets) meet these requirements. This means that most of the pallet transports should take place during night-time. Two classes of transport are considered: express-pallets with a higher transport price, for which a specific service is guaranteed, and normal-pallets with standard fare. Normal-pallets have, depending on the timetable and the volume of express-pallets, a longer waiting time in the terminals.

The challenge of the construction of the timetable for the trains are on one hand the time requirements of the users of the system, and the costs of train operations on the other. An optimal solution will fulfil these requirements with a minimum number of trains. This solution is realised by application of the simulation system TOPAS [Kessel+Partner, 2000]. An iterative procedure uses the comparison of the revenues (generated by the loaded pallets on a train) and the train operation costs (fixed and variable costs) as a trigger to find an optimal solution, while at the same time taking into account the user requirements for pallet transports. The key parameters, which are used to perform the simulation, are shown in Figure 2-6.

Train operation – Trains and timetables

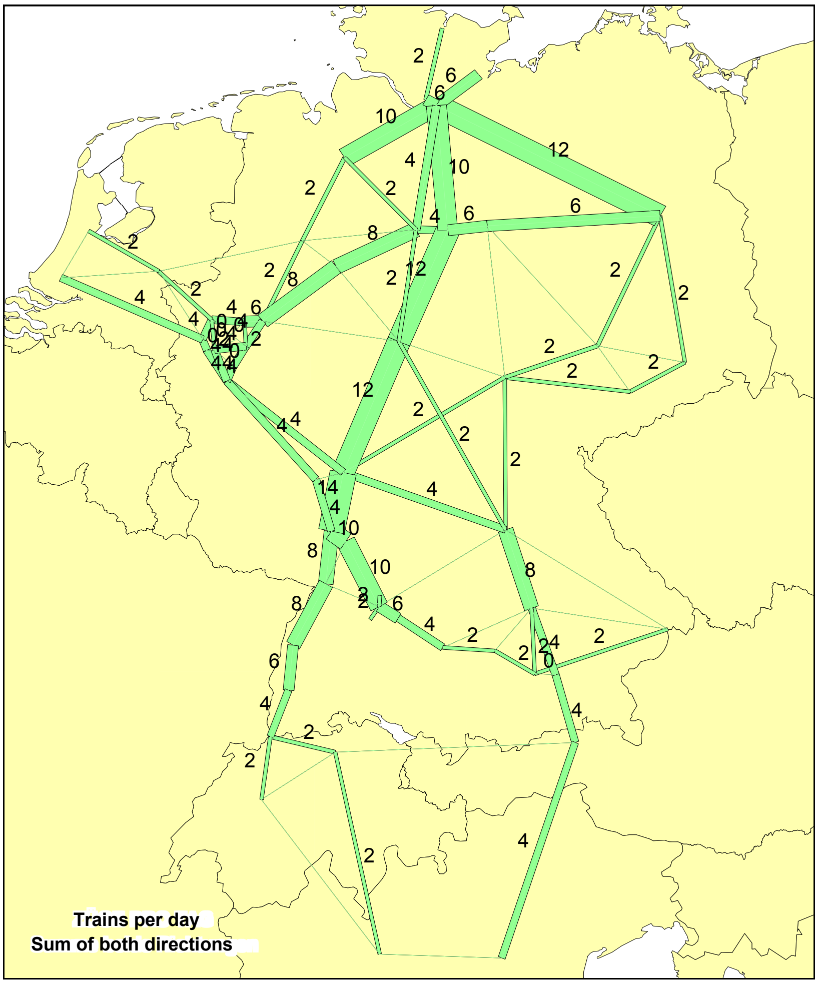
Parameters for construction of timetables

- transhipment in terminals per time interval
- max. train capacity (450 pallets per train)
- max. speed of trains (160 km/h, times for braking, acceleration)
- stop time in terminals (20 minutes)
- internal simulation parameter (distance, transport-volume)
- trigger for train selection
  - cost for train operation: 3 Euro/km, 2500 Euro fixed costs
  - price: 0,045 - 0,055 Euro per pallet-km
  - transhipment costs per pallet (7 Euro, 3,5 Euro transit)
- distance < 600 km: pallet shall reach 5.00 a.m. arrival time

Source: Kessel+Partner [2000]

Figure 2-6 Parameters for construction timetables of Rolling Shelf trains

As a result of the simulation, a set of 44 block-trains per day with 48 train operations were calculated, since 4 trains Hamburg-Berlin can make two roundtrips per day, whereas all other trains perform only one cycle per day. The assignment of the trains to the network is shown in Figure 2-7.



Source: Kessel+Partner [2000]

Figure 2-7 Assigned trains per day in the Rolling Shelf Network

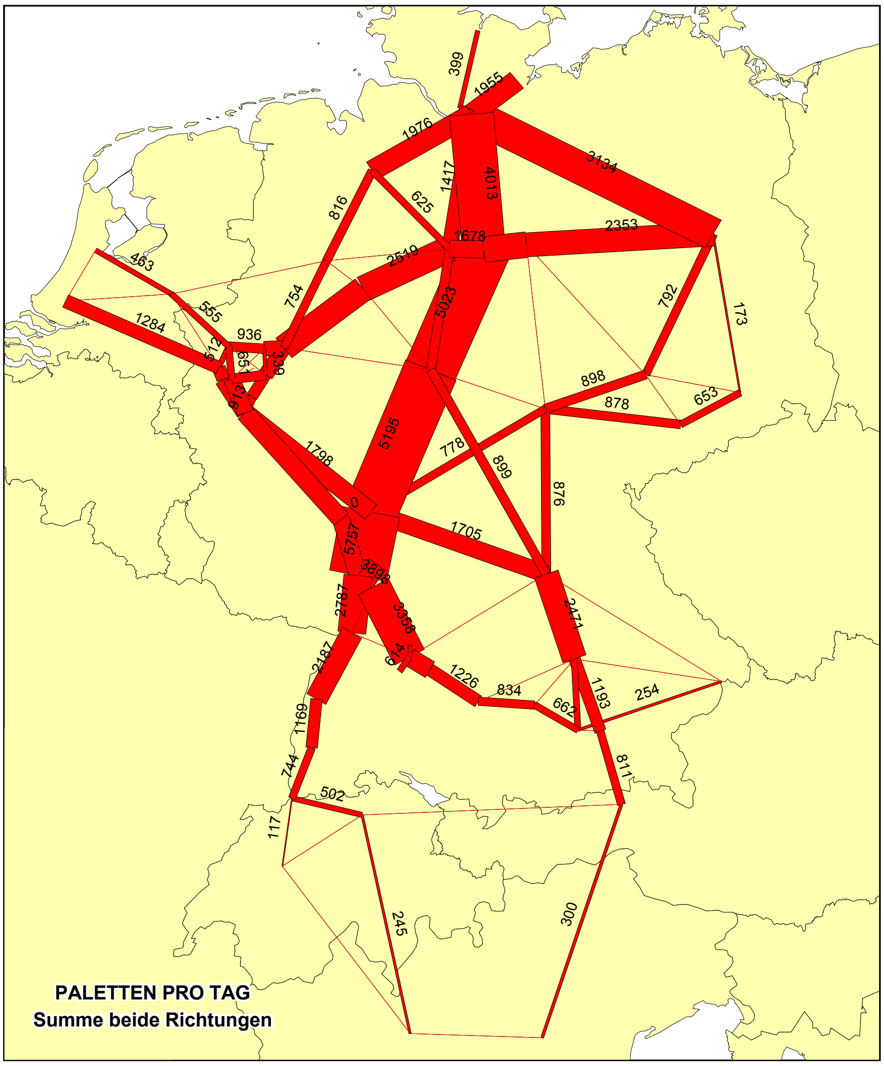
The next step after defining the optimal train sets and their timetable is the assignment of pallets to the trains. This allocation process should be done such that the best connection for the loadings is found and that the utilisation of the train capacity is optimised. In this simulation step, each pallet tries to find its best way taking into account the given timetable of trains and the given capacity of trains. The results of this final simulation step include:

- The capacity-utilisation of each train on each link;
- The transhipment volume in terminals– distinguished by incoming, outgoing and transhipped pallets;
- The daily time series of incoming, outgoing and transhipped pallets;
- Peak transhipment demand and number of trains, which have to operate in rendezvous terminals at the same time;

- Database for revenue calculation and economic evaluation of terminals, trains and the whole Rolling Shelf system.

2.6.3 Interaction between train operation and terminal efficiency

To give an overview of the pallet flows, the given pallet demand is assigned to the terminal network (see Figure 2-8).



Source: Kessel+Partner [2000]

Figure 2-8 Pallet flows per day on the Rolling Shelf network

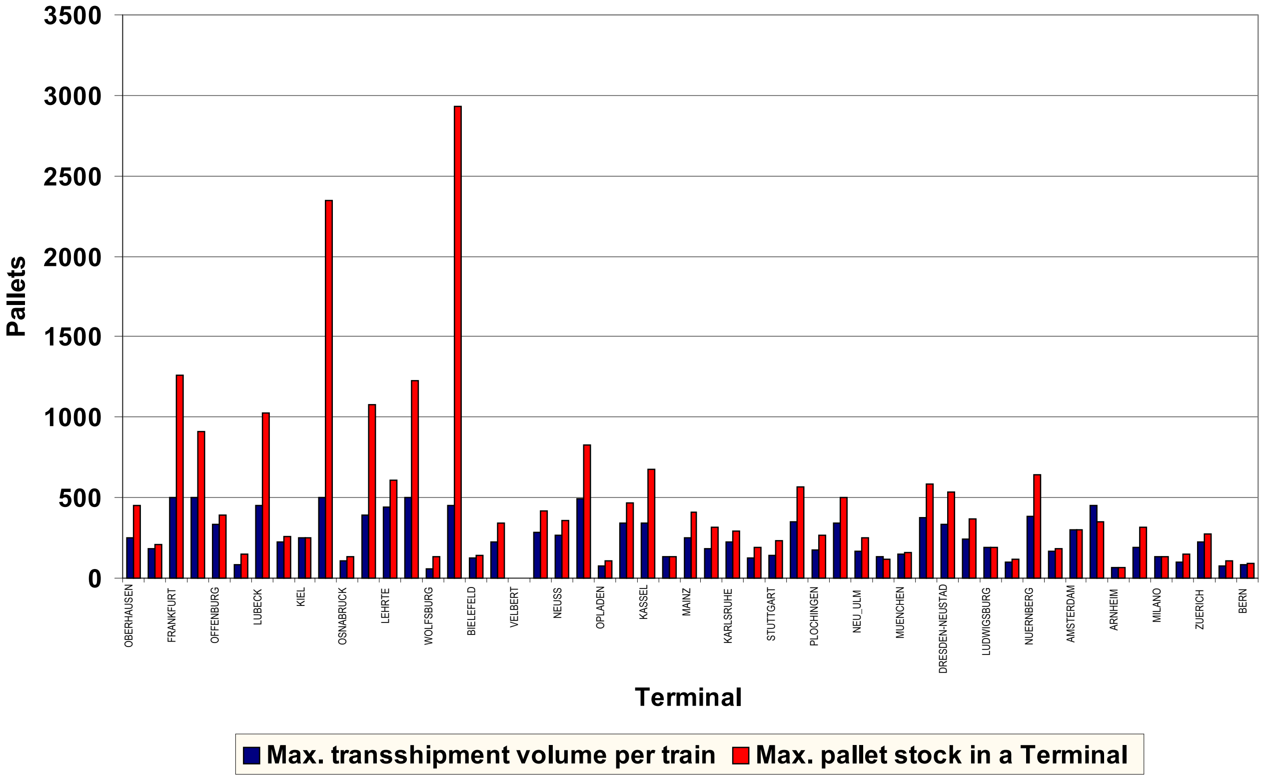
The main bundle of flows is on the north-south-axis from Hamburg via Mannheim to Stuttgart. The sum of both directions between Kassel and Frankfurt amounts to 5200 pallets – with a peak demand of nearly 5800 pallets per day. This corresponds with 12 trains per day, which requires fully loaded trains on this corridor. A high transport volume of nearly 3200 pallets per day is transported between Hamburg and Berlin.

Some 12 trains are required to process these loadings. Contrary to Hamburg, Amsterdam and Rotterdam, where seaport traffic is generated, the transport volume on the links to Milan and Verona (245 and 300 pallets per day) are relatively small. This is caused by the narrowly defined catchment areas: the considered demands are origin and destination flows of both regions only; i.e. these cities are not linked to other Italian traffic zones, so that both zones form the end of the transport chains.

The simulation of the Rolling Shelf train operations show the feasibility of the system. The prognosis and scenarios of passenger and other freight transport in the transport corridors in question showed that there will be enough track-capacity on the main railway-links in Europe for additional Rolling Shelf trains. Therefore the Rolling Shelf concept seems to be an attractive addition to the European transport market.

Required transhipment capacities

The final result of the simulation indicates the required transhipment capacity and the necessary capacity of pallet stocks. For all terminals the required ressources are shown in Figure 2-9.



Source: Kessel+Partner [2000]

Figure 2-9 Required transhipment capacities

The required transhipment capacity determines the terminal type that is needed. For example the Rolling Shelf terminals Frankfurt, Mannheim, Hamburg, Hannover and Cologne require a peak transhipment volume of nearly 480 pallets per train in the assumed transhipment time of 20 minutes (see parameters in Figure 2-6). This means that these terminals require an equipment with highly automated transhipment facilities (see for more details Part II Technical Concept). On the other hand, depending on origin and destination volumes and the timetable of trains, the terminals Hamburg and Berlin need large pallet stock facilities with storerooms of 2,300 and nearly 3,000 places respectively. This has influence on the investment costs and the profitability of the individual terminals.

PART II
TECHNICAL CONCEPT

3. Load units

Freight handling has been continuously standardised over the years. The standardisation of load units is a crucial condition for overall handling efficiency, which is one of the key features of the Rolling Shelf concept. Therefore, several load units have been considered and evaluated (from single pallets to small containers). Given the challenging logistics requirements of the Rolling Shelf concept two types of load units were identified as highly feasible. These are the specially developed system pallet (or triple-pallet unit; see section 3.1) and the Fiftybox (or small-container unit; see section 3.2).

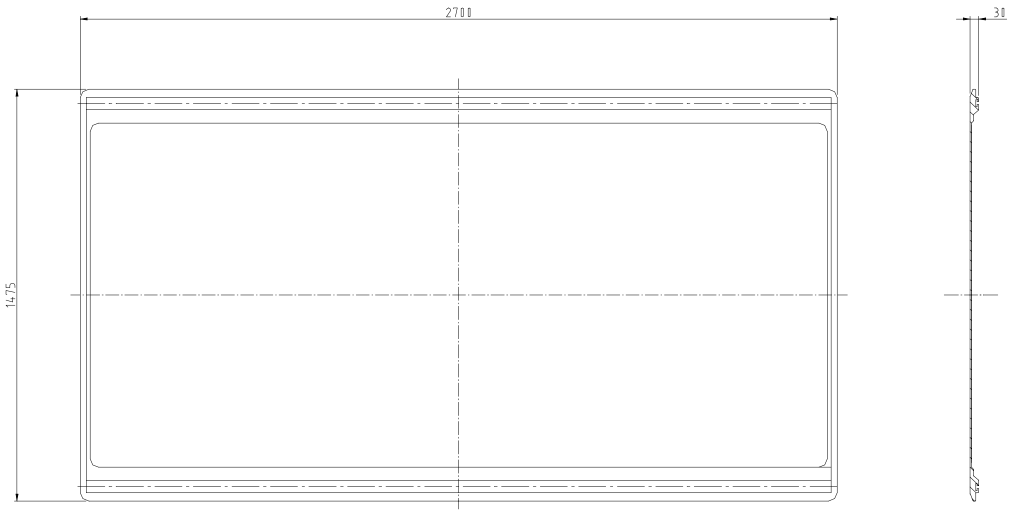
3.1 System pallet

The Rolling Shelf system pallet is designed as a loading aid accommodating palletised goods or for individual goods up to a size equal to the system pallet dimensions. It can accommodate up to three four-way flat Europallets (800x1200mm). Grid box pallets according to DIN 15155 can also be used.

The logistics features of the Rolling Shelf system pallet are comparable to the unit load devices (ULDs) used in air transport. The system pallet is made of aluminum, which ensures a very low tare weight. The floor of the pallet is a smooth sheet which is enclosed by a special section. This section stabilises the pallet, ensures proper guiding in the conveying system and is provided with grooves for safely securing the cargo elements on the pallet. Owing to its flat design the system pallet can only be conveyed on roller tracks.

The system pallet dimensions are (see also Figure 3-1) :

- Overall size (LxWxH) 2700x1475x30mm
- Loading surface (LxW) 2630x1230 mm



Source: Schäfer-Noell [2000]

Figure 3-1 Rolling Shelf system pallet

Securing the goods onto the system pallet has top priority in the Rolling Shelf system, in order to avoid damage to the goods or the wagons. The goods to be transported on the system pallet can be secured by using a net that is connected by hooks to the grooves of the system pallet (similar to air cargo ULDs).

Application in the Rolling Shelf concept

The Rolling Shelf system pallet is intended to carry conventional Europallets. The system pallet is used to form so-called triple-pallet units (TPUs) consisting of three conventional Europallets. The TPU can only be manipulated horizontally, and thereby guarantees easy, efficient and fast handling procedures.

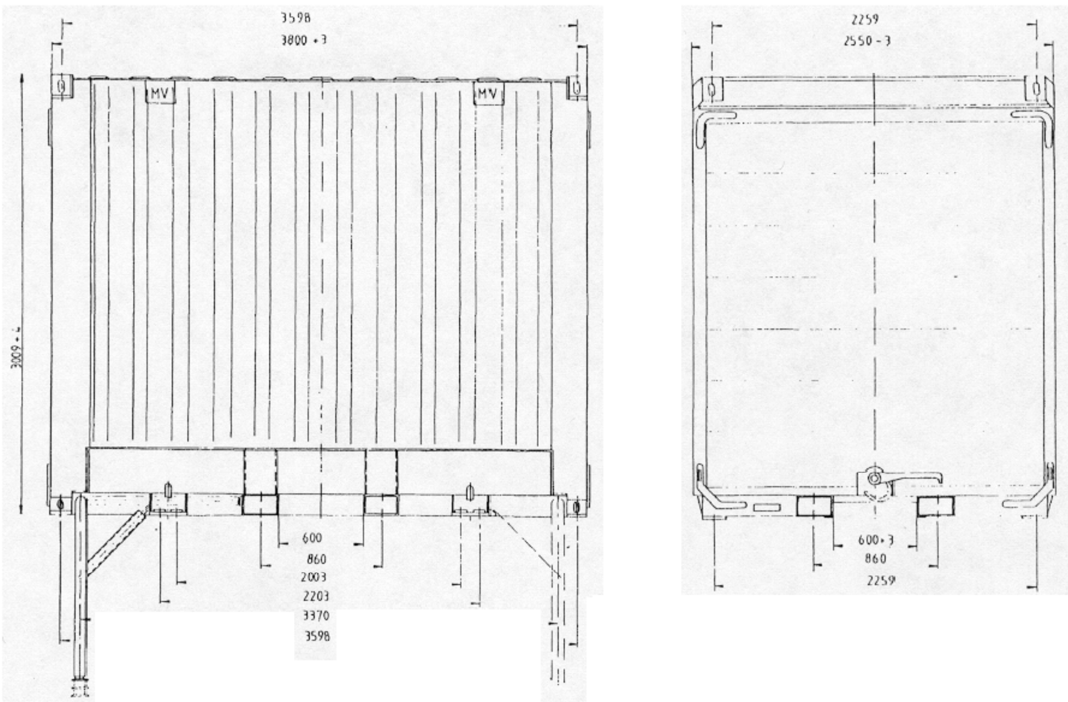
3.2 Fiftybox

A Fiftybox is a D-Class swap body (half the size of a conventional swap body), and is available in the dimensions of 3.70 and 3.80 metres (as opposed to the normal 7.45 (C745) and 765 metres (C765) swap bodies).

The logistics features of the Fiftybox are:

- Transportable on truck and trailer;
- Transhipment with fork-lift truck (accessible from all four sides);
- Stackable (double- up to triple-stack);

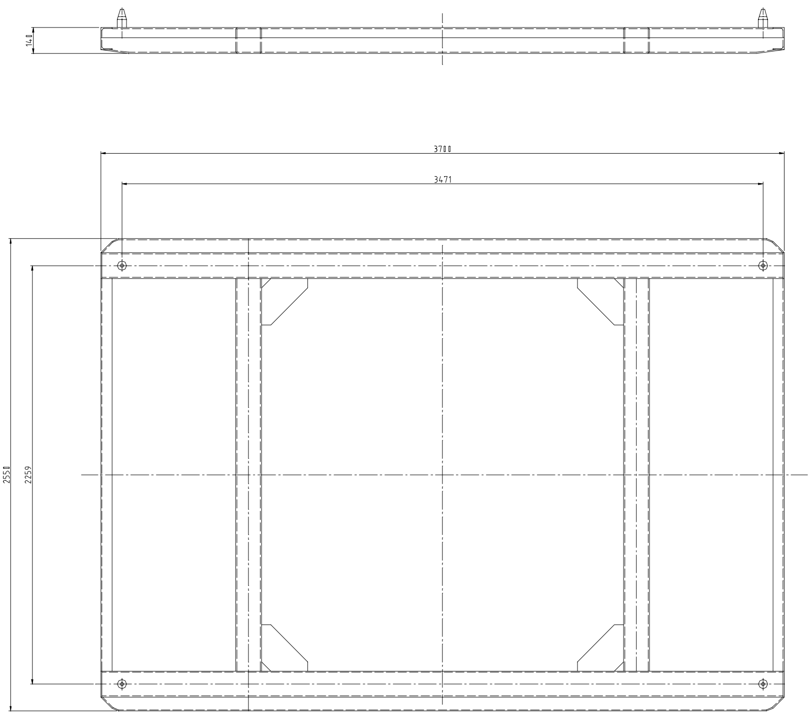
- Applicable in intermodal transport;
- Fiftyboxes can be equipped with sliding doors, enabling load shifting within and between Fiftyboxes;
- Collapsible supporting legs that allow (un)loading at common dock levels (1.2 to 1.3 metres);
- Loading capacity of D370 amounts to 8 Europallets, for D380 this is 9 Europallets.



Source : MV Lübtheen [1997]

Figure 3-2 Fiftybox D380 Dimensions

Fiftyboxes cannot be attached to current intermodal train wagons, as twist lock positions for containers below 20 ft are not yet available. The required adaptations to the existing wagons are however limited. Tests have been successfully executed to couple two Fiftyboxes into one swapbody equivalent unit, which allows common transhipment with topspreaders. The underside of the Fiftybox is not flat enough to be compatible with horizontal roller conveying systems. Therefore, a special adapter pallet was developed within the Rolling Shelf project (see Figure 3-3). This adapter pallet is used for transhipping and conveying the Fiftybox in the terminal premises (refer to Chapter 5 for more details).



Source: Schäfer Noell [2000]

Figure 3-3 Adapter pallet for Fiftyboxes and other logistics boxes

This adapter pallet comprises a low-distortion sectional steel frame with pick-up centering attachments for the boxes and, on the underside, appropriate running surfaces for the transport on chain conveyors and roller tracks. The adapter pallets remain in the conveying system and are not loaded on the train or the truck.

Application in the Rolling Shelf concept

The Fiftybox is intended for carrying parcels. The Fiftybox was selected as the most promising small container type by the large integrator involved in the Rolling Shelf project, based on its logistics features. This integrator currently actually uses logistics boxes with the dimensions of the Fiftybox. The Fiftybox system is further referred to as small-container unit (SCU).

4. Wagons and trains

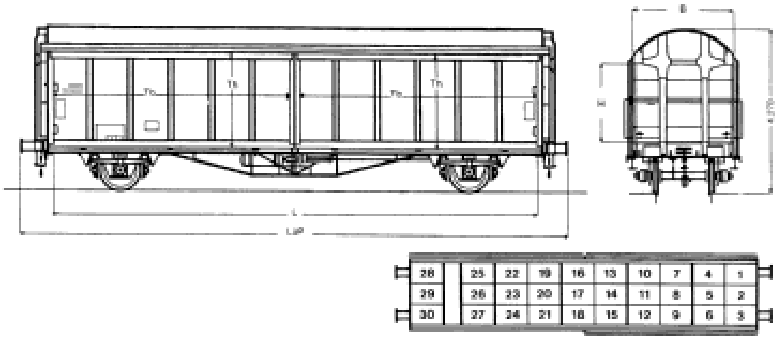
4.1 Current wagon technology

There are no rail goods transport wagons on the market with all features to perform the logistic functions needed within the Rolling Shelf system. However some wagons are on the market which offer selective functionalities. In this section, a brief summary is given.

During the late 1980s some research and development took place in the field of rail-based goods transport with 160 kmph. This development led to several results:

- Pilot and small volume production of Sgss-y 703 and Hbillss-y 307 at Talbot;
- Production of bogies for fast cargo wagons at Talbot;
- CargoSprinter, a diesel powered short train for carrying small containers at max 120 kmph. Mainly for maintenance reasons, the development was stopped. The introduction of TGV-Fret in France can also be viewed as a result of this activities.
- Starting with the project ExpressShuttle in 1996 UPS Transport started the development again. This train was designed to carry Fiftyboxes on container wagons. This project was stopped for reasons of non-availability of track assignments and disagreement on the role of the operator company. In early 2000 DB Cargo and DP started service according to very similar rules and with very similar equipment under the new name ParcelExpress.

In summary, the current wagon techniques used in rail transport of pallets may match the contemporary standards of fast transit times and fast transhipment, but are not available in sufficient volumes. Most of the presently used wagons are for example usually not allowed to operate faster than 120 kmph. Fast transhipment is also problematic; only the high-volume wagon types Hbillns and Hbbins (equipped with sliding walls: see Figure 4-1) are considered suitable for fast transhipment.



Source: Integral Verkehrstechnik [2000]

Figure 4-1 Hbillns freight wagon

The Rolling Shelf concept should unify characteristics of road transport (e.g. fast transit times, high coverage, flexibility through small load units) with the advantages of rail transport (economies of scale, environmental-friendly mode of transportation, opportunities of automated business processes). The main criteria for the future wagon technologies that need to be fulfilled in order to cash in on such a synergies include:

- High loading capacity combined with low tare weight;
- High transport performance combined with low fuel consumption (e.g. wagons suitable for double-stacked pallet loads);
- Capable of extremely fast (un)loading;
- Low loading height (using maximum loading height);
- High axle load capacity at 160 kmph;
- Modular vehicle concept with several combinations possible;
- Low noise level;
- Ease of operation;
- Low servicing needs;
- Low damage rates of freight.

First, the requirement of 160 kmph transit is a hard criterion, as fitting in freight trains on a rail network that is dominated by fast passenger trains is only trouble-free when this speed is guaranteed. Second, given the chosen pallet and container types, the transhipment is to be carried out horizontally. The wagons have to be equipped with roller beds, in order to allow fast horizontal (un)loading. Third, the loading doors of the wagons should be automatically operated in order to allow fast transhipment processes. Therefore, the following hard criteria with regard to transhipments were made within the project consortium:

- scheduled stopping period was set to 20 minutes at each station
- a train consists of maximum 10 wagons

4.2 Wagon specification

These requirements were used to draw up specifications for TPU and SCU wagons. The design studies for wagons in project phase I were made by project partner IVT; they are being used for reference only. In project phase II a sponsoring partner (Adtranz) in cooperation with UPS Transport and ÖBB provided the consortium with an alternative design, which is being used as design study and all technical as well as commercial data are based on this study.

The specification is made up of several aspects, each of which will be discussed in the following sub-sections.

4.2.1 Train speed

The speed of the train is a key feature for the Rolling Shelf transport concept. It allows the Rolling Shelf train to operate in accordance with long distance fast passenger trains. This condition again is vital for the allowance of operating the transport system on higher priority tracks. It was agreed to accept the higher maintenance costs, caused by this type of higher speed operation.

4.2.2 Weight of wagon

The tare weight of the wagon is determined by the operation conditions for driving a (relatively short) empty train and its aerodynamic conditions at maximum speed. The SCU wagons will therefore always operate with all container positions occupied. If a position is not filled, speed restrictions will apply.

The gross weight is determined by two factors: the maximum (static) load and the speed and brake profile of the train on the actual track. The maximum (static) load of the wagon will be 294 kN for the TPU wagon and 305 kN for the SCU wagon.

4.2.3 Rail gauge

The wagon will have to operate generally on all European rail tracks. However it is suggested to operate this system mainly in Austria, Germany, Northern Italy, Switzerland, The Netherlands, France and Belgium. Within the project consortium priority was given to the first five countries. This would allow to operate wagons within the given UIC gauge. For an introduction scenario of the Rolling Shelf system a local focus seems advisable.

4.2.4 International operation

It is assumed, that the new wagons will be ordered and offered for leasing by a European rail operator, not necessarily being operator of the Rolling Shelf system.

4.2.5 Loading area length

The loading area length is determined mainly by two factors: by the train loading capacity and by the required transhipment circumstances. In order to maximise the capacity of the train the gap between wagons should be as small as possible. A train concept with Jacobs bogies, offering shorter wagons with drive heads and more flexibility in drive designs was not considered as a commercially viable solution; the design was rejected during the design reviews. Mainly for cost reasons long wheel base wagon designs where selected. The wheel base selected was 16.700 mm for the TPU and 14.800 mm for the SCU wagon. This results into a required loading area length of 20.950 and 19.100 mm respectively.

4.2.6 Shock and vibration protection

The main cause of shocks affecting cargo and load units are shunting operations. Since no shunting will be done during transport operation, this effect can be largely ignored. Traditional spring suspension will handle shock and vibration resulting from regular train operation. Air suspension is considered important only for the transport of sensitive goods.

4.2.7 Loading platform

In this project, the loading platform was assumed to be flat. This is based on two arguments: manufacturing rationalisation effect for using the same base design for both wagon types, and the understanding that more in-depth efforts are needed for designing an “ideal” Rolling Shelf wagon. The height of the platform is in this design study primarily determined by the wheel diameter. In this project, a wheel diameter of 920 mm was selected for maintenance reasons. This resulted in a typical height of 1.060 mm for the loading platform.

4.2.8 Load position

The position of a load unit and a specific consignment within the wagon is part of an on-board tracing and tracking system. The data will be made available to a WAN, handling messages within the complete Rolling Shelf network. The wagon should function as a local content server.

4.2.9 Power supply

Power supply for the wagon operation will be provided by the classical locomotion system and auxiliary services and power sources on the train. Power supply for containers or wagon interior conditioning will provided aboard. The power needed to operate any loading and unloading function will be provided locally, after the train stops. The on-board services of the wagons with logistic content will be served from these sources only.

4.2.10 Load protection

The load protection covers the area of damage during transhipment and driving, theft and malfunctioning systems. The first level load protection includes a wrapping with plastic film or net, similar to air cargo. This will protect the load against the bulk of impacts. If a malfunction in a load bay occurs, manual operation of unloading must be possible. The first level load protection of load in small containers will be achieved by using protection methods widely known in truck transporting.

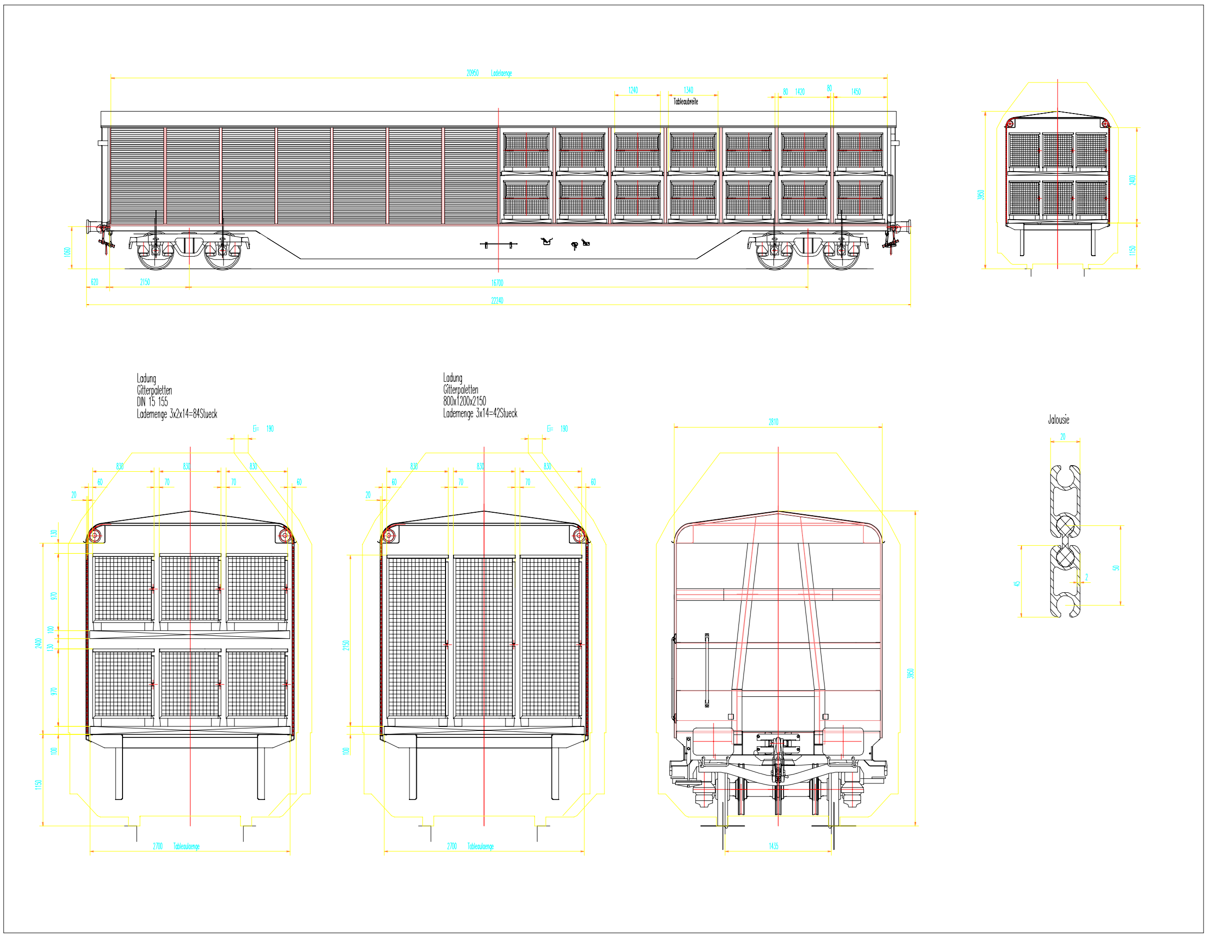
A classical form of load protection of incomplete palletised goods loads are air bags from the top ceiling, filling the free space between loads with a protection balloon. Theses methods were effective, however not accepted by the loading personnel. Their usage is very limited today. In a Rolling Shelf type of environment however, new efforts are recommended to apply these technologies if the need for additional means would occur.

4.2.11 Train length, less locomotion

The length of the train is determined by the length of the terminal transhipment length and the terminal’s transhipment performance needed. Within the scope of this project, an optimum length of 100 metres was determined. For an average terminal, an incoming train will stop along the terminal with the first half of the train. After performing all transhipment operations a push forward to perform the transhipment operation on the second half of the train is initiated. High performance terminals will have longer operating areas to avoid the time-consuming push forward operation.

4.3 TPU wagon

Data for the wagon itself are based on a design study (see Figure 4-2). The distribution of the load bay versions (alternative 1: 28 loading bays for TPUs with a maximum height of 1.100 mm, versus alternative 2: 14 loading bays for TPUs with maximum height 2.150 mm) within a given wagon can be determined according to actual transport requirements prior launching the train. In the cargo space of the TPU wagon there is a permanently installed shelf. It provides space for four system pallets with loads up to a height of 2 m and 18 system pallets with loads up to a height of 1 m.



Source: Adtranz

Figure 4-2 Rolling Shelf wagon for TPU transports

The weight characteristics of the TPU wagon is summarised in Table 4.1. The load data represent market data according to user requirements.

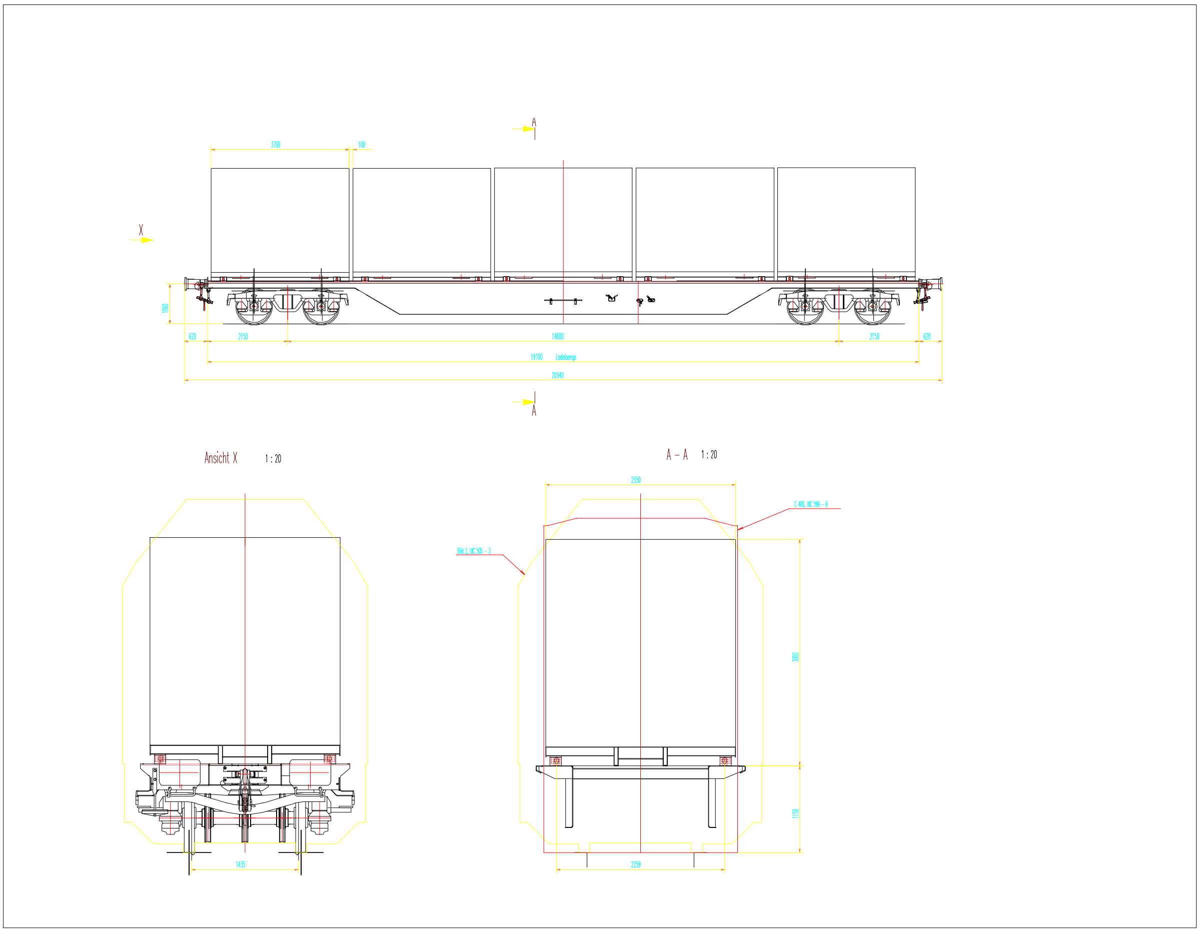
Table 4.1 Weight data of TPU wagon

Part	Type and # of units per wagon			weight / pcs [kN]	weight / wagon [kN]	
		Load unit alternative 1	Load unit alternative 2		Load unit alternative 1	Load unit alternative 2
Wagon weight data						
wagon base	customised for RS	1		100	100	
front shield	customised for RS	2		7,5	15	
Roof	customised for RS	1		20	20	
load bay equipment	customised for RS	14		1,5	21	
loading bay sliding door	customised for RS	28		0,5	14	
sliding door drive	customised for RS	4		2,5	10	
Bogie	UIC type 675	2		52,5	105	
Total wagon tare weight					285	
Load unit data						
Consignment load unit weight alternative 1 as example:	Pallet DIN 15 155	84		0,85	71,4	
Consignment load unit weight alternative 2 as example	Large box: 80x120x215 cm		42	1,5		63
TPU Triple Palet Unit	customised for RS	28	14	2	56	28
Total load units weight					127,4	91
Total wagon weight, inclusive load units					412,4	376
Net load data						
average load						
on load unit alternative 1:	maximum of all load units	84		3	252	
on load unit alternative 2:	maximum of all load units		42	7		294
Total net load					252	294
Total wagon gross weight, including load					**664,4**	**670**

Source: EveCo Software GmbH

4.4 SCU Wagon

The small container wagon carries five small containers (see Figure 4-3).



Source: Adtranz

Figure 4-3 Flat wagon for SCU transport (example with 5 Fiftyboxes)

The weight data below assume a small container length of maximum 3.700 mm, which is equivalent to a 10" container.

Table 4.2 Weight data of SCU wagon

Part	Type and # of units per wagon				weight / pcs [kN]	weight / wagon [kN]		
		Load unit type 1	Load unit type 2	Load unit type 3		Load unit type 1	Load unit type 2	Load unit type 3
Wagon weight data								
wagon base	customised for RS	1			100	100		
bogie	UIC type 675	2			52,5	105		
Total wagon tare weight						205		
Load unit data								
load unit weight, type 1	Fiftybox	5			19	95		
load unit weight, type 3	10 " container			5	14			70
Total load units weight						95	80	70
Load data								
average load								
on load unit type 1	maximum of all load units	5			61	305		
on load unit type 2	maximum of all load units		5		60		300	
on load unit type 3	maximum of all load units			5	56			280
Total net load						305	300	280
Total wagon gross weight, incl. load						605	585	555

Source: EveCo Software GmbH

4.5 Train configurations

Rolling Shelf always works with fixed block trains, i.e. no shunting on the way. Seven train configurations have been developed, with varying combinations of SCU and TPU. One can discern from Table 4.3 the efficiency and scale economies of the Rolling Shelf concept. Combined with additional logistics features such as fast transhipment and fast transit times, the Rolling Shelf concept will prove to be a promising alternative to road-only transport concepts.

Table 4.3 Used train configurations

	Train 1	Train 2	Train 3	Train 4	Train 4a	Train 5	Train 6
Number of wagons for SCU	1	2	4	6	7	8	9
Total number of SCU (5 SCU per wagon)	5	10	20	30	35	40	45
Number of pallets in SCU (9 pallets per SCU)	45	90	180	270	315	360	405
Number of wagons for TPU	9	8	6	4	3	2	1
Total number of TPU_{mix} (23 TPU per wagon)	210	187	140	93	70	47	23
Number of pallets in TPU_{mix} (3 pallets per TPU_{mix})	630	560	420	280	210	140	70
Total train capacity (pallets)	675	650	600	550	525	500	475

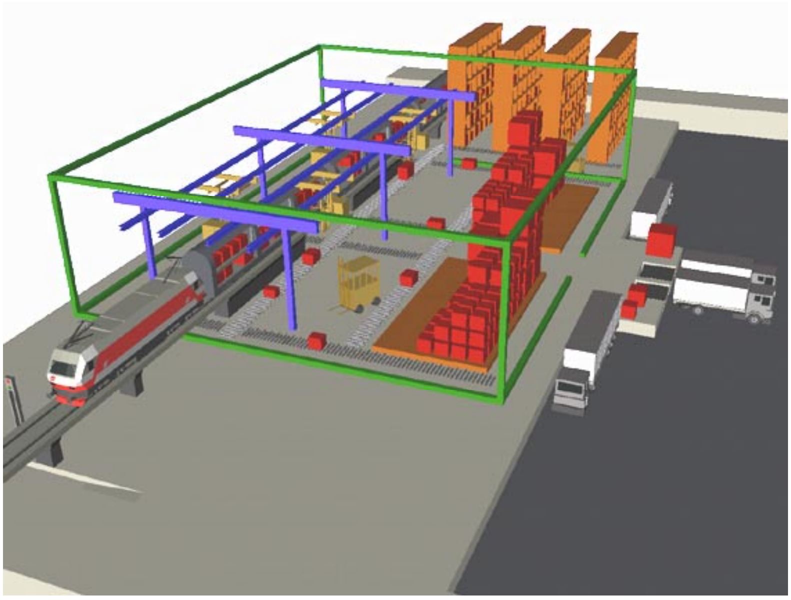
5. Terminals

5.1 Current terminal designs

To date, no terminal has been built with the full features of the required Rolling Shelf terminal. The key function of the Rolling Shelf terminal is the extremely fast transhipment of pallets between block trains and the handling/conveyor system, and vice versa. This function has to be developed, as no suitable technology is available for handling pallets in that order of magnitude and within a short time window of maximum 20 minutes yet. Most of the other required terminal functions exist in one way or the other.

- Rail track: the zone that is occupied by the block trains.
- Platform: zone where (un)loading takes place, and where short-term storage takes place.
- Temporary storage locations: where consignments just (un)loaded are kept (unpaid storage).
- Bulk storage location: all storage locations where longer term (paid storage)
- Truck loading docks: dispatch area where trucks arrive and leave.
- Supporting infrastructure: general functions that are needed to operate a terminal (e.g. office, lavatory).

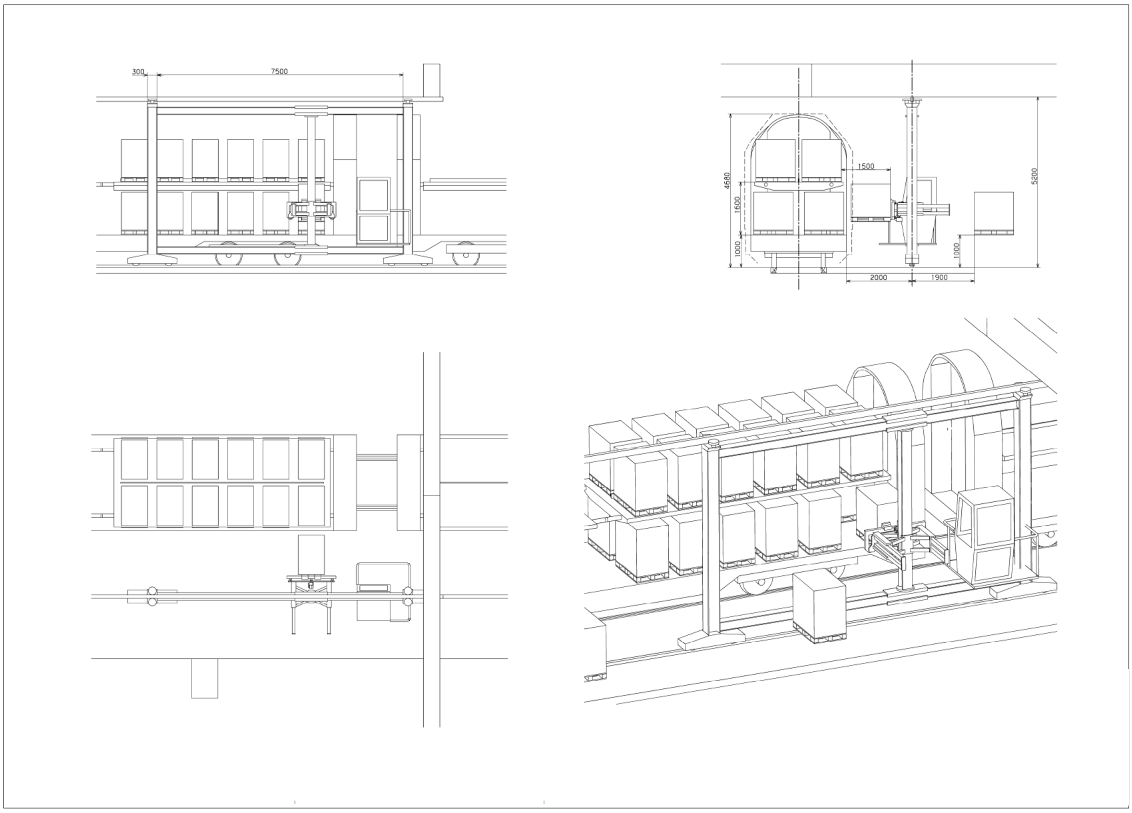
Integral Verkehrstechnik developed ten conceptual terminal designs (from complete manual transhipment by means of fork lift trucks to fully automated systems). The ten concepts can be seen as an evolutionary model: the low-cost manual terminal concepts is to be interpreted as a starting point, which can be expanded into high-performance installations. An impression of a high-performance terminal is shown in Figure 5-1.



Source: vr-architects

Figure 5-1 High-performance terminal concept

The designed manipulator for the fully automated terminal concepts is displayed in Figure 5-2. This design is basically an automated fork-lift installation that is capable of moving single pallets both horizontally and vertically.



Source: Integral Verkehrstechnik [1999]

Figure 5-2 Design of a manipulator for single-pallet conveying

This solution could be useful for smaller terminals. However, given the needed terminal performance (transhipping pallets of a full block train within 20 minutes at the most) a fully automated terminal concept is required for the larger terminal locations. However, the concepts based on single-pallet handling systems proved not to be feasible with regard to the challenging performance targets of the Rolling Shelf concept. The investments involved would be too high compared to the performance offered. Utilisation of the terminal premises would have to rise to implausible levels, in order to reach profitable operations. This dilemma was solved by a completely new transhipment concept. The onset of this new approach consisted of the idea to manipulate consolidated pallet units and small containers instead of single pallets.

5.2 Innovative terminal design

This idea was elaborated by project partner Schäfer-Noell. The system that was developed is to be suitable for pallet-packet cargo units or pallet-related containers. It can be characterized by a high degree of automated goods transfer, thus ensuring that the transfer costs can be reduced and the efficiency of the overall system increased.

5.2.1 Basic assumptions for innovative design

- The distances between the Rolling Shelf network junctions should be between 100 and 200 km. Within this network different types of terminals provide the interface between road and rail transport.
- Cargo to be transported will be palletised goods, small containers or parcels.
- Pre- and end haulage will be carried out by ordinary truck service.
- Within the terminals, goods will be handled by fully automated conveying systems, loading and retrieval devices.
- Small consignments of pallets and less than one container consignments represent the bulk of Rolling Shelf transportation potential.
- The Rolling Shelf System has to provide a “just in time”, fast and reliable transportation for various demands.
- Transportation costs should not exceed the costs for road transportation.
- Goods must be easily monitored along the supply chain.
- It must be possible to easily manage the loading space within the network system. An “ad on-” or “alternative” just-in-time booking of goods must also be possible.
- The Rolling Shelf Terminals have to be close to the consignor and consignee; pre- and end-haulage will be carried out with low cost local traffic trucks.
- Trains will run on fixed time tables.
- The Rolling Shelf System has to be an open system, accessible to all market parties.

5.2.2 User requirements and specification

The Rolling Shelf System is designed for long distance transport (>200 km) of pallets and containers by rail. The system is intended for the LTL shipment market segment. This means that a transportation using the Rolling Shelf System competes, both with respect to delivery times/transportation speed and the reliability, with road transport. This results in the different requirements to be met by the Rolling Shelf Terminal.

A Rolling Shelf terminal performs both the function of a goods collection and distribution centre and the function of a change-over station for goods. Pallets or truck part-shipments are delivered from the neighbourhood (distance from terminal: 50 to 80 km) to the terminal by truck. If necessary, the goods delivered are stored temporarily until they are loaded on the Rolling Shelf train which transports them to the terminal which is closest to their destination. There the goods are loaded on trucks again and shipped to their final destination.

On the way to the destination terminal it may be necessary for the pallets to be reloaded on (an)other Rolling Shelf train(s). For this purpose buffer capacities must be provided at the terminal in order to temporarily store the pallets during the change-over procedure.

The control of the material flow within the terminal and the administration of the temporary pallet storage capacity is performed by a terminal administration computer installed at each terminal. This computer communicates with the overriding "Booking System“. The overriding computer system informs the Rolling Shelf terminal about incoming pallets, the corresponding storage place in the Rolling Shelf train and the destination. The pallet data are captured in the system via a barcode. This is done either when the pallets arrive at the Rolling Shelf terminal or at the consignor's premises.

A Rolling Shelf train consists of wagons for transporting system pallets and wagons for transporting small containers. The order in which the different wagons are arranged along the train can vary as well as the direction the train enters the terminal. This means that handling of both system pallets and small containers must be possible along the whole platform. In return, the material flow for making the goods available for train loading and transfer to the buffer storage facility/truck loading station must be designed to meet this requirement.

Another main prerequisite for planning the terminal is the definition that the train can only be loaded/unloaded from one side. Loading and unloading the train from two sides would increase the number of pallets which can be transshipped, but this would involve technically complex and expensive measures in order to cope with the increased material flow within the terminal. A possible expansion of the terminal in order to load/unload two or more trains at the same terminal at the same time would be more difficult and expensive if the trains were to be loaded/unloaded from both sides. Three Euro pallets can be placed next to each other in the Rolling Shelf wagons for transport. Loading/unloading the train from one side requires the use of a base pallet (system pallet. Three Euro pallets or two industrial pallets are placed on one system plate. Further, the system plate can be used for transporting "loose packets". Storage capacity is to be provided at the terminal for the system pallets which remain in the Rolling Shelf system.

In summary, each of the terminals set up for the Rolling Shelf project is designed for the following basic functions:

- Transfer of arriving pallets and Fifty Boxes from the trucks into the terminal;
- Temporary storage capacity for pallets and Fifty Boxes handled at the terminal;
- Devices for consolidating the Rolling Shelf system pallet and the Fifty Boxes;
- Equipment for transporting the system pallets / Fifty Boxes within the terminal;
- Equipment for transhipment of system pallets and Fifty Boxes to the train;

- Transfer of outgoing pallets and Fifty Boxes from the terminal to the truck;
- Terminal administration system.

5.3 Terminal types concepts

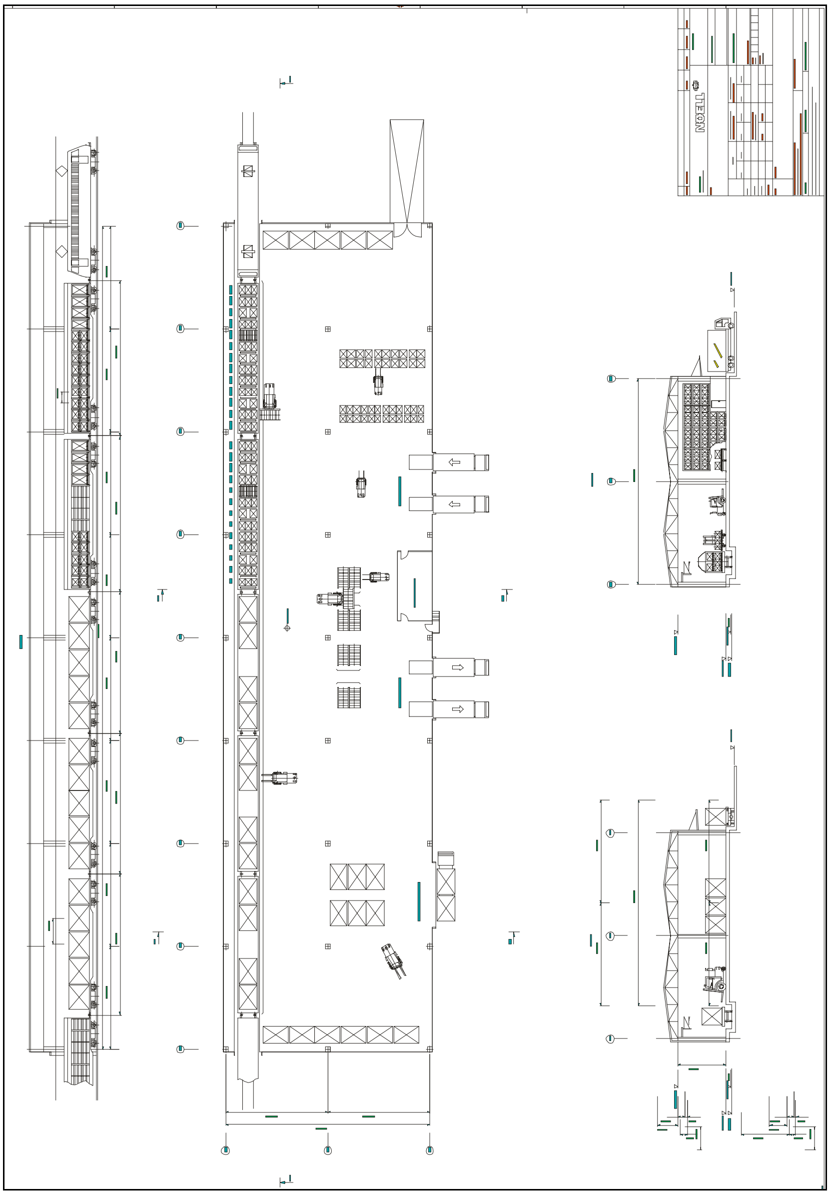
For the operation of the Rolling Shelf system 4 different terminal types with specific features and specific equipment and facilities have been developed by Schäfer-Noell. The terminal capacities range from 100 (manual or partly automated) up to over 2000 (fully automated) pallets per day.

Depending on the logistic requirements of the regional transhipment volumes, the terminals can be equipped with a fully automated warehouse and terminal administration system. A comparison of different transportation demands per region and the possible available terminal capacities has shown that about 85% of the locations within a Rolling Shelf network will require medium capacity terminals (terminal type III), 10% high capacity terminals (terminal type III, two trains) and 5% low capacity terminals (terminal types I and II).

5.3.1 Terminal I Low Capacity

Terminal I was developed as a "low cost“ version of a Rolling Shelf terminal. In order to keep the investment costs down almost no automation systems were used. For this reason the transhipment performance of this terminal is very low. This design concept was based on the idea to provide a terminal with all main components at low costs for a first pilot realisation of the Rolling Shelf system (see Figure 5-3).

Here the complete material flow within the terminal as well as the loading/unloading of the Rolling Shelf trains is done using stackers (fork lift trucks).



Source: Schäfer-Noell [2000]

Figure 5-3 Terminal Type I

5.3.2 Terminal II Medium Capacity

Terminal II is the first terminal with which a Rolling Shelf system can be operated practically. The trains are loaded/unloaded fully automatically using specially developed handling machines. These handling machines travel parallel to the train on their own track. On the side opposite the train handling and storage areas are provided for both system pallets and Fifty Boxes.

The pre-provision of the pallets to be handled ensures an accelerated loading/unloading of the train and thus a shorter stop time and a higher pallet transhipment performance. The transport of the system pallet from the consolidation to the provision area at the train is done using roller and chain conveying systems.

For the temporary storage of the pallets between truck unloading and train loading or vice versa a fully automatic high bay storage rack system with a capacity of some 1000 pallet spaces is available as well as the corresponding conveying systems. The transfer of the individual pallets between the truck and the buffer storage facility and between the buffer storage facility and the consolidation on the system pallet or in Fifty Boxes is done using stackers. The handling of the Fifty Boxes within the terminal and the loading and unloading of the trucks is also performed using appropriate stackers.

5.3.3 Terminal III High Capacity, 1 Train

In order both to be able to tranship a high number of pallets and to cope with a high train frequency in the terminal, the degree of automation was increased compared to Terminal II.

The number of handling machines at the train was increased to 5 units to match the number of wagons. A further increase of the number of handling machines would not make sense, as the devices would interfere with each other. Further a second provision line was installed, also equipped with handling machines. The second line ensures a higher throughput of system pallets and Fifty Boxes. The main reason for this expansion was the requirement to make the whole number of system pallets and Fifty Boxes available for a half train and to ensure the material flow of the unloaded pallets in the terminal.

The handling of the Fifty Boxes in the type III terminal is performed using conveying systems in the same way as in the case of the system pallet handling, That means that after the consolidation of the boxes the material flow for the provision at the train is performed automatically. The temporary pallet storage capacity and the number of truck docking stations was adjusted to the higher transhipment performance of Terminal III.

5.3.4 Terminal III High Capacity, 2 Trains

According to the studies carried out by Kessel & Partner on the break bulk cargo figures some terminals are frequented to such an extent that it will be necessary to clear two trains in the terminal at the same time.

For this application a second conveying system (corresponding to the first one) was designed for the second track. The high bay storage rack system for temporary storage of the pallets was adapted to the increased pallet transhipment. It is now arranged in the middle of the terminal and ensures the material flow to both tracks.

The centred arrangement of the terminal is based on the following considerations. The idea still was to avoid that the automated material flow is directed across the tracks. With a layout of the terminal with a centred arrangement of the tracks, and considering the above, the incoming trucks would already have to know or be informed on which side of the terminal they will be unloaded. Since some of the goods are captured by the terminal administration computer only after they have arrived, it is not always possible to direct the trucks accordingly.

A centred arrangement of the terminal requires that the truck traffic crosses a track. This can be realized by means of an overpass or an underpass or by means of a level crossing. This solution seems to be more cost-efficient than an automated material flow with the corresponding conveying equipment.

The arrangement of the truck loading doors was adjusted to the layout of the terminal between two tracks. The conveying systems on each side of the terminal have the same design as the conveying system of Terminal III for one train.

A set of 3D views of a Terminal III High Capacity for serving 2 trains simultaneously is given in Appendix 1.

5.4 Information system

The pallets/containers are delivered to the terminal either by trucks at the goods input doors or by train. The information system is different for both ways of entry.

5.4.1 Delivery by truck

If the pallets/containers are labelled at the supplier's premises already, and the TAS is informed about these pallets/containers by the overriding HOST system, the delivered pallets can be made available in the corresponding goods areas without a goods input function having to be performed, as the TAS already has all the information about the delivered pallets/containers it needs.

If the pallets/containers must be labelled at the terminal, they cannot be forwarded without a goods input function being performed.

The goods input function involves the following steps:

- Provision of the unloaded containers/pallets in defined goods input areas.
- Labelling of the containers/pallets
- Scanning of the label using a mobile terminal and linking of the pallet to the required additional information (goods input information by HOST).

After this linking the TAS has all the information required for the further processing.

5.4.2 Delivery by train

The information about the pallets/containers delivered by train is transmitted to the TAS by the HOST in advance as a "Train Occupation Plan". In this way the TAS has all the information about the incoming pallets/containers (space requirements, content) it needs for unloading and processing them.

The cargo was already labelled during the loading procedure at another terminal.

5.5 Storage systems

5.5.1 Pallet storage

The stacker driver scans the pallets placed in the goods input area and captured by the TAS, and the information about the corresponding destination (in this case the high bay storage rack) given by the TAS is displayed on the mobile stacker terminal. An active assignment via the stacker control system according to several optimising criteria cannot be used for reasons of accessibility to the individual pallets.

After placing down the pallet on the conveying system, the driver acknowledges the transport job and the conveying system takes over the further transport.

At the I-Point the following criteria are checked automatically prior to storage:

- Contour check;
- Checking of pallet for damage;
- Identification of pallet by scanning the barcode;
- Comparison with goods input information.

In case one of the above-mentioned criteria is not met, the pallet is rejected and removed, stating the reason for the rejection. When the I-Point check is successful, the TAS assigns a storage space in the high bay storage rack and takes over, together with the subordinated control level, the control of the material flow until the pallet reaches its destination.

5.5.2 Container storage

As there is only one destination for a captured container (i.e. direct forwarding to the conveying systems) the stacker driver can pick up the container without having to scan it first and place it on the conveying system for further transport.

Prior to further transport the following criteria are checked automatically at the I-Point:

- Contour check
- Container identification by scanning the barcode
- Comparison with goods input information

In case one of the above-mentioned criteria is not met, the container is rejected and removed, stating the reason for the rejection. When the I-Point check is successful the TAS will determine whether the container is to be buffered in the temporary storage facility or directly loaded on a train standing by. Before the container can be loaded on the train, the "Train Loading Plan" must be transmitted from the HOST to the TAS via an interface which is yet to be defined.

5.6 Warehouse storage and retrieval devices

The floor-travelling NORESTA S/R machine (storage and retrieval machine) is designed for storage and retrieval of complete freight units. The machine travels on a floor rail embedded in the foundation and is guided by a guide rail installed in the top area of the rack. Storage and retrieval in/from the bay is done using telescope forks.

The NORESTA S/R machines are designed according to the German "Guidelines on S/R Machines and Systems for Storage Rack Control", the applicable specifications of the Social Insurance Organizations against Occupational Accidents as well as the relevant DIN-Standards, FEM-Regulations and VDE-Guidelines.

5.6.1 High bay storage rack control

The control system described in the following is used for automatically operating a high bay storage rack. Owing to its modular design it is particularly suitable for different degrees of automation of a plant. It can be used both for the control of a simple S/R machine with manual command input as well as for high bay storage racks with several S/R machines and complex control functions, including the communication with a central computer.

This is achieved by adding the corresponding hardware and software modules to a basic system. Depending on the specific requirements of the individual applications, the control devices only differ with respect to the different composition of the modules.

Target control

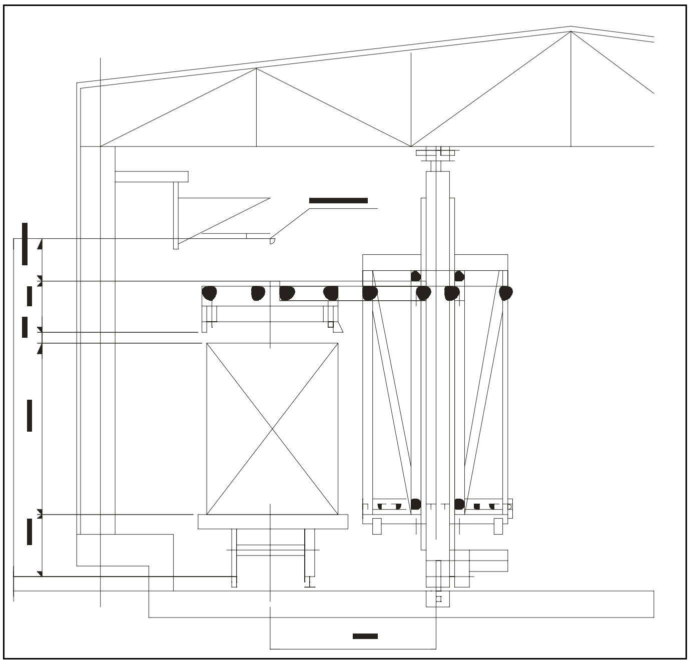
The S/R machine is provided with its own positioning control, which enables the S/R machine to store, retrieve or restore a pallet independently. A Simatic S7 series control is used for controlling the S/R machine. The data to be transmitted contain all the information required for the control functions of the S/R machine.

Positioning

The positioning in horizontal and vertical direction is performed via a position target control system. In horizontal direction a laser-type distance-measuring device detects the position. In vertical direction the position is detected by an absolute value encoder. With these position measurement systems the length and height of the rack are divided, depending on the resolution of the encoder, in a millimetre grid, and any position, which can be approached, is assigned a defined absolute value. The absolute position values are saved in the positioning control system.

5.7 Terminal loading and unloading devices

The floor-travelling NOHAGE handling machine is designed for storage and retrieval of system pallets and small containers (Fifty-Box). The machine travels on a floor rail embedded in the foundation and is guided by a guide rail installed in roof top area. Storage and retrieval of the small containers is done using telescopic pick-up equipment. The system pallets are stored and retrieved by means of a movable roller track and a friction drive (see Figure 5-4 for details).



Source: Schäfer-Noell [2000]

Figure 5-4 Combined System pallet and Fifty-Box handling system concept

5.7.1 Hoisting platform

The hoisting platform is guided by anti-friction supported rollers at the guide rails of the poles. It is designed as a welded construction in order to keep the weight as low as possible. It accommodates the load pick-up devices for the system pallets and the small containers. In addition to that it accommodates an emergency control panel and the hydraulic unit for moving the system pallet displacement frame and the small container interlocking.

5.7.2 Small container load pick-up device

For handling the small containers the telescope equipment is suspended at the upper part of the hoisting platform. Proper guiding of the moving prongs is ensured by anti-friction pressure rollers and smooth guide rails. Telescoping is possible on both sides via a gear motor and a toothed rod/chain system.

To pick up a small container the handling machine is positioned in front of the container. The telescoping device moves above the container and the hoisting platform is lowered. Now, the locking studs move into the corresponding holes of the containers (standardized container corners). By way of turning the studs the container is firmly connected to the telescoping device. Now the hoisting platform and the container is taken out of the wagon or the conveying element. After the telescope has returned to its center position, the handling machine can transport the load to its new destination and hand it over accordingly (opposite order of work steps).

5.7.3 System pallet load pick-up device

A displacement frame is bolted to the lower part of the hoisting platform for handling the system pallets. An electrically driven mobile roller track (SSI conveying system) is installed on this frame, running on C-rails and equipped with so-called utility rollers. This conveyor can be displaced laterally via a double-action hydraulic cylinder so that the gap between the handling machine and the wagon/conveying element is bridged. In addition to that the cylinder provides the required pressure of the friction wheels (arranged on both sides) on the counter roller of the wagon or the stationary conveying element. This pressure is required for the transmission of the driving torque to the load to be moved. The driving torque itself is generated by a gear motor connected to the friction wheels.

To take over a system pallet, the handling machine is positioned in front of it. The roller track and the friction wheel drive are laterally moved to the pallet to be taken up. At the same time the friction wheel drive and roller track drive are switched on. The friction wheel drive transmits the torque via a rubber wheel to the rollers of the non-driven roller tracks in the wagon or on the conveying elements. In this way the system pallet is moved on the hoisting platform of the handling machine. The handling machine now transports the load to the new destination and hands it over there again. With this method no time-consuming hoisting of the complete hoisting platform is required, which results in short cycles and thus a high transshipment rate.

The roller tracks are driven by the handling machine via a friction wheel drive. The roller tracks are designed in the same way as the roller tracks in the TPU wagon.

5.8 Transshipment system control

The control system is used for automatically operating a transshipment system. Owing to its modular design it is particularly suitable for different degrees of automation of a plant. It can be used both for the control of a simple S/R machine with manual command input as well as for a transshipment system with several handling machines and complex control functions, including the communication with a central computer.

5.9 Aisle equipment

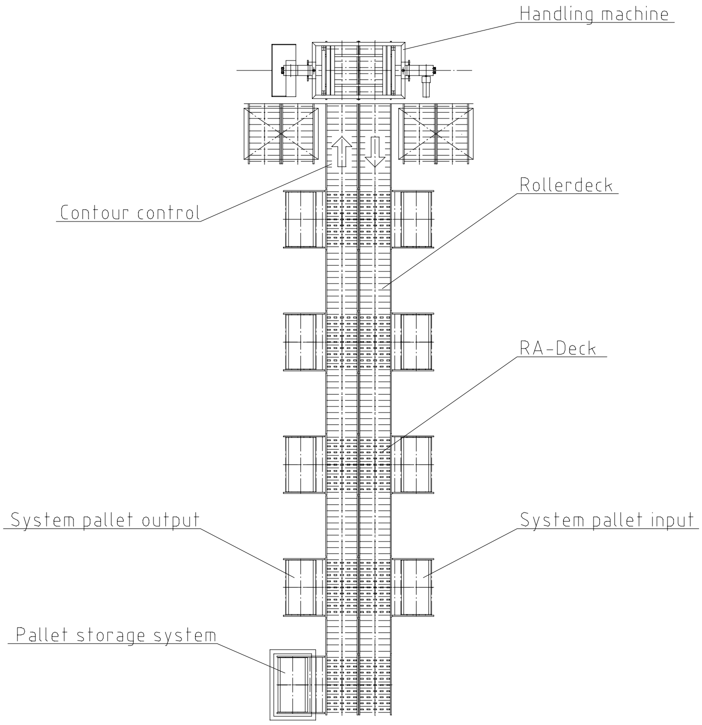
The handling machines travel on type UIC 60 rails. The length of the track depends on the terminal type. The rails are fixed using suitable, proven rail installation systems installed in a trench. After alignment the rail chairs are grouted with non-shrinking mortar. The trench is filled up to floor level using in-situ concrete. In this way crossing the rails is possible (emergency operation using fork lift trucks).

5.10 Conveying devices for system pallets

In the terminal the system pallets are handed over by the handling machine to the conveying system. From here they are conveyed on roller tracks to the unloading stations via RA decks (see Figure 5-5). At the unloading stations the load is picked up from the system pallets using fork lift trucks.

The empty system pallets are returned to the main conveying system and conveyed to the loading stations or to the empty pallet storage facility, where pallets which are not needed at the moment are stored temporarily.

At the loading stations new loads are placed on the system pallets by fork lift trucks and the loaded pallets are transferred to the handling machine.



Source: Schäfer-Noell [2000]

Figure 5-5 Conveying systems for system pallets

5.10.1 Roller tracks

The roller tracks are used for horizontal transport of the system pallets. The system pallets are conveyed on driven carrying rollers, with the drive being a tangentially acting chain drive. The roller chain runs on a replaceable plastic rail and leads, via anti-friction supported deflection rollers, to the tensioning device and the electric drive unit.

The carrying rollers, equipped with a chain wheel on one side and a galvanized roller shell with a continuous, anti-friction supported axle, are bolted to the supporting bars. The chain, chain wheels and deflection rollers are provided with guard plates to avoid unintentional contact. Lateral guide rails ensure that the system pallet remain on the roller track during the transport.

5.10.2 RA-Deck

The RA deck is used for 90° transfer of the system pallets upstream of the loading and unloading stations.

5.10.3 Empty pallet storage facility

The empty pallet warehouse, which is integrated in the conveying system, is used for temporary storage of empty, currently not needed system pallets. The system pallets which enter the storage facility via a roller track are stacked by means of an electrically driving hoisting and grabbing system. When system pallets are needed they are taken individually from the storage facility and travel via the roller track to their destination.

The capacity of the empty pallet storage facility can be specified according to the size of the terminal.

5.10.4 Loading and unloading station for system pallets

Depending on the size of the terminal a certain number of loading and unloading stations is integrated in the system pallet conveying system. Here, loaded Euro or industrial pallets as well as non-palletised goods are loaded on or taken from the system pallet by means of fork lift trucks, and the load is secured.

The loading and unloading stations consist of a roller track with long carrying rollers, which convey the system pallet laterally. A mechanical end stop protects the system pallet against falling down. Lateral guide rails ensure that the system pallets remain on the roller track during the transport.

5.11 Conveying system for Fifty Boxes and other small containers

In the terminal, the boxes and other small containers are handed over to the heavy load conveying system by the handling machine. The containers are put down on a hydraulic scissor-type elevating platform which lowers them to the conveying system level. From here they either travel, via chain conveyors, eccentric hoisting stations and roller tracks, to the loading stations or they are made available at the fork lift truck transfer point for loading the trucks. At the unloading stations the load is taken out the boxes using fork lift trucks or manual elevating trucks.

The empty boxes are now returned to the main conveying loop and conveyed to the loading stations or to the fork lift truck transfer point. Boxes which are not needed can be temporarily stored in the terminal. The NS-Cargo-Boxes and other small containers must be placed on a special adapter pallet when they enter the conveying system, as their bottom is not suitable for direct conveying. The adapter pallets remain in the conveying system and are temporarily stored in a special pallet storage facility when they are not needed.

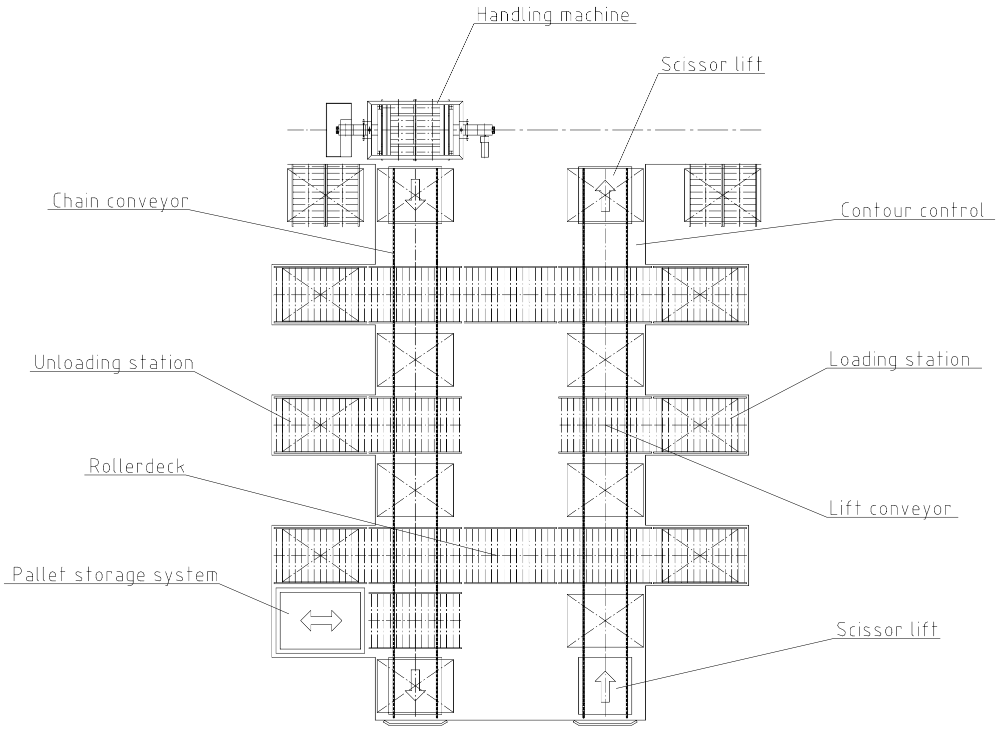


Figure 5-6 Conveying systems for small containers

The chain conveyors are used for horizontal transport of the load units. The boxes travel on two driven chain lines. One chain line is directly driven by a three-phase drive. The second line is driven via a transfer shaft. The roller chain lines run on replaceable plastic rails to the tensioning device and the driving unit.

5.11.1 Roller track

The roller tracks are used for horizontal transport of the load units. The double-chain wheels are connected to each other with roller chains.

5.11.2 Hoisting station

The hoisting station is used for 90° conveying of load units.

5.11.3 Scissor-type elevating platform

At the transfer points from the conveying system to the handling machine and the fork lift trucks, hydraulic scissor-type elevating platforms equipped with chain conveyors are used for transferring the boxes to the different levels.

5.11.4 Loading and unloading stations for boxes

Depending on the size of the terminal a certain number of loading and unloading stations is integrated in the box conveying system. Here, the Fifty Boxes or the other containers placed on the adapter pallets are filled or unloaded.

5.11.5 Adapter pallet storage facility

The adapter pallet store, which is integrated in the conveying system, is used for temporary storage of empty, currently not needed adapter pallets. The adapter pallets which enter the storage facility individually via a roller track are stacked by means of an electrically driven hoisting and grabbing system.

5.11.6 Conveying system for pallet buffer store

Goods arriving at the terminal packed on Euro and industrial pallets are temporarily stored in the high bay storage pallet rack until the train or truck for the transport to their destination is available.

PART III
ASSESSMENT AND DISSEMINATION

6. Economic feasibility of the Rolling Shelf concept

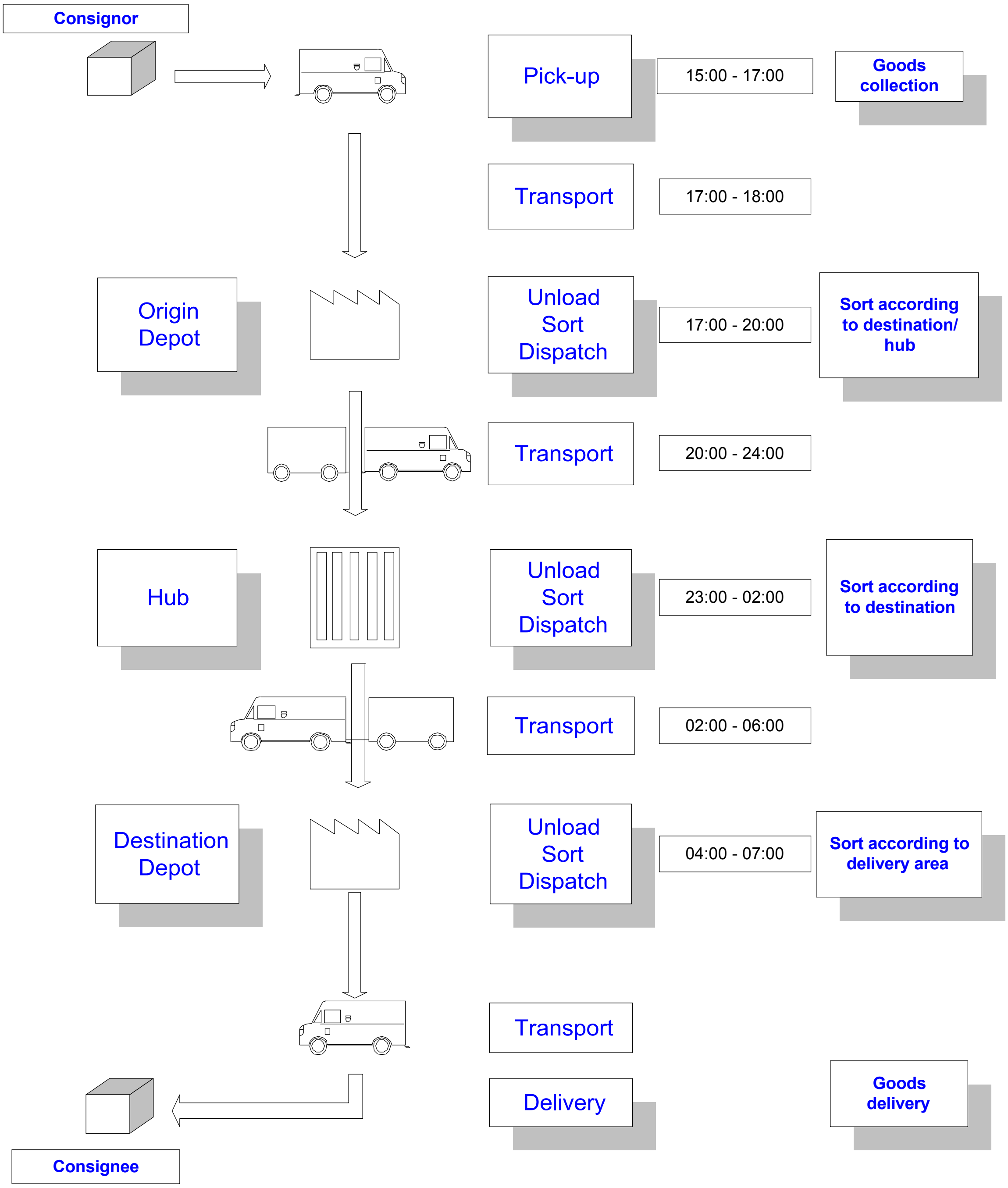
This chapter contains two business studies to determine the economic feasibility of the Rolling Shelf concept as developed in the previous chapters. First, a case study for the integration of the Rolling Shelf concept into the network of a large integrator is carried out by EveCo Software GmbH. This study confirms that the Rolling Shelf concept serves a practical purpose and makes business sense (refer to section 6.1). The second business study, performed by Kessel+Partner involves a calculation of a profitable timetable for pallet transports on the corridor Amsterdam-Milano. The required terminal capacities and the optimal number of block trains for this corridor are determined in section 6.2. Finally, the general profitability is calculated for the trains operating on the mentioned corridor in a study by EveCo Software GmbH.

6.1 Opportunities Rolling Shelf in integrator network

6.1.1 Typical transport process

The basic characteristics of an integrator network are a hub-and-spoke structure, partly highly concentrated transport volumes and above all fast and reliable door-to-door delivery times. Transport flows are consolidated and finally distributed via a series of central hubs and regional depots. In theory, these characteristics are also incorporated in the Rolling Shelf concept, at least for parts of the total transport network. In order to determine whether this theoretical match also works in practice, a business study is carried out for a large integrator.

The typical process of an integrator in shown in Figure 6-1.



Source: EveCo Software GmbH [2000]

Figure 6-1 Typical transport process of an integrator

As can be seen in Figure 6-1, the time frames are partly overlapping. In order to stay competitive and to improve the quality of service, all times directly affecting the customer must be permanently improved and adjusted. This for example means accepting later LCP (latest time of consignment pick-up) or later LCA (latest time of consignment acceptance at origin depot) and earlier GTD (guaranteed time of delivery). Therefore the transport process from consignor to depot and from depot to consignee is faced with extremely small time buffers. The time needed for the sorting operation can also be considered fixed, i.e. the only time window to be compressed is concerned with the depot to depot transport. These transport flows can be considered a potential market for the Rolling Shelf concept.

The use of small containers was thereby seen as a good supplement to the existing transport with C745 swap-bodies. The Fiftybox could be used for transport on relations where the C745 container is half empty. As it appeared, the Fiftybox could even be brought into action for so-called bypass transports (see Figure 6-2). With the help of the SCUs frequently occurring origin-destination pairs can be fed directly (i.e. without intermediate sorting and consolidation at hubs). The integrator defined exact decision criteria as to when SCUs should used for which freight volumes. It appeared that SCUs are the optimal load unit for specific volume relations between origin and destination depots.

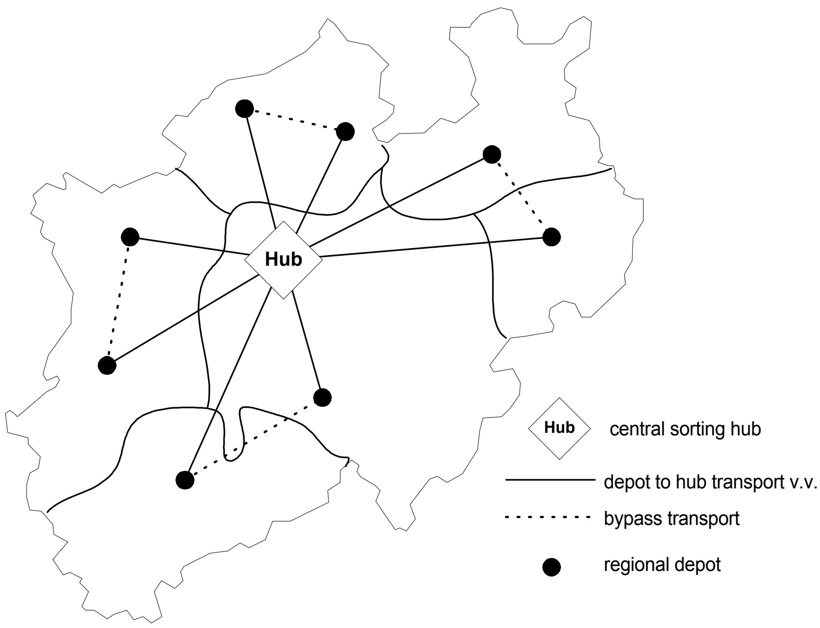


Figure 6-2 Example of bypass transport

6.1.2 Rail-based SCU parcel shipments

At present, the depot to depot transport of swap bodies and SCUs entirely relies on road transport. In order to establish a modal shift on specific relations, several key requirements were formulated by the integrator. The main requirements for a rail-based network of swap bodies and SCUs are:

- Fast transport from terminal to terminal, allowing transport from origin depot to destination depot within the given time windows.
- Dense network of transport routes allowing to transfer a significant volume onto rail transport;
- Fast transhipment of small containers;
- Full integration into information network;
- Low infrastructural investments.

The overriding criterion therefore is the relative competitiveness of rail transport versus road transport.

6.1.3 Estimation of potential

A study was carried out to find the potential for transport with small containers. The actual parcel volumes of an average day in October 1999 were thereby taken as a basis for the calculations. This study existed of following steps:

Step 1: Preparation of base data

1. Feasible train schedules identified according to following criteria:

- Time in transit;
- Time of day.

2. Assignment to terminal(s) according to criteria:

- Valid origin center identified;
- Valid destination center identified.

3. Volume adjustments according to criteria:

- Volume matrix is reduced to Rolling Shelf compatible lanes and service levels.

Step 2: Addressing actual needs from integrator at current volume distribution

4. Setting of criteria:

- 100% in a fifty-box equals 400 parcels;
- Volume between 250 and 600 parcels or between 1150 and 1500 forms range for using Fifty-box;
- Depot to depot volume only;
- Manual intervention to avoid suboptimal results.

Step 3: Operating integrators small container bypass transports with trains according to Rolling Shelf rail network

5. Determining train transport capacities:

- Potential volume per terminal inbound;
- Potential volume per terminal outbound;
- Used trains and used terminals;
- Potential lanes: 926;
- Lanes with potential volume: 299 - 307;
- Loads available: 217.

The results of the estimation procedure are listed in Table 6.1.

Table 6.1 Potential volume and terminals between 1999 and 2015

Year	Potential volume (boxes/day)		Potential terminals		
	Longhaul	Regional	Origin+destination	Destination	Origin
1999	217	42	28	8	1
2005	292	47	32	8	0
2010	400	86	34	7	0
2015	516	92	35	6	0

Source: EveCo Software GmbH [2000]

In total a significant share of the transports can be performed by using small containers. The share of small container transport on the average day's volume is approximately:

- 1999 volume: 13,2%
- 2005 volume: 15,0%
- 2010 volume: 17,6%
- 2015 volume: 19,9%

6.1.4 Further results

The positive environmental impact of the use of the small containers on rail wagons could not be determined within this project, but is expected to be significant. The major contribution of the bypass transport model with small containers would be in the reduction of road congestion.

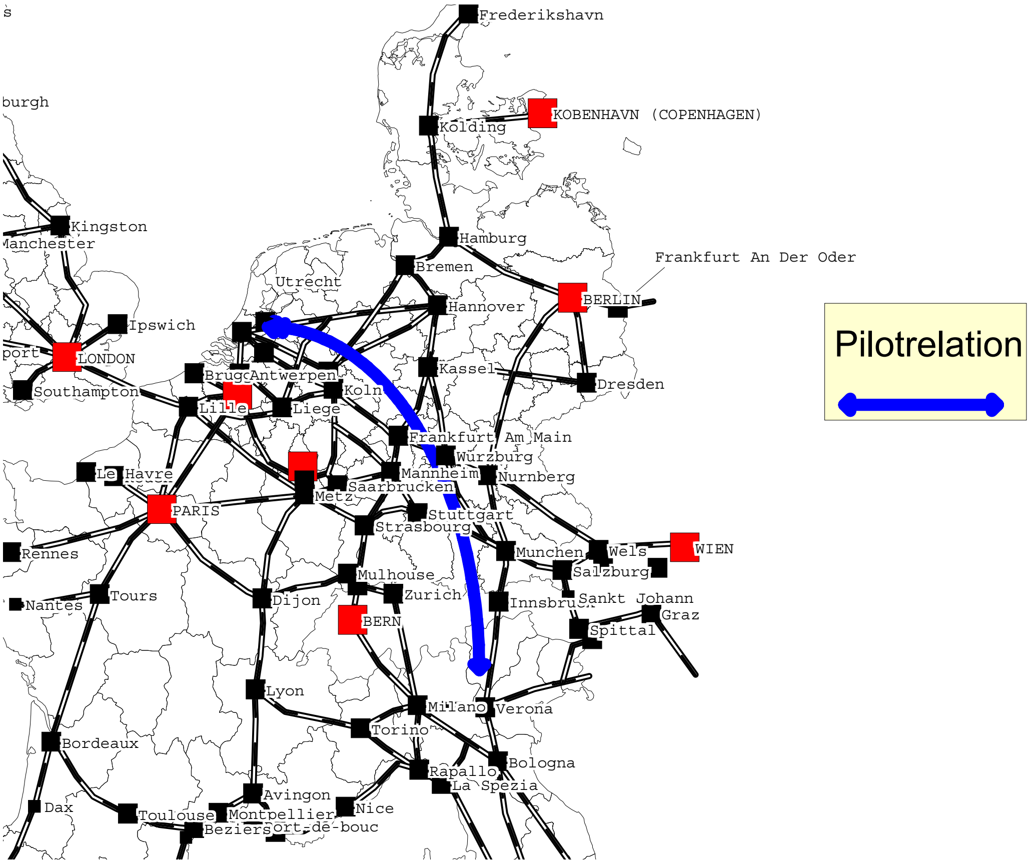
A practical problem facing the actual modal shift of SCUs from road to rail is the gap in current subsidy programmes: all load units equal to or smaller than 10 feet are not considered combined transport, and are therefore eligible for combined transport subsidies. Commercial investments are therefore relatively risky, which provides a barrier to future adoption of small containers in rail-based operations.

6.2 Amsterdam – Milano corridor

Since the real operation of trains and terminals entails high financial investments, a first step is to simulate real train operations with realistic parameters and actual transport demand figures. The results will help to evaluate the system and to estimate the market potential for the Rolling Shelf concept.

6.2.1 Selection of pilot corridor

Therefore a test corridor for a pilot relation was chosen. The basis for the selection was the European pallet matrix, as described in section 2.3. The flows were examined with regard to possible potential for the Rolling Shelf. Furthermore the possible pilot relation was discussed during a workshop in Freiburg, during which all partners contributed their experience to the selection of a suitable relation. The outcome of the discussions and analyses is a test corridor that runs from Amsterdam via Cologne, Mannheim, Frankfurt, Munich, Brenner, Verona to Milan. The corridor (see Figure 6-3) includes several types of representative transport relations like longhaul bordercrossing transports as well as regional transport relations (e.g. Amsterdam-Cologne or Frankfurt-Munich).



Source: Kessel+Partner [1999]

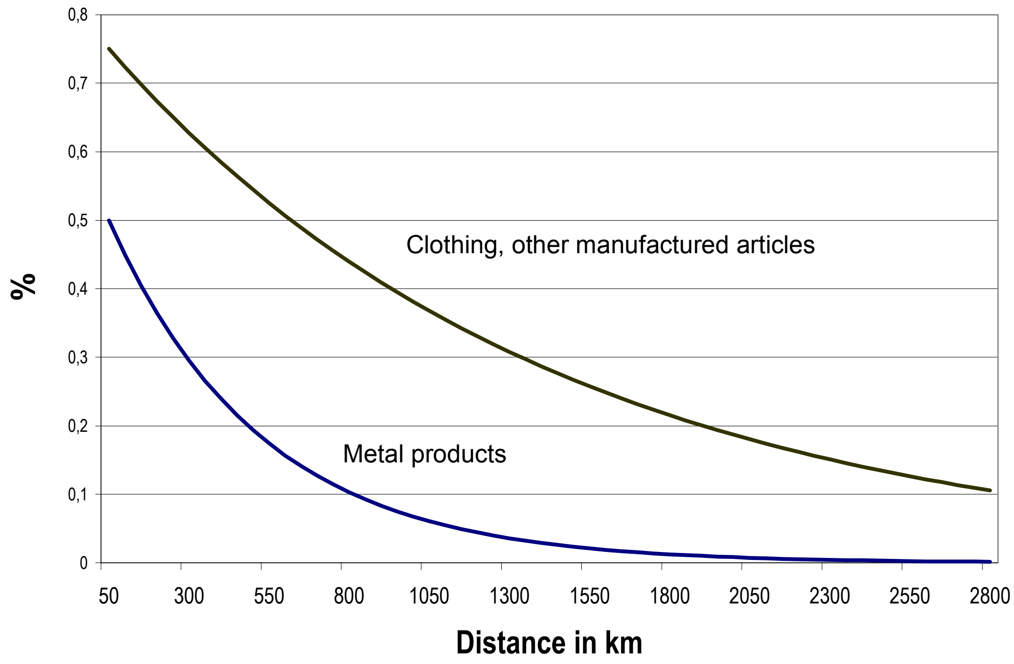
Figure 6-3 Pilot relation between Amsterdam and Milano

6.2.2 Transport demand and train operation on the corridor

The estimation of the transport demand on the corridor were worked out in a joint effort of Kessel+Partner and UPS. Kessel+Partner prepared the flows on the corridor, UPS developed the concept for the train operation on this basis.

The total transport flows were filtered in three steps:

- Selection of the relevant traffic zones within the catchment area of the test corridor;
- Estimation of the share of LTL palletised transport flows on each relation. The correlation between the share of LTL and the distance of two commodity types are shown in Figure 6-4 as an example;
- The utilisation of the entire market potential was assumed to be approximately 10%.



Source: Kessel+Partner [1999]

Figure 6-4 Correlation between share of LTL consignments and transport distance

The result of the filtering was a flow matrix of pallets between the terminals on the corridor. The computed transport volumes on the respective terminals are shown in Table 6.2.

Table 6.2 Calculated transport volume on Rolling Shelf terminals (loading and unloading)

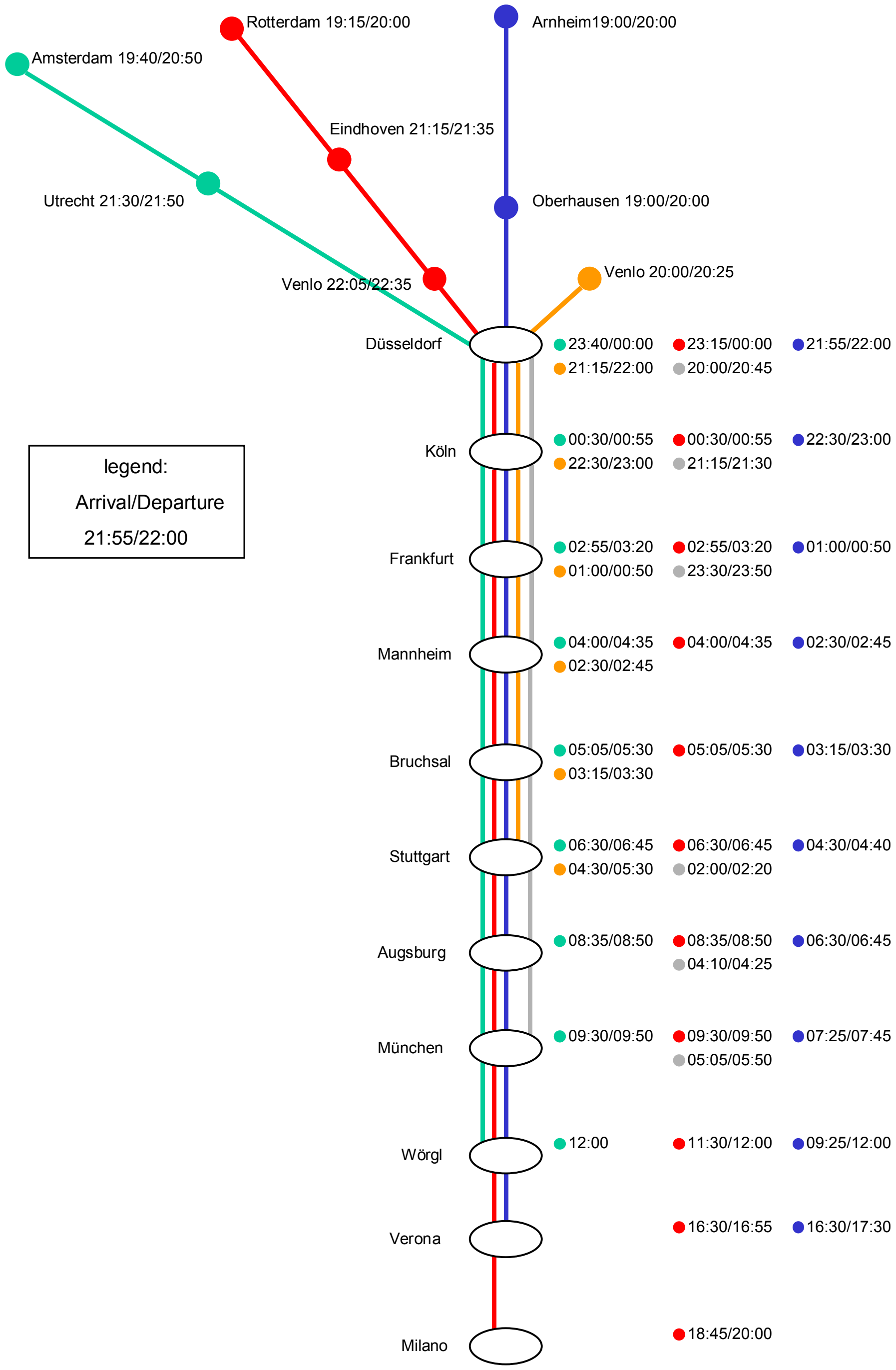
Rolling Shelf Terminal	Pallets / day
Amsterdam	234
Utrecht	122
Arnheim	489
Oberhausen	215
Rotterdam	306
Eindhoven	308
Venlo	156
Düsseldorf	1122
Köln	605
Frankfurt	1141

Mannheim	422
Bruchsal	452
Stuttgart	842
Augsburg	336
München	787
Wörgl	423
Verona	685
Milano	403

The volumes represent the transport demand of the terminals on the corridor in both directions. The corresponding flows were used to develop a timetable for five block trains on the corridor Amsterdam-Milano. The timetables of the trains are synchronised so that the utilisation of each train is optimised. On the other side the developed timetables guarantee a sufficient transport time of the pallets on the whole corridor. A central consolidation point is the terminal in Düsseldorf. The five block trains

- Amsterdam - Wörgl
- Rotterdam - Milano
- Venlo - Stuttgart
- Düsseldorf - München
- Arnhem – Verona

and their arrival and departure times at the terminals are shown in Figure 6-5.



Source: Kessel+Partner [1999]

Figure 6-5 Time table of the Rolling Shelf block trains (North to South)

In Figure 6-6 the terminal-specific pallet volume per day and the required maximum transhipment capacity per minute are shown. The latter value, which reaches (in the terminal Frankfurt) a maximum of 9 pallets/minute indicates the high requirements for the technical equipment.

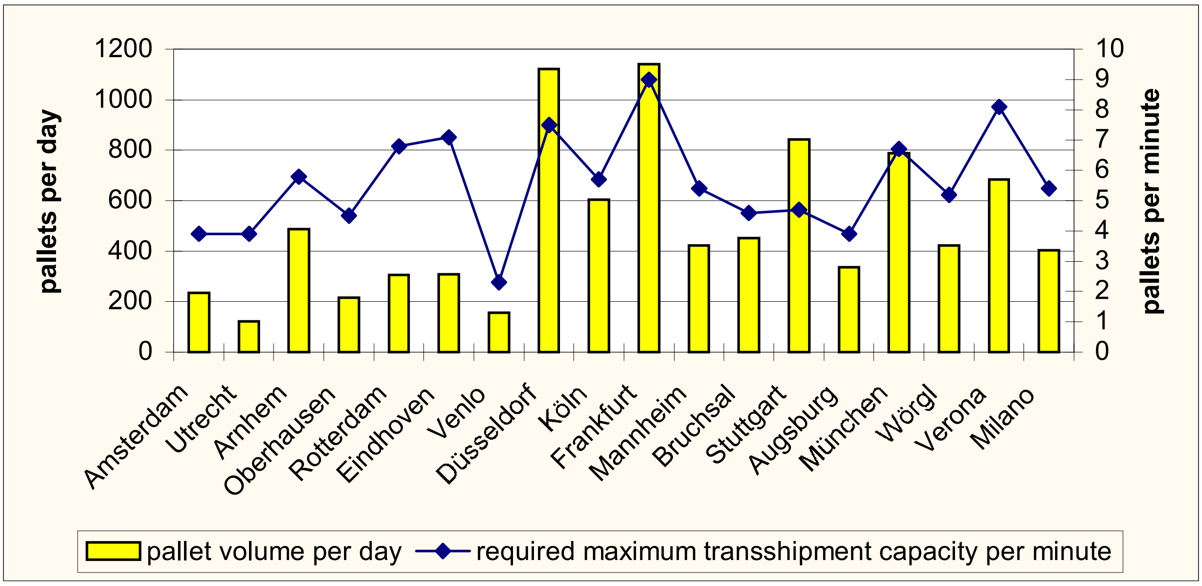


Figure 6-6 Pallet volume per terminal and required transhipment capacity

6.3 Profitability of the Rolling Shelf concept

In order to be able to make judgements about the profitability of the Rolling Shelf concept, EveCo Software GmbH developed a calculation model. The pallet flows estimated by Kessel+Partner and the five block trains identified on the corridor Amsterdam-Milano are used as a calculation basis in this model. The weekly revenues of each train is calculated based on these data.

6.3.1 Average utilisation

The pallet flows are expressed in units SCUs and TPUs, since the Rolling Shelf train consists of combinations wagons for SCU (9 pallets each) and TPU (three pallets each). Only pallets that share the same origin, destination and vehicle can be loaded on one load unit. This only causes suboptimal utilisation of load units in a few cases. The average calculated volume utilisation rate of the load units therefore amounts to 94 per cent. The loading space utilisation on the wagons however comes to 46 per cent. This is caused by the assumption that the Rolling Shelf trains always comprise ten wagons on the corridor (different combinations of SCU and TPU wagons), in order to standardise transhipment procedures at the terminals and to keep aerodynamic forces under control.

The variation around the average vehicle utilisation rate is large (see Table 6.3). For instance for the train from Amsterdam to Wörgl, the average utilisation of the TPU wagon is 42 per cent. The highest measured utilisation lies around 83 per cent, while the lowest possible utilisation is as low as 26 per cent.

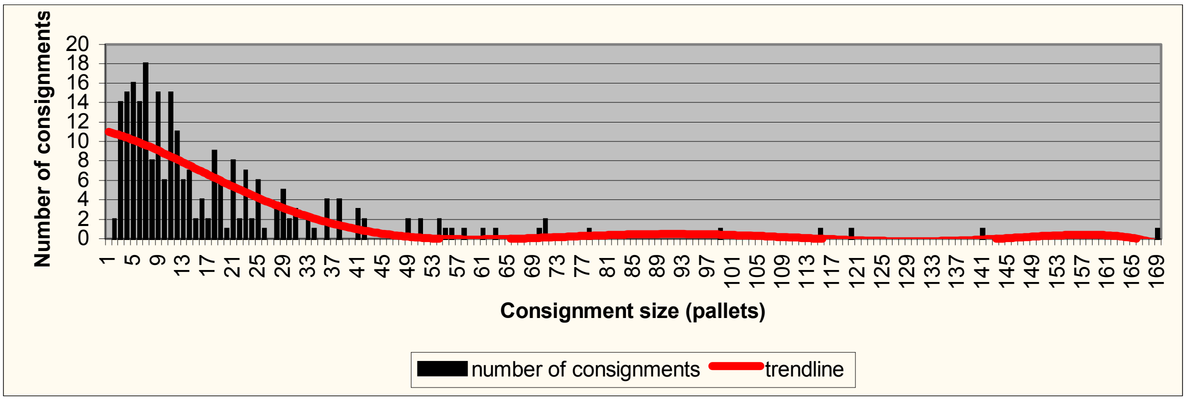
Table 6.3 Utilisation of vehicle capacity on train all ten routes

	Average		Highest		Lowest	
Train	**TPU**	**SCU**	**TPU**	**SCU**	**TPU**	**SCU**
Amsterdam-Wörgl	42%	46%	83%	93%	26%	0%
Wörgl-Arnhem	42%	46%	83%	93%	26%	0%
Rotterdam-Milan	50%	64%	76%	98%	30%	25%
Milan-Rotterdam	50%	64%	76%	98%	30%	25%
Venlo-Stuttgart	18%	46%	22%	90%	9%	0%
Stuttgart-Venlo	18%	46%	22%	90%	9%	0%
Düsseldorf-München	17%	60%	24%	93%	4%	28%
München-Düsseldorf	17%	60%	24%	93%	4%	28%
Arnhem-Verona	42%	46%	83%	93%	26%	0%
Verona-Amsterdam	42%	46%	83%	93%	26%	0%

6.3.2 Transport prices dependent on consignment size

As regards the cost calculations for the transport units to be transported, the cost statements of Versteijnen Logistics are used. These costs are summarised in a transport costs matrix: a matrix that provides differentiated prices per pallet-km that depend on consignment size and transport distances. These prices have been converted to prices per TPU and SCU, assuming that transport prices with these load units are cheaper than for single pallets. Two cost scenarios have been used: one neutral scenario (moderate price policy) and one aggressive scenario (i.e. low cost case).

Since transport costs are dependent on the consignment size, the distribution of the consignment sizes is calculated for the trains on the corridor Amsterdam-Milano (see Figure 6-7). A consignment is defined as the number of pallets with the same origin, destination and the same transport vehicle.



Source: EveCo Software GmbH

Figure 6-7 Distribution of consignment sizes on the corridor Amsterdam-Milano

Because some large consignments influence the average consignment size significantly, it is necessary to use the median of the data. The average, median and other statistical data are summarised in Table 6.4.

Table 6.4 Key statistics on consignments sizes

Largest consignment	168 pallets
Smallest consignment	1 pallet
Average consignment size	18 pallets
Median of consignment size	11 pallets
95% of all consignments	Consignment size between 1 and 60 pallets

Source: EveCo Software GmbH

With a median consignment size of 11 pallets and an average distance of 553 kilometres, a transport price of €0.07 in the neutral scenario and a transport price of €0.06 in the aggressive scenario are used.

6.3.3 Transhipment costs

The integral transport costs of the shipments on the corridor Amsterdam-Milano consists of transit and transhipment costs. The transit costs are assumed to be independent of the train composition. The transhipment costs correlate with the terminals type. As is described in the previous chapter, Schäfer-Noell defined four terminal types. These terminals differ with respect to equipment, transhipment capacity and costs. The different terminals are summarised in Table 6.5.

Table 6.5 Cost levels of different terminal designs

	Terminal I	Terminal II	Terminal III	Terminal III,2
Transhipment capacity (TPU/20 min.)	10	36	36	72
Transhipment capacity (SCU/20 min.)	8	22	36	72
Investment costs (x1,000€)	2,500	6,500	10,000	17,700
Operational costs (x 1,000€/year)	400	900	1,300	2,600

Source: Schäfer-Noell [2000]

For the integral transport cost calculations, the following transhipment costs are deduced (based on the terminal designs).

- Transhipment costs of one TPU: €4.54
- Transhipment costs of one SCU: €20.45

This price includes the costs for loading or unloading the load units onto the wagons. These cost levels are very favourable compared to the transhipment costs of a single pallet unit (€3.58).

The Rolling Shelf transport system within the corridor consists of 10 trains (five trains in two directions) that together call at 18 terminals. Ten of these terminals serve more than one train. The terminal costs therefore can be spread over the different trains. Because the number of units that need to be handled at the terminals is known, a terminal type was found for all locations. The table shows the terminal types and the number of terminals of this type used.

Terminal Type	Number of terminals needed
TI	3
TII	14
TIII	1
TIII,2	0

6.3.4 Final profitability calculation

Profit calculations on the corridor Amsterdam-Milano show, that the Rolling Shells train is almost profitable when transporting the pallets resulting out of the pallet flows estimated. The low utilization of the train, the large consignments and the relatively long travel distance of the pallets make the price per kilometer to low.

However, if the train transport small consignments over smaller distance, it is very well profitable, even with relatively low utilization. A train utilization of 50% makes the Rolling Shelff transport system on the corridor Amsterdam-Milano profitable.

7. Legal issues

This chapter briefly discusses the legal issues and applicable regulations that are involved with the introduction of the Rolling Shelf concept. These legal matters were evaluated in a study by Logotrans [2000]. For details, refer to this study. Here, we summarise the findings. The main applicable regulations are:

- *Uniform Rules concerning the Contract for International Carriage of Goods by Rail (CIM)*: these regulations determine the legal relationship between consignor and carrier. The regulations of the railway company guide the way the wagons are loaded. Furthermore, the delivery time of the goods is agreed between consignor and railway carrier. This allows the adjustment to the actual transit speed of the Rolling Shelf concept. The financial responsibility of the railway carrier in case of delays is limited to four times the value of the freight transported;
- *Regulations concerning the international Haulage of Private Owners' Wagons by Rail (RIP)*: these regulations only contain basic rules on the use of freight private wagons within railway companies. Existing risks as regards liability of various partners include improper use of wagons, inadequate maintenance, or Acts of God;
- *Uniform Rules concerning Contracts of Use of Vehicles in International Rail Traffic (CUV)*: the wagons developed in the Rolling Shelf project can be considered as special constructions. Given the insights as of the year 2000, there will be no objection towards the admission and use of the wagons by a railway company which meets usual operational requirements. The precise implications of the rules can however not be foreseen;
- *Uniform Rules concerning Contracts of Use of Infrastructure in International Freight Traffic (CUI)*: these rules have only recently been introduced. The legal relationship between railway company and the infrastructure provider is to be agreed upon within this framework.

8. Evaluation

This chapter evaluates the features of the Rolling Shelf concept in the light of the current rail transport trends and the present logistics requirements stemming from different business industries.

8.1 Rail transport trends

The European transport trends that have taken place in the last decades can be characterised by a sharp growth in the volume of goods carried (mainly in international traffic) and a strong preference for road transport. The European REDEFINE research project for instance already revealed that economic growth alone insufficiently explains the substantial growth of freight transport by road in the European Union during the last 15 years. Instead, logistics factors appear to play an important role in determining the ever-stronger position of transport by road.

The logistics causes of increasing transport demand can be summarised by the trend towards *space-time compression*. On the one hand, spatial barriers have progressively been demolished (e.g. liberalisation of trade, internationalisation of markets, wider sourcing), while on the other hand time requirments seem to be higher than ever. Internationalisation has for example resulted in longer delivery distances. Acceleration of business has caused increasing frequencies of deliveries (e.g. as a consequence of zero-stock policies) and smaller consignment sizes. Shippers are eager to reduce inventory costs, because they are confronted with higher product value densities, shorter shelf-life of products and a larger number of product variations. The higher service levels required to support these inventory reductions go along with the emergence of part shipments (lower utilisation rates) and a stronger preference for road transport.

As the facts and figures show, intermodal transport services have not gained enough ground to capture a large market share in this highly competitive context. The core problem of intermodal services appears to be its economic viability. As various studies have unveiled [see e.g. TRILOG-Europe, 1999; Kribich and Nolte; 1996], the economic viability of intermodal services is negatively influenced by a number of organisational and technological factors:

- *Relatively high tariffs*: high transport costs are caused by the fact that intermodal services usually involve capital intensive transhipment technologies and more than one service provider. Technologically complex transhipment processes are simply money- and time-consuming. Furthermore the involvement of several transport service providers (with their own variable and overhead costs) usually means that higher tariffs need to be calculated. Innovative freight rail concepts can be competitive in price through efficient transhipment procedures, high utilisation rates, extended operational hours and through goal-oriented marketing of the rail product.

- *Failing to meet service standards*: long transit times, low on-time reliability and a lack of flexibility are mentioned as weaknesses of the current intermodal alternatives. Again, the transhipment of freight to another vehicle can cause time delays or unreliability. The average speed is further frustrated by frequent stops, shunting operations and the limited availability of door-to-door services. Current average speeds of freight trains are typically 80 kmph. Addition of pre- and endhaulage means that current cycle times are long in comparison with road-only alternatives. Additionally, freight trains do not mix with passenger trains very well. Because of the diverging speeds, freight trains often block passenger trains and vice versa. Harmonising speeds of both passenger and freight trains would immediately reduce delays. Finally, rigidity (e.g. fixed departure times) is mentioned as one of the weaknesses of current intermodal transport systems.
- *Lack of intermodal information systems*: modern companies require real-time status information about their deliveries, in order to anticipate on disruptions or changes in the original production or delivery schedules. Current intermodal services often result in a fracture of the information chain. Integrated door-to-door information systems are not exploited to the full extent.
- *Lack of standardisation of load units*: the fast and cheap exchange of freight between and within transport modes is restricted by the limited standardisation of load units. It is important to use standard load devices along the entire logistic chain (in order to reduce handling time and costs). Where standard load units are lacking, new interfaces should be designed to cash in on economies of scale during transhipment operations (e.g. putting roller carts on system pallets). Furthermore, the lack of interoperability between countries stands in the way of future development of intermodal transport services. The problem of standardisation is also shown by other recent research programmes, such as the COST339 study.

In short, the root causes of the above weaknesses of current intermodal transport services can often be found in organisational and technological factors. In turn, these factors have major economical implications: under the existing market conditions, many intermodal services have therefore found it difficult to survive. Moreover, intermodal alternatives seem to suffer from a poor image. That is, even if they were capable of offering competitive rates and service performances, intermodal service providers will have a hard task of convincing and persuading shippers of the benefits of intermodal transport services. This obviously calls for demonstration projects, where the actual benefits of intermodal services are shown.

However, despite the seemingly negative past of intermodal services, there are promising opportunities for the future. The future of road transport is not entirely carefree either (e.g. road congestion, higher variable and fixed costs), while the past experiences with intermodal initiatives can give the impetus for improvements to the future intermodal services. Moreover, some autonomous market developments could boost the relative attractiveness of intermodal services. First, the rationalisation of distribution networks results in thicker freight flows and increasing transport distances, both of which are favourable conditions for intermodal development. Second, the increased outsourcing of transport activities to third–party logistics service providers (LSPs) have made shippers more ‘mode-abstract’. Shippers do not prefer road transport itself, but are merely interested in the functional characteristics of the LSPs’ services. In this way, modal choice becomes an irrelevant choice to the shippers. Additionally, LSPs have more opportunities to generate consolidated shipments, thus increasing the potential for intermodal shipments. The numerous examples of road transport companies who are actively involved in developing intermodal alternatives (also inspired by the problems facing road transport) show that intermodality is gaining ground. Finally, the increased possibilities of information and communication technology (ICT) offer opportunities for chain control and bundling part shipments (e.g. through web-based transport market places). Due to the large shipping capacity offered (which can be considered sunk costs), rail alternatives are always challenged to achieve sufficient load factors. New ICT technologies could be helpful in achieving this goal.

8.2 Evaluation of the Rolling Shelf concept

To what extent and how does the Rolling Shelf concept fulfil the requirements mentioned above, and to what extent does Rolling Shelf fit in in the business environment of today?

Main conclusions:

- Rolling Shelf fits within autonomous current business trends, such as the trend towards smaller consignment sizes.
- The technical concept is an innovative and smart solution for tackling the basic problems of current rail transport services. By focussing on fast and flexible transhipment and on fast train technology, the RS consortium has succeeded in finding a technical and moreover economically feasible solution by establishing a synergy between the system characteristics of the road and rail technology.

- As different business studies have shown, the RS can be profitable on specific relations.
- Success factors of the RS system are the fast transit time (which allows smooth blending in on dominant track speeds; passenger trains) and the fast transhipment times (through intelligent transhipment concepts based on TPU and SCU).

8.3 Dissemination of Rolling Shelf knowledge and experiences

The following dissemination activities have been carried out:

- Conferences
- Videos
- Articles
- Presentations

Rolling Shelf was presented at following Conferences:

- European Transport Conference, Lille , 8-10 November 1999
- Hispeedmix Final Workshop, Paris, 27. April 2000

The project produced two videos.

- Rolling Shelf – The transport alternative for the next Millenium
- Terminals for Rolling Shelf

Two explicit articles were published:

- Rolling Shelf, Unseld, Hans, Distribution, Issue 10/99
- Rolling Shelf, Röhling, Wolfgang, DVZ, 16.07.99

Numerous presentations were made. The final presentation was:

“Addressing Technology Challenges: for taking next steps toward implementation of a Rolling Shelf network” (8th Feb 2001).

8.4 Potentials for pilots

8.4.1 Existing initiatives

Today’s transport market for rail-based services is moving fast. Numerous initiatives show that the market for fast international rail services is emerging. The OverNight Express between Amsterdam and Milano (NS Reizigers) and the Parcel Intercity Express (DB/Deutsche Post) are examples of the gradual but steady growth of the market for rail-based innovations. Furthermore, user and provider platforms (e.g. Efforrt and the European High Speed Rail Forum) have come into existence. This is promising as regards the future of fast rail services. Finally, several follow-up research programmes have been defined and are on their way (e.g. CO-ACT, CaRL). The basic knowledge gained in the Rolling Shelf project is used and implemented in these projects.

8.4.2 Generating a general framework of interacting projects

We have witnessed a strong dynamism in the rail transport market and the amount of different initiatives. This section aims at combining these initiatives into one general framework, in order to show the different application domains the Rolling Shelf results can have. The framework is then used to identify the potentials for pilots of the Rolling Shelf concepts. Different aspects of the entire concept are handled in different projects. Together they however form a complete coverage of the issues at hand.

The framework consists of several projects. These projects however all aim at introducing fast rail transport concepts to market within four to five years. The investigations within the Rolling Shelf project unveiled the technological and commercial feasibility of the fast rail concept. The next step towards market introduction is the execution of test trials or pilots. These pilots serve to demonstrate the practical utility of the concept, enable incremental learning and activate latent demand.

- *CO-ACT*: the CO-ACT project includes a series of test trials. CO-ACT aims to demonstrate the practical feasibility of fast cargo trains and transhipment between the airports of Amsterdam and Frankfurt. The pilots are organised and executed by a consortium of experienced logistics service providers and rail operators. Given the need for mixed loads, the logistics service providers will secure loads from different sources (air cargo, perishable goods, time-sensitive freight). The parties involved (including the airports) explicitly view the test trials as a preliminary step towards structural traffic. The results of the test trials will provide important inputs for future rail systems.
- *TTT ex AMS*: The name stands for **T**ime **T**able driven Rail **T**ransport **ex AMS**terdam. Amsterdam Airport Schiphol prepares further integration of international rail services with the projected OLS (Underground Logistic System), and intends to extend the CO-ACT test trials into a structural service between selected destinations.
- *New Rail Wagon (in preparation)*: this project aims at the development and prototyping of suitable high-speed wagons. The project is basically run along

two parallel lines. A first wagon is defined for speeds up to 160 kmph, while a second team designs wagon types that are allowed to exceed 160 kmph. The results of such a project would be the preparation of permission to use the wagons on the high-speed tracks throughout Europe. The technical requirements are specified on the basis of the results from CO-ACT and Rolling Shelf.

- *Wagon provision*: the research activities up to now have shown that high-speed freight wagons are scarce. Therefore, in order to successfully carry out the test trials and later structural rail services, a separate project for wagon provision is required. This project should ensure availability of high-speed wagons through financing and purchasing. Subsidy through the PACT 2002 programme is conceivable.
- *FC Terminal D&F*: terminals, just as wagons, are essential components of a fast rail cargo system that need additional attention. The strategic development, funding criteria, and provision of a fast cargo terminal network require coordination in a separate project.
- *European Rail Forum for High Speed Cargo*: This programme is in preparation and will focus on developing standardised approaches at important European air ports for goods rail transport.
- *CaRL*: this project coordinates the German interest in fast rail cargo. The project is aimed at developing a joint German terminal network for several important players in the German market for time-sensitive cargo. A business plan for relevant players is developed on the basis of the work done in Rolling Shelf. The project should result in the operational exploitation of a fast cargo train by the year 2005.

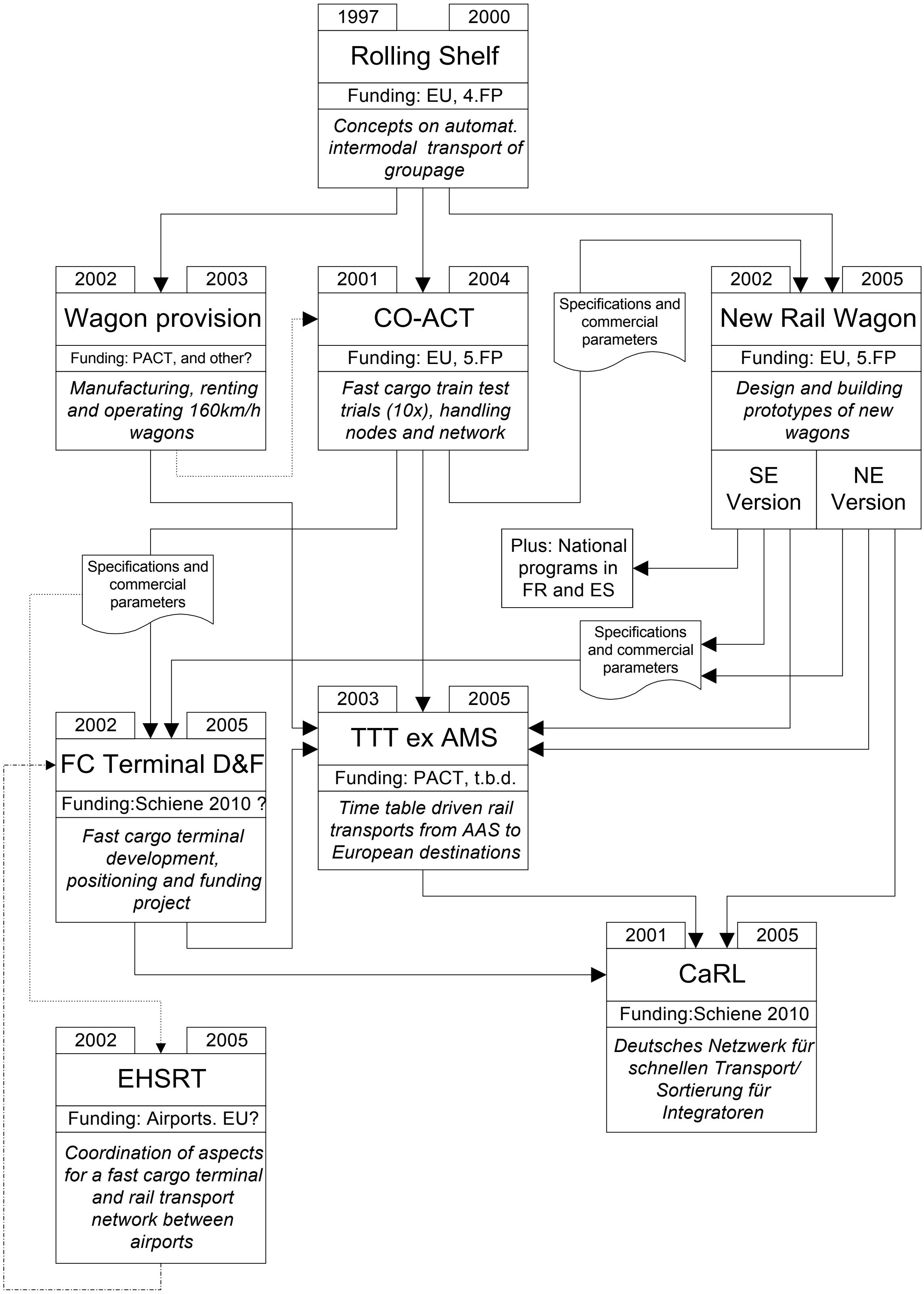


Figure 8-1 Project initiatives started from Rolling Shelf (EveCo)

PART IV
APPENDIX 1. HIGH VOLUME TERMINAL, TYPE III

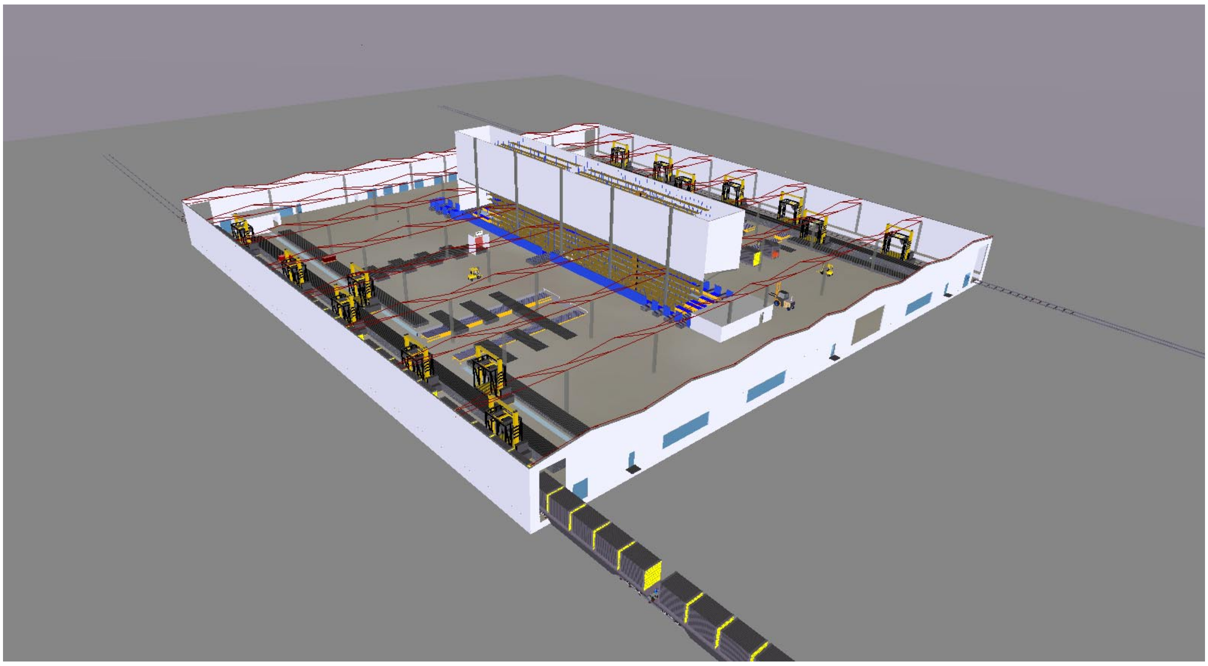


Figure A1-1. High Capacity Terminal III serving two trains simultaneously

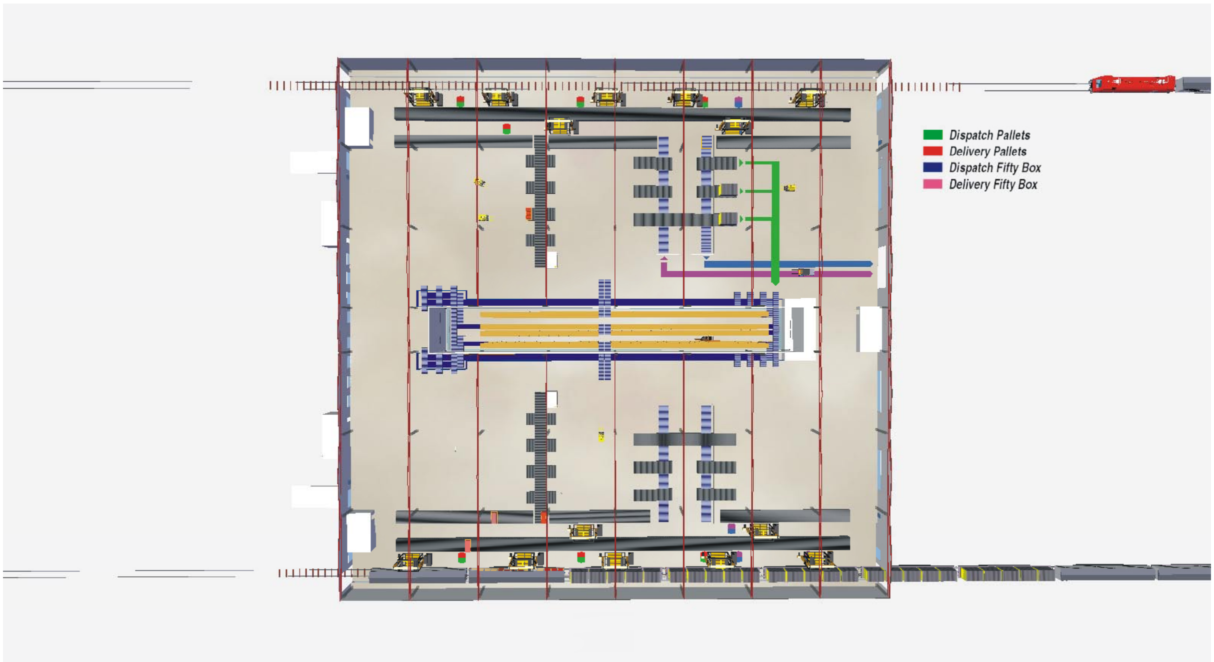


Figure A1-2. Layout of High Capacity Terminal III

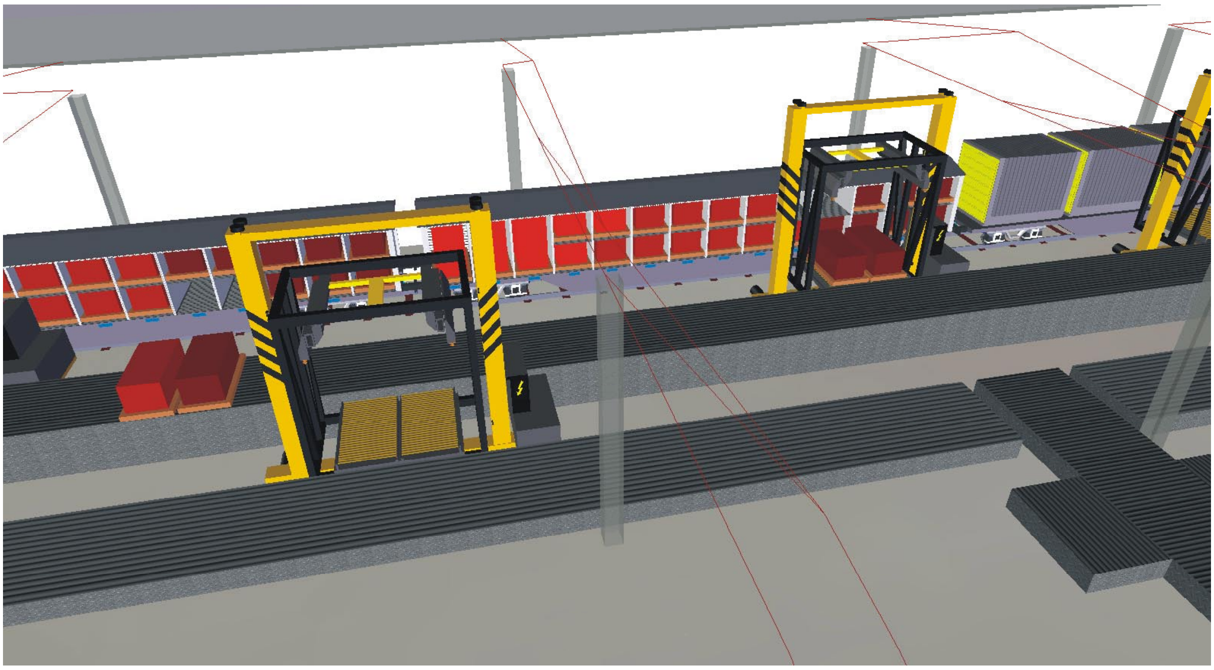


Figure A1-3. Transhipment of Triple Pallet Units on System Pallets

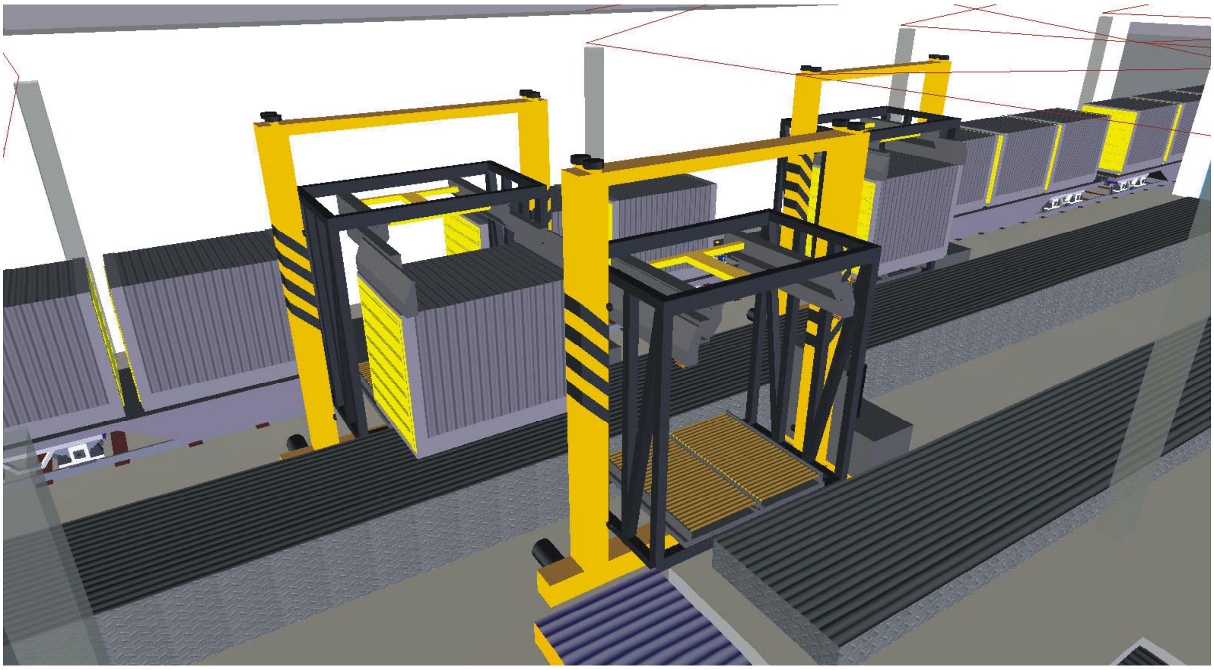


Figure A1-4. Transhipment of Small Container Units (Fifty-Box)

9. Glossary

Consignor

Company or person providing shipping orders in contract form to a logistics service provider for goods transport to their customers.

Logistics service provider

An organisation which acquires orders from consignors and manages all services to fulfil these orders as a general contractor.

LTL

Less-than-truckload; consignment sizes that are incapable of fully utilising truck loading capacity (as opposed to full truckloads; FTL).

Rail network operator

Organisation that offers rail network capacities within the context of EU regulations 91/440.

Rail transport operator

A service company providing regular transport services to the public on its own discretion.

SCU

Small-container unit; in the Rolling Shelf project this unit is represented by the Fiftybox (see section 3.2).

Terminal operator

A service company or department with commercial responsibility for performing transhipment and temporary storage services.

TPU

Triple-pallet unit; this unit is formed by a base pallet (system pallet; see section 3.1) which carries three conventional Europallets.

10. References

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