OPTIONS FOR THE INTEGRATION OF COMBINED TRANSPORT INTO EUROPEAN DISTRIBUTION SYSTEMS – THE CASE OF TRANS-EUROPEAN RAIL FREIGHT FREEWAYS (TERFF)

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Abstract

An overview is given of the EU transport policy in the area of freight and logistics. The current state and shortcomings of international intermodal transport are illustrated.

Then, the concept of a "Virtual Warehouse System (VWS)" is proposed, assuming fast, frequent and predictable freight services by rail in shuttle trains along the European main corridors, and multi-functional terminals integrating warehousing functions. Within a VWS, rail freeways act as catalysts for an integration of warehousing and distribution into an intermodal logistics network.

INTRODUCTION

Whereas there is widespread agreement at European level on the objective of increasing freight on rail and reducing the growth of road freight, progress so far is slow. At a time when companies act globally and the fastest growth is visible in international traffic, the rail business in Europe is still predominantly organised and often „administered" on a purely national basis. When issuing of EEC Directive 91/440, the European Commission had intended to reform the state-owned railway companies to become active actors in open and competitive markets. It demanded the economic independence of railway companies, the separation of infrastructure and operations, third party access to railway networks and not at least a solution of the debt problem of the railways. After six years, it has become clear that most EU member countries have been hesitating to implement the directive in its full scope and have opted for minimal solutions, often only fulfilling the formal requirements. As a result, the railways continue to lose market shares, while innovative logistics concepts implemented throughout Europe rely on the flexibility of the road haulage industry.

The EU White Paper of July 1996, "A Strategy for Revitalising the Community's Railways" (COM(96)421) (EU, 1996), promotes faster international railway operations and a strengthening of intermodal transport systems. As a first step, the paper proposes a network of so-called Trans-European Rail Freight Freeways (TERFF). Infrastructure managers will be responsible for the marketing of each freeway, along which freight trains will operate with increased speeds and drastically reduced border-crossing delays.

After a lengthy consultation process, the first "prototype freeways", linking North Sea ports and Italy, were defined and presented to the public in April 1997, followed by other route proposals. At the same time, the differing positions of several countries and railway companies concerning railway reform and liberalisation became apparent. Besides the issue of granting access to the network to other operators, track infrastructure usage fees - as an important part of operating cost, but treated differently by EU countries - appear to be one of the problem areas. Nevertheless, from January 1998 on, some of the proposed freeways started operating; at least slots or train paths were offered to potential customers.

The implementation of a system of rail freight freeways, allowing for fast, frequent and predictable freight transports by rail in shuttle trains along the main axes may act as a catalyst for an integration of warehousing and distribution. Railway freight or combined transport (CT, in US/UK terminology known as intermodal transport) is used in the transport chain of many companies to some extent. However, so far a "rail leg" is hardly fully integrated into the logistics system of producers, as the services currently offered by the railways are not flexible, reliable, fast or cost-efficient enough.

The concept of a "Virtual Warehouse System" under development at the IWW will be briefly described: Integrated into a network-based warehouse location model which covers road, rail and intermodal transport chains, proposed and potential future rail freight freeways (TERFF) are explicitly represented in the model. Centrally managed distributed warehouses at terminals of the TERFF could be frequently serviced by shuttle trains and can exchange stock if necessary. Hence, levels of stockholding and associated costs can be close to those in a central warehouse. The warehouses do at the same time act as transshipment centres, where the containerised goods are shifted between rail and road. The crucial precondition however is, that the services along the freeways are competitive with road haulage in terms of service levels (time and reliability) and costs. Scenarios, e.g. describing different pricing schemes of service level requirements, will be tested to assess the viability of the concept.

EU INITIATIVES IN THE FIELD OF TRANSPORT, ESPECIALLY RAILWAYS AND COMBINED TRANSPORT (CT)

The massive increase of traffic in Europe over the past decades, created by economic growth, motorisation and closer interaction between different people and regions, has prompted the European Union and its predecessors to repeated interventions. Transport was already defined in the Treaty of Rome as part of European tasks, but only much later this started to be really filled with life, i.e. the EC and then EU showing an active interest in the importance of transport, culminating in the concept of the Trans-European Networks.

In May 1985, the European court of justice ruled - following an initiative of the European Parliament - that the European Council of Ministers had infringed the Treaty's rules on the freedom to provide international transport services: For nearly 30 years, the European Council of Ministers had not actively implemented a policy guaranteeing the free movement of people, goods, capital and services and had failed to take measures against national protection and discrimination policies. But immediately after the court ruling, a series of deregulation and liberalisation activities was started:

- In June 1985, a White Paper on the completion of the Single European Market was published, on the EC summit the same month the date of its completion was fixed to be end of 1992,
- In November 1985, the guidelines by the Council of Ministers of Transports for a free transport marked were released. The main elements were the establishment of a free transport market without quantity restrictions until 1st January 1993, a stepwise adjustment of bilateral transport quota, in order to reduce the apparent distortions of competition on the European transport market.
- In 1986, a number of Directives about the access to the road freight market, the abolition of customs formalities at borders, social requirements (driving and resting hours) and the harmonisation of technical standards and weights of road vehicles (maximum weight 40 tons, maximum axle load 11.5 tons) came out. Full cabotage in the road sector is allowed since 1998.

The deregulation efforts concentrated on the road sector, resulting in a drop of the freight rates (e.g. about 30% to 40% in Germany) and increasingly fierce competition. This is accompanied by a lacking enforcement of social standards, and the trend of road haulage companies to contract out the transport services to owner-operators. In fact, the former drivers often were offered to take over a vehicle and a contract to drive as formally self-employed subcontractors for their old companies that act as forwarding agents - but now carrying many risks themselves. The efficiency of the now truly competitive road freight market has certainly increased if measured in terms of price to the customer, service quality or improved vehicle use, leading to rising market shares for the road freight sector.

In air transport, the EC Council of Ministers commissioned a package of stepwise liberalisation in 1987. Its last stage was reached in April 1997 with the abolishment of all former cabotage regulations, and the full implementation of an "Open Skies" policy in the European Union.

In the railway sector, dominated by large national quasi-monopolistic companies, progress is much slower. Only in 1991, the directive 91/440 came out, demanding a limited access right to track infrastructure and a business-type accounting system with separate accounts for the infrastructure and the operation of services on the infrastructure. Progress in the railway sector - traditionally dominated by national railway monopolies - was slow so far, as can be seen in the hesitating implementation of directive. Railway share in (EU) European freight transport has fallen from 32% in 1970 to 15% in 1995 (EU, 1996), with railways running the risk to become a marginal supplier of transport services. Railways now have to follow the service quality standards (and prices) set by the road haulage sector, except possibly in traditional, shrinking bulk good markets.

Passenger and especially goods traffic are generally expected to grow further within the EU and beyond, as people and markets become more and more international. With the limits of traffic growth becoming visible especially on the roads, new strategies are sought to overcome the problems of congestion and pollution in the densely populated centres of Europe, where an extension of road capacities becomes more and more politically infeasible and socially unacceptable.

Railways are a comparatively environmentally friendly means of transport, as it was repeatedly recognised. Hence the EU transport policy has a tradition to highlight their role for the future development of transport in Europe. This is manifested in documents like the Green and White Papers of the early nineties (e.g. COM(92)46: Green Paper on the Impact of Transport on the Environment; COM(92)494: The Future Development of the Common Transport Policy - A Global Approach of a Community Framework for Sustainable Mobility), in the Green Paper of 1995 on "Fair and Efficient Pricing" (COM(95)691). At the same time, "interoperability" and "intermodality" became keywords to describe a transport system in which modern technology should allow an intelligent and efficient use of all modes of the transport system. Integration of the railways into that process is crucial, where underused resources seem to be available which are however inaccessible due to existing institutional and pricing arrangements.

In an attempt to break up the reform standstill on the railway side, which leads to continuously shrinking market shares due to the marked-adaptability of the competitors, the White Paper of July 1996, "A Strategy for Revitalising the Community's Railways" proposes the so-called Trans-European Rail Freight Freeways (TERFF) as a test-bed for the introduction of market forces in the railway sector. Intermodal or combined transports may especially benefit from the proposals, as reduced travel times and better services would improve the competitive position in comparison with road transport.

CURRENT STATE OF COMBINED ROAD/RAIL TRANSPORT IN EUROPE

The idea of a combined use of transport modes is as such nothing new, more or less standardised "containers" are in use since more than a century to allow a quick transfer of goods between e.g. ships, rail wagons and road vehicles.

The base unit for Combined Transport (CT) operations are TEU (twenty-foot equivalent units), derived from overseas container sizes. The main figures of international border-crossing CT in 1994 were as follows (Bukold, 1996), and have not significantly changed since then. International CT amounts to about 3,3 mio TEU, of which

- 60% originate or terminate in Germany,
- 70% are Alpine-crossing transports, touching A, CH or I,
- 95% originate or terminate in either A, CH, D or I.
- Of the total national CT, 35 to 40% occur in Germany and another 15-20% in France.

The strong role of combined transport in cross-alpine traffic is not necessarily based on high efficiency of the relevant CT operations, but rather on political influence. The Swiss 28-ton-limit forms a very effective barrier against transit traffic by road. Further east, the limited number of transit permits in Austria, coupled with the ecopoint system, forms a strong incentive to use the "rolling highway" trains. An indication of the possibly not-so-free choice of that option is that most traffic leaves the "rolling highway" on the Brenner pass just inside Italy, whereas the through services to Verona show much lower load factors.

International intermodal operators are organised in two organisations: Currently 17 CT companies are joined under the umbrella of the UIRR (Union Internationale des Sociétés de Transport Combiné Rail-Route), marketing and organising the rail transports from terminal to terminal. The more than 1000 road hauliers as shareholders of the UIRR companies who sell their transport services under own responsibility perform the access and egress road legs between terminals and customers. The UIRR accounts for about 55% of the international CT volume in Europe. The second main player is the ICF (Intercontainer-Interfrigo) consortium specialising in container transports. In order to allow to set up a direct CT train connection, preferably a non-stop shuttle train, a certain minimum flow between origin and destination is needed. Seidelmann (1997) gives an idea of the flow necessary to set up a direct CT service: A full CT trainload consists of 60 TEU (e.g. 60 swapbodies or 30 sea containers). Assuming 250 working days per year, per direction an annual flow of 60*250 = 15,000 TEU is needed on a connection. Lower flows do only justify running groups of CT wagons in traditional freight trains, leading to low O-D-speeds due to marshalling operations.

The following figure shows the hypothetical number of daily trains between **countries**. It was calculated using the actual CT flows in 1995, assuming one train per 15,000 TEU per annum.

To From	A	B	CH	CZ	D	DK	E	F	H	I	NL	PL	S	UK
A	–				15				4	1				
B		–	1		1			1		9	2		1	
CH		1	–		4					2	1			
CZ				–	7									
D	15	1	5	5	–	1	3		1	20		1	1	
DK					2	–				2				
E					2		–							
F		2						–		4				
H	4				1				–					
I		9	2		21	2		4		–	3		2	1
NL	1	2	1							3	–			
PL					1							–		
S		1			1					1			–	
UK										1				–

Source: adapted from (Schöpfer, 1997), based on UIRR and ICF statistics

Figure 1: Hypothetical number of full CT trainloads per day 1995 (empty cells = no or less than one trainload per day)

It becomes apparent how few attractive relations currently exist, especially when considering the disperse distribution of supply and demand within the countries. Therefore, many CT trains connect seaports (Antwerp, Rotterdam, Bremen, Hamburg) and gateway terminals, from where the final destinations are served by road. (The connections from and to Hungary and Czechia are mainly short-distance piggyback services). An observation that may be noted is that the flows are relatively balanced, hence empty running of wagons does not occur to large extent.

An important market for CT, not treated here in detail, are seaport hinterland services. As a handling operation (ship to road or rail or barge) is necessary whichever access or egress mode is used, railway transports become economically viable from about 200 km on, as opposed to road-rail-road CT operations, where the break-even distance is 350 km or more.

THE PROBLEM OF SPEED AND TRANSPORT TIME IN COMBINED TRANSPORT OPERATIONS

Modern logistics approaches are very demanding concerning the quality of the transport operations. Speed, reliability and flexible response to customer demands are key factors in the competitive markets of consumer as well as high value investment goods. Physical goods flows along the supply chain are accompanied by (or follow) information flows, hence a sophisticated EDI network gains importance. The daily range of a lorry with one driver on a motorway is, when adhering to the social regulations, about 700 km (nine driving hours x 80 kph). When changing drivers, or breaching the rules, much longer distances become possible. Within 24 hours, it is possible to reach nearly all destinations within the core of Europe.

The maximum operating speed of CT trains is usually 100 kph or 120 kph, depending on the rolling stock employed, hence higher than the top speed of lorries. The actual time between latest delivery of goods to a terminal and earliest pick-up at the destination terminal leads to much lower speed figures. An example for Germany-based CT operations is given below, based on an evaluation of ca. 250 international Origin-Destination pairs listed in the 1995 timetable of Germany's main operator Kombiverkehr.

Table 1 - Average speeds of international CT transports in 1995

Countries linked	Avg. Speed in kph
D-F	36.3
D-DK	29.3
D-CH	26.3
D-B	34.7
D-I	36.4
D-A	36.6
Overall average (ca. 250 O/D pairs)	32.7

Source: Own computations, based on Kombiverkehr 1995 timetable

Even "premium services", like a Rotterdam-Novara shuttle train operated in co-operation by Hupac, Cemat and Trailstar (UIRR, 1997), do not operate significantly faster: A travel time of 30 hours for the 1150 km distance means an average of 38.3 kph.

It becomes apparent that CT finds it difficult to compete with road, where no constraints occur. Reasons for the low speeds are apparent and manifold, like

- priority for passenger traffic, so that most of CT operations are performed at night-time,
- insufficient international timetable co-ordination,
- traction and staff changes and repeated „technical checks" at national borders,
- interruptions in the information chain,
- loading gauge limitations on some corridors, and different track gauges in E, P, FIN, CIS,
- certain capacity problems along main corridors,
- (currently) low transport volumes, making shuttle trains uneconomical.

These facts have led, at least indirectly, to the EU TERFF initiative, as an improvement potential is eminent, especially in the field of organisation and co-operation between railway companies.

The success of the Eurocity system in international rail passenger transport with its high quality standards (speed, border stops, comfort) shows that attractive international rail products are possible, if the partners involved show an active willingness to cooperate. CT operators have developed products that can be integrated into a modern supply chain, if the speed requirements of customers are met. For example, a "shuttle train" product was defined and developed by the Swiss operator Hupac, and now carries some 80% of Hupac's transport volume (UIRR, 1997). It fulfils the following prerequisites:

- fixed train composition and number of wagons, at least five trains per week and direction,
- a train is shuttling exclusively between two terminals, without no shunting operations at or between terminals,
- HUPAC buys "one piece of train" from the operating railway company, and carries the commercial risk of capacity utilisation,
- Only a single consignment note is needed for the whole train, instead of a separate document for each single wagon or loading unit.

This leads to the advantages of

- planning safety for shippers, especially concerning prices due to long-term contracts,
- a good reliability and punctuality record, allowing to integrate CT in a just in time transport chain,
- careful treatment of cargo, as shunting shocks are avoided,
- potential for integration into gateway concepts, where loading units are transferred to connecting trains, without the need for shunting operations.

By means of international shuttle trains, which necessitate a stable flow of goods over time, the annual mileage of platform wagons can be increased from 40,000 to up to 120,000 km – when combined with the better interlinking of the national railway networks including the traction and staff change, and high priority in the train path allocation. (Olsthorn, 1997),

THE TRANS-EUROPEAN RAIL FREIGHT FREEWAYS (TERFF) PROPOSALS

The White Paper does describe the purpose of the proposed TERFF, however it did not contain the showing a possible freeway network. In April 1997, the Community of European Railways (CER) presented its concept for the Trans-European Rail Freight Freeways (TERFF) to the EU (DVZ, 1997a). The result of an assessment of railway corridors had shown that the delay at borders can be reduced by 80%, and the speed of trains can be increased by 20% within short time. By now, several different potential freeway corridors were more or less widely discussed, plus a number of variants:

1. Antwerp (B) - Luxembourg (L) - Dijon (F) - Modane (F) - Torino (I) - Genova (I)/Milano (I). Length ca. 1350 km. Proposed by CER. The French part is one of the main French rail freight corridors, whereas passenger traffic plays only a minor role. Later, a 1200 km long extension along the Italian west coast to the Mediterranean hub of Gioia Tauro was added,
2. Rotterdam (NL) - Emmerich (D) - Cologne (D) - Mannheim (D) - Basel (CH) - St. Gotthard (CH) - Milano (I). It follows one of the most important and highly utilised routes for freight as well as passengers. Proposed by CER. Length about 1250 km,
3. Brindisi-Verona-Brenner-Hamburg/Bremen, about 2150 km (Weise, 1997). Currently operating CT services need about 85-90 hours to cover the distance, leading to an average speed of 25 kph,
4. Wien-Passau-Rhein/Ruhr, about 1000 km, currently covered within 35 hours or 30 kph,
5. Wolfsburg-Barcelona, about 2000 km,
6. London-Sopron (Hungary), about 1700 km

The announcement of a corridor through France (No. 1) was at least partially a surprise, due to the traditional position of the SNCF. For example Armand Toubol, director of the freight division of SNCF, had expressed strong reservations against granting open access to the TERFF (Intermodal, 1997). In his opinion, TERFF should be created first, organising the freight flows between major centres effectively, and open access should be allowed only later, after a "successful implementation". To overcome questions like the lacking harmonisation of traction systems, co-operation between national rail companies would be better than competition. Toubol argument that allowing "amateurs" to operate rail services would create safety problems, and damage the reputation of the railways. This opinion, reflecting the French point of view, has not changed since, in late 1997 Toubol still sees difficulties to implement the "very liberal concepts" of the EU commission, as the peculiarities of railway operations call for a certain degree of regulation (Klingsieck, 1998).

Indeed, the corridor disappeared from the list of candidate corridors. In May 1997 Jan Gert Koopman, member of the cabinet of Neil Kinnock, has given an interview on the functioning of the TERFF in mid-May (Weise, 1997) in which two freeways were called "safe", however differing from the original proposal:

1. Rotterdam to Milan and Genova via Switzerland (St. Gotthard), as proposed earlier, and
2. Hamburg and Bremen to Milan via Austria (Brenner), linking the main German seaports with the North Italian industrial centre.

Two others, through France and from London to Budapest would "still need some time" until implementation. Other details were given:

- Brussels aims to introduce the new European signalling system under development, ERTMS, along freeways to increase capacities.
- Diesel engines will be allowed to run on electrified tracks.
- National governments have to intervene, if freeways are too expensive, addressing e.g. the high track usage fees charged in Germany.
- Passenger trains will keep their priority; trains on freeways will have no special advantages.

In autumn 1997, Heinz Hillbrecht, railway policy coordinator of the EU DG VII, has critisised the freeway proposal of the French, Belgian and Luxembourgian railways, as not constructive (DVZ, 1997e) – involving only new agreements between the involved railway companies, to offer improved train timings, without liberalising infrastructure access. He praised the Dutch-German-Swiss-Italian effort to set up Rotterdam-Verona and Hamburg/Bremen-Brindisi freeways. (DVZ, 1997e)

Nevertheless, the first "freeway", however in its French version, operates since 12th of January 1998. In November 97, the heads of the French, Belgian, Luxembourgian and Italian railways signed an agreement of for the operation of a Brussels-Muizen (B)-Bettembourg (L)-Metz (F)-Lyon (F)-Torino (I)-Genova (I)-La Spezia (I) -Gioia Tauro (I) service, co-ordinated by a central manager in Luxembourg responsible for planning and slot allocation. The railway administrations speak of a 20 % reduction of travel time, and hope to attract an extra 2 mill tons annually. On the same day, a declaration of intent to set up a link to Barcelona and Valencia was signed by the abovementioned and Spanish railway representatives (DVZ, 1997i).
In the meantime, a CT service along an envisaged freeway route will be withdrawn: Intercontainer-Interfrigo (ICF) announced to discontinue its twice-weekly train between London and Sopron/Hungary via the Channel Tunnel after about one year of operation. The reason given was the apparent impossibility to buy in traction services at competitive prices: Mr. Rasmussen, CEO of ICF was quoted expressing his regrets that "the five railway companies involved in the project failed to commonly design a traction offer such to make the train a competitive offer at the market" (DVZ, 1997f).

THE PROBLEM OF TRACK ACCESS FEES AND COST RECOVERY

Until now, CT has proven to be often unprofitable for the actors involved, but of benefit to the society as a whole due to the environmental friendliness. As the profitability becomes a central goal of railway operation, the public funding of research (supply side) and terminal installations (demand side) will have to help to close the gap between individual and social costs. For example, Armand Toubol, director of the SNCF freight division, regrets that the strategically important important CT is still making losses: The railways carry all cost, the general public enjoys the advantage of reduced environmental strains – which justifies further public financial aids, especially in the terminal sector (Klingsieck, 1998). The head of German DB AG, Johannes Ludewig, states that CT in Germany does not cover its costs but produces heavy losses for the DB AG, and announced that the situation has to change, e.g. by optimising the terminal network (DVZ 1997h). Probably this will mean a reduction of CT services.

In 1994, the Deutsche Bahn AG has published its first directory of track usage fees, which appears to be oriented towards full cost recovery. Taking the Rotterdam-Milano freeway as an example, the track usage fees for the 656 km (NL)-Emmerich-Köln-Mannheim-Basel-(CH) section amount to 7445 DM for 656 km, or 11.35 DM/km (ca. GBP 4.0/km; based on: "Trassenpreise" as of 1.7.95, table G1. From 1st January 1997 there was a price reform, however the change should not amount to more than 10%). Assuming a full trainload of 60 TEU and 12 tons average load per TEU, for every ton-km through Germany this equals 1.6 Pfennigs (0.56 pence) for track use alone. This massively limits the attractiveness of the freeway use, as the variable running costs (without driver costs) of heavy lorries are of the same order. As most proposed or planned freeways will touch Germany, it has to be checked whether track fees closer to marginal costs can be applied at least for additional transport orders, in order not to threaten the whole concept from start.

In addition, there are views that track usage fees rather have to rise than fall, if no political solution to cover infrastructure costs is found. Stöwe (Stöwe, 1997) mentions that track usage fees amount to ca. 40% of railway costs (in Germany), but this could even increase when the depreciation for newly-built railway infrastructures has to be covered in future.

The German institute DIW (Link, 1997) has calculated that revenues from fees are far from covering the infrastructure costs, since the system was introduced in 1994. Under THE given conditions of the transport market – full cost recovery has been impossible. The calculations of the DIW resulted in total infrastructure costs of 13.5 billion DM in 1996, and to revenues of 7080 million DM:

Table 2 - Infrastructure Costs, Track Usage Revenues and Cost Recovery Rate of the German DB AG

(1996 values)	Infrastructure Costs (Mill. DM)	Track Usage Revenues (Mill. DM)	Cost Recovery Rate (%)
Passenger traffic	6080	5590	92
- long distance	2130	1760	83
- short distance	3950	3830	97
Freight traffic	7430	1490	20
TOTAL	13510	7080	52

Source: (Link, 1997)

In the meantime, the head of DB AG, Mr. Ludewig, demanded activities from the EU commission, criticising distortions created by zero or low track usage fees in Sweden and the Netherlands: "We are the only country in Europe that fully recovers the track infrastructure through usage prices" (DVZ, 1997h) and asks for EU support (DVZ, 1997d).

DEVELOPMENTS IN TERMINAL AND WAREHOUSING TECHNOLOGY - PREREQUISITES FOR THE INTEGRATION OF FREEWAYS INTO THE LOGISTICS CHAIN

A whole range of technical concepts which can integrate the handling operations between rail and road vehicles, and warehousing operations have been proposed in recent years. Especially in Germany, where labour costs are high in international comparison, and where high densities and shipment volumes call for transfer technologies suitable for fast transshipments along main freight corridors, industry has presented solutions like the

- Krupp Fast Handling System (prototype installation)
- Mercedes Benz Kombilifter (prototype)
- Noell Fast Transshipment System "SUT", Noell Distribution Centre Concept (design stage)
- Thyssen Container Transport System (CTS) (concept stage)

Some concepts do integrate storage functions, and uncouple the goods flows on the road and rail side. An argument for this is that conventional intermodal terminals show quite large variations during one day concerning the use of the handling facilities, often rail-road transfers show a morning peak, whereas transfers from road to rail take place in the late afternoon, many CT trains running overnight services.

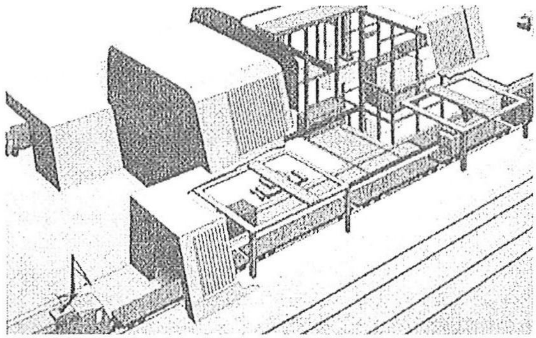

Figure 2 - Krupp terminal concept incl. storage facilities (Source: VDI (1996))

The demonstration installation of Krupp's "Schnellumschlaganlage", or fast handling system, in Duisburg was supported through the EU PACT (pilot action for combined transport) programme. The idea is to automatically transfer loading units from and to slowly moving trains, and includes the possibility for a temporary storage of the loading units. This modular concept is hoped to offer an efficient solution for small and medium-sized terminals, as its capacity can be increased to growing transfer volumes.

Integrating storage operations and possibly commissioning and repackaging functions could balance the capacity use, as more value-adding parts of the logistics chain can be integrated and co-ordinated with the transport and handling function of classical CT. An additional advantage of terminal warehouses is that the cost intensive lorry transfer between CT terminal and warehouse becomes unnecessary.

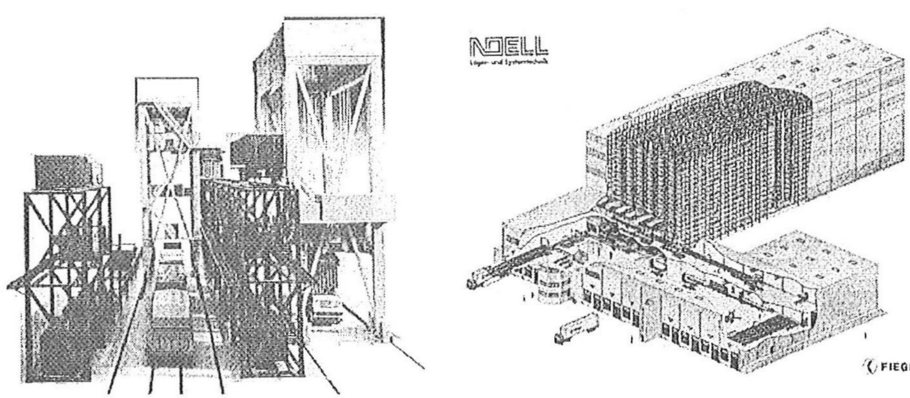

Figure 3 - Noell „SUT terminal and Noell distribution centre concept (Source: VDI (1996))

The pictures show different technical solutions suggested by different companies (Krupp, Noell), as examples for already designed - however not yet realised - technologies available. Most of them integrate modern (automated) warehousing and terminal technologies. As they are capital-intensive solutions designed for heavy throughputs, these or comparable concepts could inspire terminal warehouses at freeways or freeway junctions, where the demand justifies to run shuttle trains, allowing the operation of several terminal warehouses forming a "Virtual Warehouse System".

THE „VIRTUAL WAREHOUSE" CONCEPT

Given that background, the concept of a "Virtual Warehouse System" has been developed and integrated into a network-based warehouse location model which covers the road and the rail mode respectively intermodal transport chains. Computerised road and rail networks with Europe-wide coverage form the basis of the computations. The combined transport network in Europe, and especially services along the envisaged rail freight freeways are represented in the model. In combination with cost parameters for warehousing, handling and the several modes and stages of transport a coverage of the complete logistics chain is achieved.

A combined cluster-analytic/network-based heuristic model is employed to find preferable terminal locations. Cost-minimising warehouse configurations and transport chains are computed for scenarios describing possible future conditions, for example different pricing regimes and service levels.

The three basic ideas, which form the cornerstones of the approach, are:

- The integration of warehousing and CT opens cost reduction potentials by reduction of access/egress and handling operations, as storage is concentrated at intermodal terminals. The warehouses do at the same time act as transshipment centres, where the containerised goods are shifted between rail and road.
- The bundling of flows along main axes allows for efficient production methods of the railways (e.g. frequent block trains), in the case of the rail freight freeways competition may lead to innovative and flexible solutions.
- The integrated treatment of warehouses and the transport chain as a "Virtual Warehouse System" gives cost savings through reduction of safety stocks. Centrally managed distributed warehouses at terminals of the rail freight freeways are frequently serviced by shuttle trains and can exchange stock if necessary. Therefore, levels of stockholding and associated costs can be close to those of a central warehouse.

Given these factors, a long-term change in logistic patterns might be achieved: In recent years, the cost of warehousing and the savings derived from centralisation through the reduction of stockholding, and hence capital, have led to a reorganisation process in which warehouses are centralised and replaced by long distance transports, usually by road. It can be demonstrated that a "Virtual Warehouse System", using the proposed rail freight freeways as its backbone, may lead to a reversal of such trends, being competitive in terms of service levels (time and reliability) and distribution costs under current conditions, and more so given the predicted future growth in traffic and congestion.

MODELLING EXERCISE

At this place, only a few impressions can be given of the implementation. A description and application of an earlier model version, covering only the road mode, can be found in (Eberhard, 1994) and (Eberhard, 1997). Basis is a heuristic warehouse location model, using cluster analysis to find initial warehouse configurations, and employing a network-based heuristic optimisation model is to find preferable terminal locations. Cost-minimising warehouse configurations and transport chains are computed for different scenarios, for example different pricing regimes and service levels. The production stage, and interchanges of goods between warehouses, can be simulated as well. Four freeway routes are currently integrated in the model:

- Antwerp-Luxembourg-Dijon-Torino-Milan/Genova
- Rotterdam-Cologne-Basel-Milano
- Hamburg-Munich-Brenner-Verona-Brindisi
- Madrid-Lyon-Bern-Basel-Nuremberg-Prague

Three of these corridors were already proposed by or to the EU Commission, whereas the last was included to simulate the effects of an East-West corridor, which interlinks with the other freeways at certain places. For the an integrated modelling of the freeways, parameters like speed, user cost, terminal handling times and costs have to be chosen in addition to attributes that already describe the cost of warehousing and road haulage. Then, a warehouse location search can be started; an example of the result for five warehouses to supply the European market with high-value consumer goods by lorry (without use of freeways) is depicted in figure 4 below. The system distributes about 180,000 tons annually, leading to distribution costs in the order of 40 million Euros.

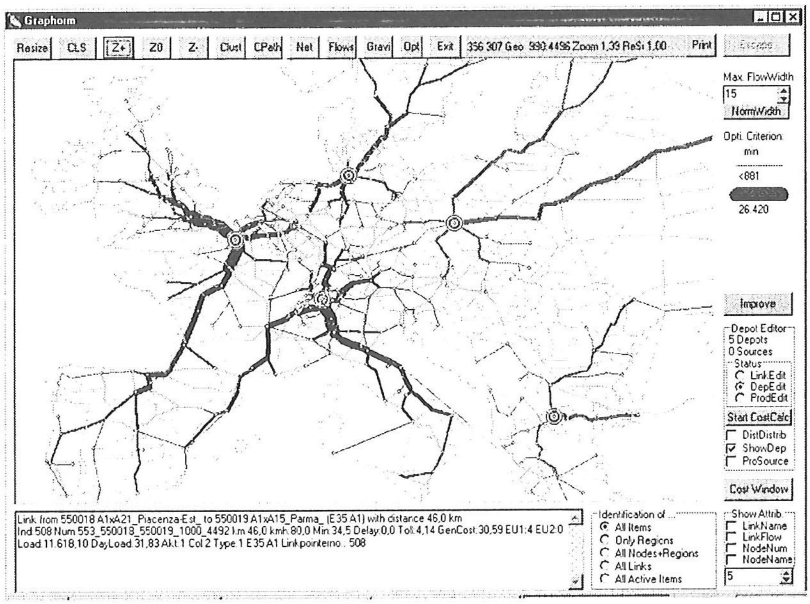

Figure 4 - Five Depot Solution

A heuristic optimisation procedure, in which number and locations of warehouses are adjusted to achieve a cost-minimal solution for sets of input parameters, can follow. Figure 5 on the following page shows the results of a computation for a purely road-based system. Using the resulting warehouse configuration (Depots in Moescroen/Belgium and Verona/Italy), but introducing a freeway option leads to a potential of below 8% of ton-kilometres that could be shifted to the freeways at best.

When introducing a freeway option with adequate services, the solutions for a cost-minimal warehouse configuration may differ to a large extent. Figure 6 depicts the optimal solution found for a two-warehouse configuration, proposing depots at the freeway terminals in Würzburg/Germany and Metz/France. In both cases the starting point was the same 5-warehouse configuration, however the optimisation process led to completely different outcomes. The example shows a reorientation of the flows and depot locations, large flows are bundled along the freeways. In total, 23.4% of ton-km necessary to serve the customers throughout Europe are shifted from the road towards the freeways.

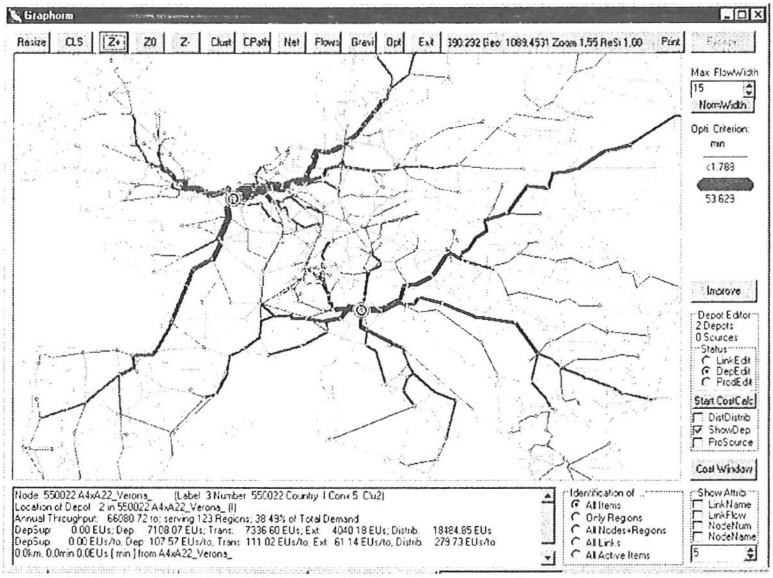

Figure 5 - Two-Depot Solution, optimised for a purely road-based system

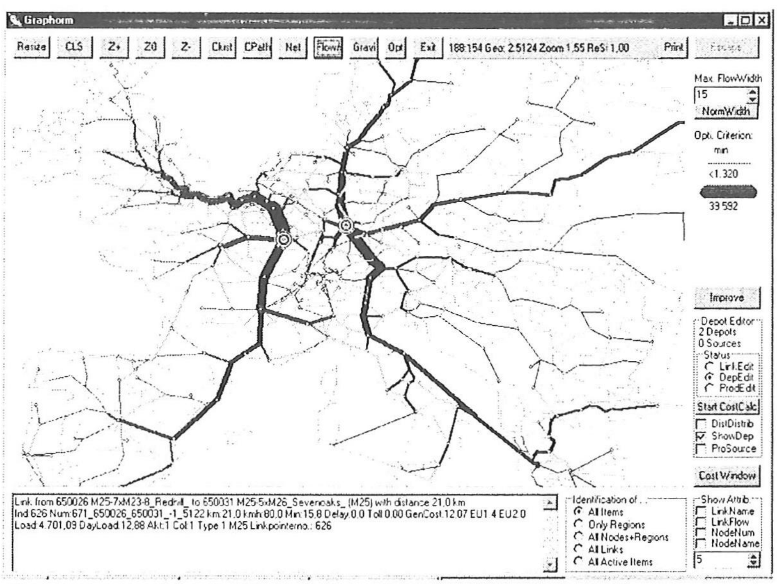

Figure 6 - Two-Depot Solution, optimised for a system including a freeway backbone network

Naturally, the outcome depends on the system parameters, namely service parameters and costs, which are still largely unknown concerning the TERFF. Nevertheless, it can be shown that rail freight freeways have the potential to have a visible impact in the reorganisation and optimisation of logistics chains in Europe.

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