EUROPEAN COMMISSION

DG TREN

SIXTH FRAMEWORK PROGRAMME

THEMATIC PRIORITY 1.6

SUSTAINABLE DEVELOPMENT, GLOBAL CHANGE & ECOSYSTEMS

INTEGRATED PROJECT – CONTRACT N. TREN-06-FP6TR-SO7-69821

RETRACK

REorganization of Transport networks by advanced RAil freight Concepts

Deliverable no.	D2.1
Title	Transhipment Techniques for Rail Intermodal Freight Transport
Dissemination level	PU
Work Package	WP 2
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Status (F: final, D: draft)	F-20122007
File Name	D2.1-Public-State of Art Transhipment Techniques-Final v2-Islam-20122007
Project Start Date and Duration	01 May 2007 - April 2011

TABLE OF CONTENTS

TABLES

FIGURES

1 Introduction

Intermodal transport requires the transfer of cargo units between, for example, road to rail at terminal and thus requires extra handling effort compared to uni-modal transport, for example, by road. In the competitive market the transfer must be cost and time efficient and effective. This is particularly important in the European context where road transport is dominant. An appropriate technique such as the use of cranes or forklift trucks (FLT) according to the cargo type is essential to perform efficient transhipment. The economic and efficient performance of a terminal facility is a key for competitive terminal operations that will ensure a high quality service to be integrated with the transport network. The terminal is one element (see figure 1) of the complete door-to-door inter-modal chain, and therefore terminal issues, especially as far as costs are concerned, should be evaluated within the general framework of the complete integrated transport chain (ETUP, 2007). Most European intermodal terminals are operated as multi-purpose-centres. Increasingly they handle every intermodal loading unit, such as standard freight containers by spreader, swap bodies and semi-trailers by grappler arms (SAIL Study, 2002).

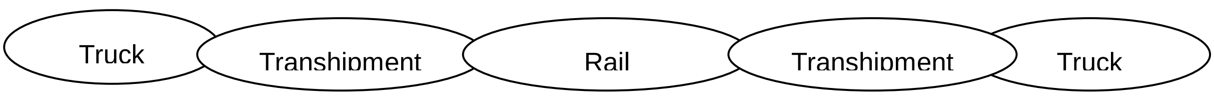
KombiConsult and Transport Consultants (2004) forecasted that there will be a transhipment capacity gap for 1.7 million load units by 2015 in 18 European (studied) corridors (although none of these corridors exactly matches with the corridor of the current RETRACK project). Under the circumstances they recommended the following actions for upgrading terminal capacity:

It is crucial that terminal enlargement investments come into operation on time to avoid temporary capacity shortages. There must be sufficient time for planning, approval procedures and financing, construction and opening of the enlarged terminals and their access infrastructure.

As an interface between road and rail, the terminal is the most crucial part of the intermodal supply chain and thus, sufficient handling capacity is a prerequisite for ensuring high performance and also to allow capacity reserves to prevent the terminal becoming a bottleneck.

The objective of WP2.1 is to evaluate transhipment techniques available in the open market and proven in previous projects and projects which were completed before RETRACK started (i.e. April 07). An evaluation of the available techniques will recommend any which is able to load/offload traffic rapidly, reliably, efficiently and with lower cost compared to orthodox methods and within the emerging parameters that the customers demand. The use of techniques that minimise noise generation at any part of the transaction activity including loading/unloading operations will be an important criteria.

Figure 1 Intermodal door-to-door rail freight service



First, we conducted a state-of-the-art survey of different types of intermodal loading units such as ISO-containers, non-ISO containers, semi-trailers followed by a review of the actual vehicles involved in the movement of the unit including road vehicles and rail wagons. Then we analysed the role of the different actors involved in efficient terminal operation in section three. This was followed by discussion of transhipment area requirements, its design layout and transhipment functional elements in section four. Then in section five we describe some transhipment techniques related to EC funded projects, followed by a description of different transhipment techniques in section six. A summary of the state the art is dawn in section 7. Then in section 8 transhipment technique on the RETRACK corridor is discussed and conclusions are drawn in section nine.

2 Intermodal Freight Unit Typology

The Innovative Technologies for Intermodal Transfer Point (ITIP) Survey on Intermodal Transport Unit (ITU) Typologies (ITIP, 2001a) found that

The fleet of non-standard (non-ISO) containers and specialised loading units is increasingly important, although the larger and dominant group remains the 40ft dry cargo container, originally developed to meet the requirements of maritime transport.

In the US the development of non-standard units generates larger containers (45ft, 48ft and 53ft), which can be transported double stacked on the trains. In Europe the evolution of swap bodies has been generated by the market, optimised for the continental road segment of the intermodal chain, but not directly compatible with the traditional equipment used for vertical handling of standard containers.

The continuous development of non-standard containers is based on the specific requirements of road and rail transport networks, which in turn is related to the optimisation of inland movements of goods which have dictated the use of this specialised equipment.

In Europe there is a growing demand for new typologies of units, capable of combining the flexibility of swap bodies with some features typical of containers (e.g. stackability) and pallets (largely adopted by the industrial and commercial market).

The high flexibility required by the freight transport market creates additional difficulties in defining new standards.

The market size of non-standard units is increasing due to the development and integration of distribution operators and logistics chains. Lack of standardisation is creating a large number of parallel intermodal freight transport chains which are adopting “customer designed” load units, circulating them in large, but separate, “customer managed” networks.

Thus, the possibility of inter-operability, through the use of innovative equipment for the intermodal transhipment of all types of loading units (containers, swap bodies, and customer designed units) is a key to an effective and successful market presence.

Integrating such parallel networks could be achieved through the development of simple, low cost horizontal transhipment systems which would interface road (mainly adopting horizontal mode) and rail (mainly adopting vertical mode), adopting an innovative concept of modular, flexible and fully interoperable units. In the following sub-section different types of rail intermodal cargo units are discussed in detail.

2.1 ISO-Containers

The ISO Technical Committee 104 developed a series of terminology, standard dimensions, technical characteristics, handling, security, seals, and identification of container, and information exchange about containers. The following is a list of ISO regulations (ISO, 2007) for freight containers:

ISO 668:1995 Series 1 Freight containers - Classification, dimensions and ratings

ISO 830:1981 Freight containers – Terminology

ISO 830: 1999 Freight containers - Vocabulary

ISO 1161:1984 Series 1 Freight containers - Corner fittings – Specification

ISO/PAS 17712: 2006 Freight containers - Mechanical seals

ISO 1496-1:1990 Series 1 Freight containers - Specification and testing - Part 1: General cargo containers for general purposes

ISO 1496-2:1996 Series 1 Freight containers - Specification and testing - Part 2: Thermal containers

ISO 1496-3:1995 Series 1 Freight containers - Specification and testing - Part 3: Tank containers for liquids, gases and pressurised dry bulk

ISO 1496-4:1991 Series 1 Freight containers - Specification and testing - Part 4: Non-pressurised containers for dry bulk

ISO 1496-5:1991 Series 1 Freight containers - Specification and testing - Part 5: Platform and platform-based containers

ISO 3874:1988 Series 1 Freight containers - Handling and securing

ISO/DIS 3874 Series 1 Freight containers - Handling and securing (Revision of ISO 3874:1988)

ISO 6346:1995 Freight containers - Coding, identification and marking

ISO 8323:1985 Freight containers - Air/surface (intermodal) general purpose containers - Specification and tests

ISO 9669:1990 Series 1 Freight containers - Interface connections for tank containers

ISO 9711-1:1990 Freight containers - Information related to containers on board vessels - Part 1: Bay plan system

ISO 9711-2:1990 Freight containers - Information related to containers on board vessels - Part 2: Telex data transmission

ISO 9897-1:1990 Freight containers - Container equipment data exchange (CEDEX) - Part 1: General communication codes

ISO/DIS 9897-1 Freight containers - Container equipment data exchange (CEDEX) – Part 1: General communication codes (Revision of ISO 9897-1: 1990 and ISO 9897-3:1990)

ISO 9897- Freight containers - Container equipment data exchange (CEDEX) -- General communication codes

ISO 9897-3:1990 Freight containers - Container equipment data exchange (CEDEX) - Part 3: Message types for electronic data interchange

ISO 10368:1992 Freight thermal containers - Remote condition monitoring

ISO 10374:1991 Freight containers - Automatic identification

ISO/TR 15070:1996 Series 1 Freight containers - Rationale for structural test criteria

ISO/ TR 15070: 1997 Series 1 Freight containers - Handling and securing -Rationale for ISO 3874 Annex A

ISO 3874 1997 Series 1 freight containers - Handling and securing

ISO 14829:2002 Freight containers - Straddle carriers for freight container handling - Calculation of stability

ISO 18185 -1: 2007 Freight containers - Electronic seals - Part 1: Communication protocol

ISO 18185 -2: 2007 Freight containers - Electronic seals - Part 2: Application requirements

ISO 18185 -4: 2007 Freight containers - Electronic seals - Part 4: Data protection

ISO 18185 -5: 2007 Freight containers - Electronic seals - Part 5: Physical layer

The series 1 freight container dimensions are described in the standard ISO 668, which was first defined in 1970 and successively modified in several editions. The kind of containers described by ISO are the 10, 20, 30, and 40ft length, 8ft width, and 8', 8'6'' and 9'6'' height. But the most common lengths of ISO container are 20 and 40ft. Table 1 shows the dimensions of ISO containers.

Table 1 ISO Series 1 Containers Dimension

Container	Type	Length (mm)	Width (mm)	Height (mm)	Position
40'	1AAA	12192	2438	2896	Outer
		11.998	2330	2655	Inner
40'	1AA	12192	2438	2591	Outer
		11998	2330	2350	Inner
40'	1A	12192	2438	2438	Outer
		11998	2330	2197	Inner
30'	1BB	9125	2438	2591	Outer
		8931	2330	2350	Inner
30'	1B	9125	2438	2438	Outer
		8931	2330	2197	Inner
20'	1CC	6058	2438	2591	Outer
		5867	2330	2350	Inner
20'	1C	6058	2438	2438	Outer
		5867	2330	2197	Inner

Source: http://www.haguidetofreight.co.uk/TechnicalInfo/id80.htm

The ISO containers were primarily for maritime transport. On the one hand, standard containers along with standard handling equipment allows faster and cheaper transfer of cargo from one mode to another, on the other hand, the operators have introduced different/modified containers to meet their specific traffic or commodity based demand. Usually these modifications were introduced by sticking to some technical aspects (such as the corner fittings positions) as they were in standard containers, in order to assure the compatibility with terminal facilities and handling devices. The first modification introduced was the increase of the height, first to 8.5ft and finally to 9.5ft (high cube containers). Another modification introduced was the increase of length, keeping the position of corner fittings at 40ft.

2.2 Non ISO-Containers

Nowadays non-ISO containers, such as the 48ft and 53ft, have a higher annual rate of introduction than the traditional 20 or 40ft ISO container, due to their large use in the US domestic market. On the other hand, a specialised series of containers has been developed in order to optimise the use of the rail mode. An example is the 6'4'' high container that can be triple stacked on a rail car. The 48' x 8' x 6'4'' unit can carry a payload of around 22 tonnes. Three 6'4''-high boxes are equivalent in height to two standard 9'6'' boxes doubly stacked. These intermodal US domestic boxes are designed to carry heavy and dense commodities and give the opportunity to load the equivalent of three highway trucks on a single rail car.

In Europe, land containers have been developed to optimise the loading of the common pallets used in Europe (Europallets). This kind of container has completely different dimensions than the ISO ones. These containers are wider, and particular care must be applied (e.g. not to stack them together with ISO ones). For this reason, warning labels are placed on their sides showing the effective width.

The UIC fiche 592-2 describes the dimension of land containers (marked as “T” containers) admitted to the rail network. They are grouped into 4 classes:

- Class 1 containers that have the same width as the ISO containers;
- Class 2 containers that have a width of 2,500 mm;
- Class 3 containers that are thermal containers having a width up to 2,600 mm;
- Class 4 containers are of the classes 1,2 and 3 having maximum gross mass of 4,000 kg.

All these container types are stackable (unlike swap bodies) up to three high.

2.3 Swap Bodies

Swap bodies were developed in Europe to carry the same volume as road vehicles, but with the advantage of being containers. They are mainly used in Europe for road-rail operation, although their use in sea and inland water is not precluded. Because, they are built to a less stringent standard than the ISO containers and have a soft superstructure, swap bodies are often not stackable.

Two classes of swap bodies are prevalent; A and C. Class C has a length of more than seven metres whereas Class A has a length of more than 12 metres. There is no set inner dimension for swap bodies. Table 2 shows the outer dimension of swap bodies.

Swap bodies are more compatible with standard pallet dimensions and are able to utilise the full advantage of their loading patterns. The disadvantage with ISO containers is that they do not offer as much volume when loaded with standard pallets, and thus, are not competitive against road transport and swap bodies for domestic transport activities. So, swap bodies are used more in intra-European transport than containers.

Table 2 Outer Dimension of Swap Bodies

Class	Type	Length (m)	Width (m)	Height (m)
A	A 1219	12.192	2.550	2.670
A	A 1250	12.500	2.550	2.670
A	A 1360	13.600	2.550	2.670
C	C 715	7.150	2.550	2.670
C	C 745	7.450	2.550	2.670
C	C 782	7.820	2.550	2.670

Source: http://www.haguidetofreight.co.uk/TechnicalInfo/id80.htm

2.4 Road vehicle dimensions

The maximum length permitted for rigid road vehicles is 12 metres. On the other hand, the maximum length permitted for articulated vehicles is 16.5 metres provided the combination can turn within the minimum sweep circle of 5.3 metres radius and the maximum sweep circle of 12.5 metres radius. Otherwise, the maximum permitted length is 15.5 metres.

The sweep circle requirement does not apply to certain types of combinations such as car transporters and vehicles constructed to carry exceptional loads. For road trains that are a rigid vehicle pulling a trailer, the maximum length permitted for the combination is 18.75 metres.

The maximum permitted vehicle width for vehicles and trailers is 2.55 metres for all vehicles exceeding 3500 kg. If the towing vehicle has a maximum permissible weight of less than 3500 kg, then the maximum permissible width of the trailer is 2.3 metres. Refrigerated vehicles have a maximum permissible width of 2.6 metres provided the thickness of side walls is at least 45 mm.

There are no legal maximum height limits for vehicles, but practical requirements limit the height to the obstacles prevailing along the route. Full details of the restrictions on vehicle dimension and weights are given in "The Road Vehicles (Construction and Use) Regulations 1986" and "The Road Vehicles (Authorised Weight) Regulations 1998". European limits are given in EC Directive 96/53/EC of 25 July 1996.

2.5 Pallets

A pallet is a platform of wood, metal or other material on which cargo is stacked and secured which is able to be moved by forklift or other handling devices. Although it can be adapted and designed for specific purposes, its major advantage is to follow standard dimensions, so it is interoperable and its transportation can be optimised. The following is a list of ISO regulation dealing with pallet characteristics (ISO, 2007):

- ISO 445:1996 Pallets for materials handling - Vocabulary
- ISO 6780:1988 General-purpose flat pallets for through transit of goods – Principal dimensions and tolerances
- ISO 8611:1991 General-purpose flat pallets for through transit of goods - Test methods
- ISO/TR 10232:1989 General-purpose flat pallets for through transit of goods – Design rating and maximum working load
- ISO/TR 10233:1989 General-purpose flat pallets for through transit of goods - Performance requirements
- ISO/TR 10234:1990 General-purpose flat pallets for through transit of goods - Phytosanitary (plant health) requirement for wooden pallets
- ISO/TR 11444:1995 Quality of sawn wood used for the construction of pallets
- ISO/TR 12776:1995 Pallets - Slip sheets
- ISO 12777-1:1994 Methods of test for pallet joints - Part 1: Determination of bending resistance of pallet nails, other dowel-type fasteners and staples
- ISO 8611-1: 2004 Pallets for materials handling - Flat pallets - Part 1: Test methods
- ISO/TS 8611-2: 2005 Pallets for materials handling - Flat pallets - Part 2: Performance requirements and selection of tests
- ISO/TS 8611-3: 2005 Pallets for materials handling - Flat pallets - Part 3: Maximum working loads.

The standard pallets most commonly used in Europe are the ISO type 1 (800mm x 1200 mm) and type 2 (1000mm x 1200mm). The dimensions of standard pallets had a great influence on the evolution of inland loading units. The 2.5m-wide inland containers and swap bodies gained their popularity as they allow the optimal transportation of two wooden Europallets (ISO type 1- 800mm x 1200mm) side by side, and they are therefore preferred to ISO containers. Europallets, with logo 'EUR', are also known as E pallets or CEN pallets. The Europallets were first developed by Swedish companies in 1940. The four most used sizes are:

- The "Pallet EUR" with dimension 800 x 1200mm;
- The "Pallet EUR 2" with dimension 1200 x 1000mm;
- The "Pallet EUR 3" with dimension 1000 x 1200mm; and
- The "Pallet EUR 6" with dimension 800 x 600mm (called a "half pallet")

Source: http://pallets.indinf.com/euro-pallets.html

2.6 Trailer Dimensions

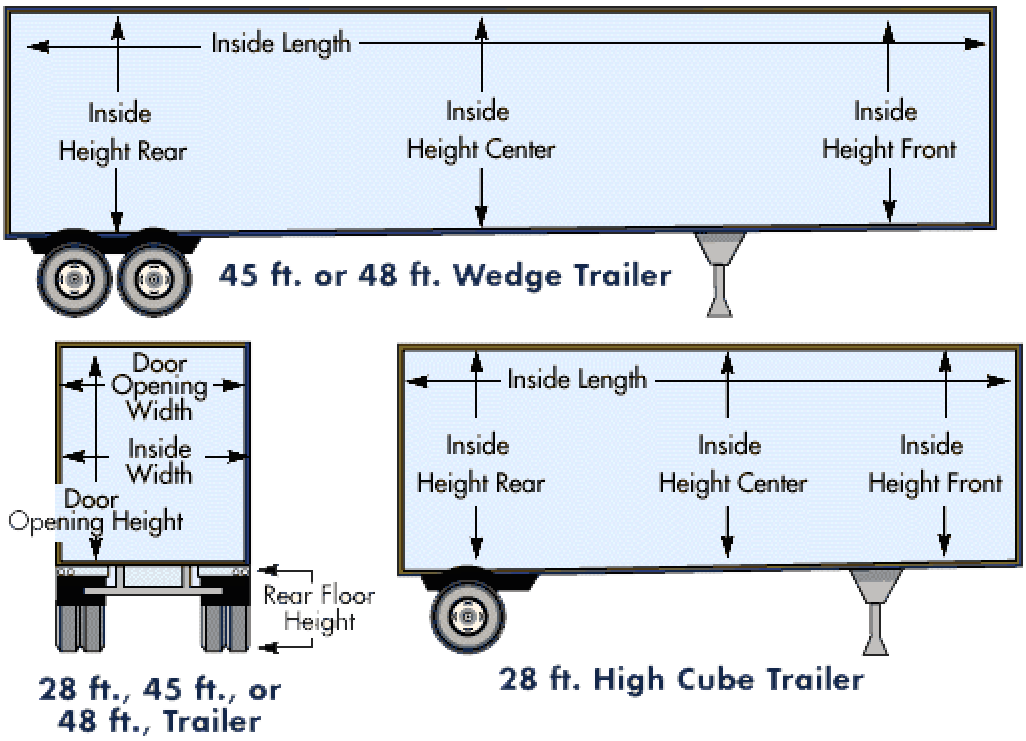
Figure 2 and table 3 show typical trailer dimensions

Table 3 Trailer Dimensions

	Length	Inside Width	Inside Height Rear	Inside Height Center	Inside Height Front	Door Opening Width	Door Opening Height	Rear Floor Height	Cubic Capacity	Overall Width	Overall Height
28' High Cube	27'3"	100"	110"	109"	107"	93"	104"	47-1/2"	2029 cft	102"	13'6"
45' Wedge	44' 1-1/2"	93"	112"	109"	106"	87"	105-1/2"	50"	3083 cft	96"	13'6"
48' Wedge	47'3"	99"	112-1/2"	110-1/2"	108-1/2"	93"	105"	48-1/2"	3566 cft	102"	13' 6"

Source: http://www.roadway.com/shippers/dimensions.html

Figure 2 Trailer dimensions



Source: http://www.roadway.com/shippers/dimensions.html

2.7 Semi Trailer

The noticeable difference between tractor units in the U.S. and Europe is that most European models are "cab over engine" (COE or forward control), while most U.S. trucks are conventional (or normal control). In European design, the driver's cab is normally positioned above the engine. For repairs, the entire cab hinges forward to allow maintenance access. European trucks, whether small rigid or fully articulated, have a sheer slab face on the front. This allows greater manoeuvrability, as the driver need only gauge distances behind his seating point, and this allows for shorter trucks with longer trailers (i.e. larger freight capacity) within the legal maximum total length. In Europe the entire length of the vehicle is measured as total length, while in U.S. the cabin of the truck is not normally part of the measurement.

From 2006, 25.25 m truck trailer combinations are to be allowed on restricted routes within Germany, following a similar (on-going) trial in The Netherlands. As in Scandinavia, these vehicles in The Netherlands will have a 60 tonne weight limit. Two types are to be used: 1) a 26 tonne truck pulling a dolly and semi-trailer, or 2) an articulated tractor unit pulling two semi-trailers linked by a dolly. The UK government has so far decided not to have these 60 tonne vehicles, but to monitor the other countries' trials.

Using a dolly, which generally has to be equipped with lights and a license plate, rigid trucks can be used to pull semitrailers. The dolly is equipped with a fifth wheel to which the trailer is coupled. Because the dolly attaches to a pintle hitch on the truck, manoeuvering a trailer hooked to a dolly is different from manoeuvering a fifth wheel trailer. Backing the vehicle requires the same technique as backing an ordinary truck/full trailer combination, though the dolly/semi setup is probably longer, thus requiring more space for manoeuvering. The tractor-semitrailer configuration is rarely used on timber trucks, since these will use the two big advantages of 1) having the weight of the load on the drive wheels, and 2) the loader crane used to lift the log from the ground can be mounted on the rear of the truck behind the load, allowing a short (lightweight) crane to reach both ends of the vehicle without uncoupling. Also construction trucks are more often seen in a rigid + midaxle trailer configuration instead of the tractor + semitrailer setup.

In continental Europe, most semi tractors have 2 axles, again with the front, steer, having two wheels, and rear, drive, having twin wheels on each side. Thus, the most common configuration has 6 wheels. The cargo trailer usually has three axles at the rear, with single wheels, or 6 wheels in total. The entire vehicle thus usually has 5 axles and 12 wheels in total, although the trailers can vary in number of wheels.

In Sweden the allowed length is 24 metres (78.7ft) for all vehicles and 25.25 metres (82.8ft) for trucks with two trailers. In 1997 the rules were changed, following the European Economic Area rules, allowing trucks to pull two trailers with a total length of 25.25 metres (82.8ft), assuming certain conditions were met, like ABS on all vehicles. In Finland most trucks can tow any trailer as long as the total length stays within 25.25 metres (82.8ft). The exception to this is a tractor unit pulling a semi-trailer, which can be only 16.5 metres (54.1ft) long. The allowed gross weight in both countries is up to 60 tonnes (132,277lb) depending on the distance between the first and last axle. In Sweden the old style tractor-trailer is still the most common, but in some areas, especially container haulage, 25.25 metre (82.8ft) vehicles are available. In Finland most new trucks and trailers are built with 25.25 metre (82.8ft) in mind.

In the UK, to carry the maximum permitted gross-weight of 44 tonnes, both tractor and semi-trailers must have 3 or more axles each and a maximum travelling height of 16' 6" (5.03m). No heavier vehicles are permitted on the UK road network, except for indivisible loads which would be classed as abnormal (or oversize), these vehicles are required to display an STGO

(Special Types General Order) plate on the front of the prime mover and under certain circumstances are required to travel by an authorised route and have an escort.

Most UK articulated trucks have 8 wheels on the tractor with either the centre or rear axle having single wheels which normally steer as well as the front axle and can be raised when not needed (i.e. when unloaded or only a light load is being carried), while the trailer unit has 3 axles with most modern trailers using super single wheels and most older trailers now also have been converted to super singles. In the UK two wheels bolted to the same hub are classed as a single wheel, therefore a standard six axle articulated truck is considered to have twelve wheels, even though it has fourteen tyres.

The Semi trailers in Advanced Intermodal Logistics study report (SAIL 2002) recommended that semi-trailer heights must not exceed 4000mm. An increase in road vehicle heights over 4000mm would signify a major restriction for intermodal transport, because it would technically be impossible to meet the requirements given by the railway loading gauge.

2.8 European rail intermodal wagons

The SAIL study (2002) found that within the national railways and the rail intermodal transport companies there are little differences or additional variants for the rolling material and consequently also for the loading units or for the transfer techniques. In the 40 years of Combined Transport many other systems have been conceived and successively prototypes have been manufactured. But in this case simple solutions requiring little maintenance proved to prevail. This is very important since wagons for Combined Transport are subject to an aggressive and intensive working environment.

2.9 Intermodal Trains

The gross mass of an intermodal transport train can reach 1500 tonnes with a total length of 600m. The average delivery distance amounts to 450-500km. The running performance amounts to 120,000 – 150,000km per year.

A comparison can be made with a normal freight car with around 15,000km per year. With the increase of higher speeds and loads of intermodal transport trains up to 120km/h to 140km/h, it is necessary that these wagons are suitable for such intensive operation, including braking system. An irregular load distribution on the wheel-sets can take place due to the fact that a train may transport empty, part as well as full loading units. So an over-braking of the less charged wheel-sets has to be avoided. On the other hand, the given braking distances, normally 1,000m, have to be followed. For this, intermodal transport wagons are equipped with a load-controlled brake with an automatic and infinitely variable effect.

Wagons in the European intermodal transport pool are built according to national and international railway directions. Should wagons diverge from UIC or RIV directions, an agreement between the national railway companies has to be reached as to their running authorisation.

It can be noted that the utilisation period of a Combined Transport wagon comes up to a depreciation time of about 15-20 years by the railways and Combined Transport companies, while road vehicles with their loading units depreciate within five years. The motor vehicle engineering is subject to a faster development due to this shorter depreciation time. So the long-life railway vehicles need regular adjustment measures.

2.10 Modalohr

Modalohr is a low-floor articulated railway wagon that enables the quick, safe and economical transhipment of standard semi-trailers from road to rail. The concept of Modalohr is proven and patented in commercial operation and is currently being used between France and Italy. More routes are in active consideration or will be opened soon including between France and Luxemburg. It allows horizontal loading of trucks to be directly carried out with the roadway tractor without any handling equipment. It does not require other roadway equipment, for example, the use of piggy-back trailers which is required in conventional combined transport and transhipment. The lateral loading of trucks facilitates simultaneous, rapid transhipment of the trucks. It uses a fully mechanical but very simple system, for articulation and opening of the wagons that significantly reduces maintenance requirement and cost. The transhipment terminal consists of simply built asphalt areas on either side of the railway track which are equipped with fixed operated opening systems installed on the track itself that can be easily serviced. The very low loading platform enables 4m high trucks to be loaded within the limits of existing railway gauges (UIC GB1). Source: http://www.modalohr.com/gb.htm

3 Efficient Terminal Operation

The business nature of container handling in a terminal is capital intensive. It is quite difficult to create service differentiation among terminals. Geographical location is one important factor. But, there is ample scope of improvement in terminal efficiency through horizontal integration with actors (Notteboom, 2002). Thus, today, the most important aspect of efficient terminal operation is to consider the terminal as but one integrated element of the complete door-to-door intermodal supply chain, and therefore to evaluate terminal issues within the general framework of the complete integrated transport chain. Its connection to the railway system is extremely vital because on the one hand it influences the terminal configuration by imposing operational constraints and on the other hand it is influenced by terminal performance. A rail terminal can appear as a competitive element through the efficient actions of three actors: firstly, the terminal operator, secondly, rail operators and thirdly, road transport operators.

3.1 Actions for the terminal operator

There are different terminal designs, layouts and handling equipment configurations, each being effective for a certain cargo volume range and restricted by its capacity limitations, which can be defined by its weakest sub-system. So, a single optimal terminal design and layout cannot be suggested. The two major sub-systems that restrict terminal capacity are:

The capacity of the (rail-side) transhipment tracks, and

The capacity of the terminal’s handling system.

The ITIP (2001b) Study suggests that the terminal's capacity limitations are mainly imposed by the capacity limitations of the rail sidings i.e. transhipment track sub-system rather than by the handling (sub-system) - equipment capabilities, at least for the majority of terminal configurations with limited rail-rail transhipments. Thus, the effective utilisation of siding tracks can dramatically improve the performance on the rail-side, but it imposes additional costs, which vary according to the handling technologies adopted. The major disadvantage of this system is that the incoming train has to be unloaded totally before it can be taken out of the transhipment area.

A truck pattern arrival linked to loading unit availability rather than train arrival could be helpful. This can be achieved by improvement of the communication between pre- and end haulage operators and the terminal. The other limiting factor, the capacity of the terminal's handling system, depends on the type and amount of equipment used (ITIP, 2001b).

3.2 Actions for Rail Operators

The rail operators play a key role in the development and efficient operation of a terminal. The choice of alternative technology and terminal design are mainly linked to the chosen operational forms over the rail network. The enhancement of the rail sector should be based on advanced rail forms since the technology is able to provide the required support (advanced/fast cargo container handling systems, advanced/improved rolling stock capable of intensive high speed service with high levels of reliability, advanced access systems, identification/location /positioning systems).Many of the items identified as being relevant to road transport operators (see next section) equally apply to rail freight.

Improvements of the rail operation are achieved through the complementary and comprehensive use of all operating forms (direct trains, feeder systems, shuttle-shuttle forms, liner trains, hub-and-spoke systems, full-load traffic).

3.3 Actions for Road Transport Operators

ITIP Study (2001b) suggests that the benefits accruing to road transport operators are linked to two groups of issues:

- Time-saving at the terminal gate, and
- Improvement of the overall quality of service.

The improvement in terminal performance will be primarily in assuring time-saving at the gate. Thus, the main focuses would be linked to quality factors such as reliability of delivery time, completeness of information, wider time windows for the delivery and collection of ITUs, etc. The road transport operators need efficient communication systems for the connection to terminal operators. Thus, an optimal arrival pattern should be feasible, with the spotlight on both the overall performance of terminal and for the individual shipment. A number of technologies are available and adaptable to the needs identified, but the main problems lie in the following:

- The needs have to be defined at a global level in a realistic manner (i.e. think global, act local) by the actors in the chain and not only by the operator.
- Obtaining synergies between technology, organisation and procedures is fundamental.

- Human factors are essential, so make it simple (i.e. information is good, communication is better).

4 Transhipment Functions

The transhipment, performed in intermodal terminals, can be of two types: inland terminals, located in rail yards, inland ports, or freight villages, providing for rail and road access and port terminals, if they are operated separately as a Rail Service Centre (RSC), or where transhipment between vessel, road transport and rail is taking place on the quay. They can either focus on maritime ISO containers if they are dedicated to marine terminal activities or they can offer mixed handling of maritime and continental loading units. In some cases the port terminal operators are extending their activity to the operation of an inland terminal or terminals top expedite the movements of boxes from the quay. Examples include ECT at Rotterdam port, Antwerp based terminal operator Hessenatie. (Notteboom, 2002) There could be another type of terminal: private transhipment facilities e.g. at shippers' sites, which do not ensure non-discriminatory access. The SAIL study (2002) recommended some precise characteristics and variations of transhipment functions and technologies listed in table 4.

Table 4 Transhipment functions at a Rail Intermodal terminal

Number	Area/ Function	Number	Area/ Function
1	Railway Operation	2	Internal Transport/ Buffer/ Storage
01	Entering into Reception Siding	21	Internal Transport
02	Transfer from Reception Siding to Transhipment Track	22	Storage
03	Identification of Train, Wagon and/or ITU	3	Roadside Transhipment
04	Change to new loading scheme (spigots, semitrailer)	31	From Road to Buffer/Internal Transport
05	Exit Transhipment Track	32	From Road to Storage
06	Wagon Inspection/Visitor, Loading gauge (Dispatch) Breaking test	33	From Road to Rail
07	Internal Transport/Buffer/Storage	34	(not applicable)
2	Rail-side Transhipment	35	From Road to Buffer/ Internal Transport
11	Unloading Rail to Buffer/Internal Transport	36	From Road to Storage
12	Unloading Rail to Storage	37	From Road to Rail
13	Unloading Rail to Road	4	Road Traffic
14	From Rail to Rail (direct	41	Pre-Gate Inspection of transport ability of ITU
15	Loading Buffer/Internal Transport to Rail	42	Gate Procedure

16	Loading Storage to Rail	43	Movement on Driving paths and parking
17	Loading Road to Rail	44	Driving and Loading Lane

4.1 Railway Operation in Terminal

The first part of the railway operation is "Entering into Reception Siding". This aspect becomes more interesting and complex when the railway infrastructure provider, train operating company and terminal operator are separate companies but have clear responsibilities. The same applies to the next function Transfer from Reception Siding to Transhipment Track (02), which can be done by different procedures:

- By electric locomotive under catenary,
- By momentum with electric locomotive,
- By a diesel marshalling loco (with e- loco connected),
- By a diesel shunting robot (with e-loco connected),
- By a diesel marshalling loco (only wagon connected, and
- By a diesel shunting robot (only wagon connected).

The next step is the Identification of Train, Wagon and/or ITU (03) - with personnel present at the station, between tracks or only at one side of the track or without personnel present at the station at all. Its execution is widely dependent on the application and coverage of automated identification systems and EDI support. If the loading is diverging between incoming and outgoing trains a change to a new loading scheme option (semi trailer) has to be fulfilled either:

- By wagon-based technology,
- By "robot" at the terminal, and
- By operators between tracks or at distinct places in the terminal.

Function 05 deals with the Exit of the transhipment track which can be done in a similar way to the alternatives given with function 02 as well as function 07 which is comparable to function 01. In-between commercial and technical reasons may require a Wagon Inspection/Visitor (06). They have to verify the technical status of the empty wagon, the conformance with the loading gauge in case of Dispatch and finally the braking test of the coupled wagons.

4.2 Rail-side Transhipment

For the rail-side transhipments, unloading and reloading of rail wagons has been distinguished. The directions are: a) from/to rail, b) to/from buffer/internal means of transport, c) to/from storage place(s), d) to/from road vehicle, and e) direct rail-to-rail transhipment can be foreseen.

The key issue of terminal management is to guarantee a timely and safe treatment of the transhipments. It is therefore necessary to develop rules for the sequence of operations and strategies for direct or indirect loading. In most existing terminals the so-called "direct" transhipment is seen as advantageous, because any additional handling causes additional expenditure. Indirect transhipment, especially in conjunction with innovative train and truck operation forms has to demonstrate its impact. However, the type of transhipment depends on the requirements of the network modes (clients) and not the terminal. Here, flexible adaptation to changing market requirements is recommended. Gateway systems for example, demand buffering of ITU and rail-rail movements.

4.3 Internal Transport and Buffer

Internal transport and buffer may be required in complex terminals in case the operation procedures of rail wagon and trucks cannot be matched or the customers demand the terminal to work as buffer place. Function 21 covers internal transport by either the crane, conveyors or “sorting tables” or mobile equipment, whereas function 22 is dealing with pure storage in either blocks or flat storage. The latter is space consuming whereas the former requires good organisation and/or continuous re-shuffling.

4.4 Roadside Transhipment and Road Traffic

Parallel to the rail-side transhipment, some functions may have to be carried out on the road or terminal yard area.. The functions 31 to 33 and 35 to 37 link the lorries with buffer or storage places and trains in either direction. In addition, road traffic in the terminal has to be organised as Pre-Gate Inspection of transport ability of ITU (41), the gate procedure itself (42), the organization and planning of movement on driving paths and parking areas (43) and the procedures in the driving and loading lane (44).

4.5 Terminal Organisational Structure

The approach is based on the identification of specific terminal characteristics that are considered important from the organisational point of view. The terminal characteristics are:

- Shunting operations schemes,
- Truck booking schemes,
- Cut-off time and acceptance of last minute arrivals,
- Percentage of direct and indirect train transhipments,
- Dwell time ability (more than one day) for incoming/outgoing loading units,
- Operational scheme for the empty wagons,
- Service/Storage preplanning activities, and
- Location (in or outside the terminal) of the truck parking.

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

- Truck service discipline,
- Instructions and priorities issued to and for Handling Equipment Control and Communication Systems.

Analysis of the above characteristics led to data concerning the organisational aspects of the terminal that are categorised into five main blocks:

Rail side operations,

General organisational issues,

Road-side Gate-in procedures and checks,

Terminal handling procedures, and

Road-side Gate-out procedures and checks.

The SAIL Study report (2002) suggests that the procedural aspects have dominated the organisational ones. The management breakdown for an intermodal terminal has largely been drafted independently from the precise organisational connection. All these jobs are performed in the terminal by either staff of the separate mode operators or the terminal.

5 Transhipment technique related projects

5.1 Integration of interoperable intermodal horizontal transhipment techniques in intermodal transport (IN.HO.TRA)

The project aimed at promotion of specific transfer technologies for intermodal transport. The transfer of loading units between different modes, through an improved system, must be less costly with improved reliability compared with existing technologies and methods of operation. The project introduced new operational approaches of horizontal transfer technologies in road-rail intermodal transport. This technique is particularly useful to organise economic road-rail transport on shorter distances. Also the integration of such systems in the existing operational systems was examined. The influence of these technologies on the design of current intermodal transport equipment and loading units was evaluated. Three different technology demonstrators were developed as “proof of concept” designs. Regrettably none has been developed further largely on the grounds of excessive technological complexity or cost compared to existing equipment already in active use and accepted by operators as a credible option for inter-modal transfer activities.

5.2 Integration of technologies for European short intermodal corridors (ITESIC)

The objective was to develop and demonstrate a one stop shop for intermodal freight transport in Short and Medium distance corridors by developing a working environment capable of covering the requirements of the logistics planners and operators. ITESIC attempted to fill up the gap between existing information systems that do not communicate to each other. It effectively, re-engineered the process of sending cargo to the corridors, eliminating, for instance, the need to send the same information to the maritime leg, the railway leg and customs, and replacing it with a single procedure capable of delivering the information to all interested parties regardless of the mode of transport that they operate.

Firstly, it tried to improve the services layer by applying information technology and transport telematics. Namely creating an Extranet connected to the existing EDI and information systems within the corridors. Secondly, transferring the impact of these technologies to the operational layer, re-engineering the necessary processes in order to meet the requirements of clients. Thirdly, maintaining a unified user interface, using standards to facilitate the harmonisation at a European level. The most important aspect of the ITESIC project was to consider the corridors as a unified transport system rather than a set of different transport services that are occasionally related to each other.

5.3 Innovative rail intermodal services (IRIS)

The project investigated Rail, Road and Short sea modes. The project showed, on the basis of the three demonstrators, that trucks currently dominate the field of transport, for short and medium distances, and whether this can be exploited by intermodal rail transport technologies or services. The project contributes to the EC policy to increase the use of intermodal transport in comparison to the mono-modal approach, to achieve sustainability of transport by a more balanced utilisation of capacities and, as a consequence, to increase the efficiency and competitiveness of the European economy.

5.4 Improvement of transfer facilities of the Port Bou terminal

The RENFE Intermodal Transport Terminal at Port Bou is used for ITU transfer in border transit at the Port Bou/Cerbere Complex for intermodal railway traffic for the International Freight Corridors that link the Spanish Mainland to the rest of Europe.

The port has a huge traffic volume but appeared to be a bottleneck in the corridors as it has limited handling capacity. In 1997 it handled 159,000 TEU, compared with 126,000 in 1995. The Terminal had two sectors of four gantry tracks, and each sector before the project had one useful gantry crane, one of them quite recent, with a revolving spreader, which was co-financed by the EC.

The project consisted of installing a new gantry crane with a revolving spreader at one of the terminal sectors, and also of renovating one of the runways of the gantry cranes that was in a very poor condition. With the implementation of this project, the terminal had three cranes that solved the bottleneck. It achieved a 15% increase in the capacity of the ITU transfer at the terminal, although the station had the problem of shunting. There was a 10% real increase in intermodal traffic handling capacity at the Border Complex. The ITU mean handling time at the terminal was reduced by 8%.

Punctuality and reliability of train departures dispatched by the terminal is around 100%.

5.5 CargoSpeed- transhipment technique for semi trailers

The project CargoSpeed conducted a feasibility study for an innovative concept for the faster transfer of semi-trailers permitting rail freight to operate as a sustainable intermodal transport system with high-throughput and efficiency. It brings in Roll-On-Roll-Off technology and efficiency to the road/rail sector and aims to halve the economic break-even distance to around 300 km. The CargoSpeed Road-Rail system is comprised of rail well-wagons equipped with moveable well-floors which rest securely in the wagon wells. The well-floors carry non-craneable standard semi-trailers on top. Between the rails in the interchange terminals ‘Pop-Up Mechanisms’ (PUMs) are positioned. A train arriving at the terminal from either direction locates the wagons over the in-terminal PUMs within a train positional tolerance of 70 centimetres. The PUMs rise to engage the well-floors followed by elevation to pop-up and rotate the semi-trailers into precise alignment with waiting truck cab unit. which have been pre-positioned between kerbs on either side of the rail track. (Source: http://www.cargospeed.net/).

6 Transhipment Techniques for Rail-Road Terminal

All transhipment functions at rail-road terminals can be performed through four types of techniques: i) transhipment devices, ii) transhipment and internal transport devices, iii) internal transport equipment, and iv) stacking devices.

6.1 Transhipment Devices

In this functional category the ITIP study (2001b) found the following systems:

- Fast Transfer TECHNICATOME COMMUTOR Handling Device and
- KRUPP Fast Handling Device

6.1.1 Fast Transfer TECHNICATOME COMMUTOR Handling Device

The COMMUTOR fast transfer handling devices are composed of the transhipment equipment that is designed and developed as loading units (container and swap body), the rolling stock (wagon or truck) and the spreader. The COMMUTOR transhipment equipment is equipped with a typical spreader allowing automatic handing. The spreader uses the bottom lift technique in order to be able to handle different types of loading units on its own. It can be:

- “static”, with a fixed length, able to handle all the loading units present on a wagon during only one move, or
- “mobile”, with adjustable length.

The transhipment equipment can be:

Uni-directional bridge crane-perpendicular to the rail track can move within one “span” corresponding to a wagon that is accurately positioned in this span, or

Bi-directional rolling gantry crane can move in both directions - perpendicular and parallel to the rail track.

6.1.2 Krupp Fast Handling Device

The automatic loading and unloading of flat-wagons in the transhipment plant and in general between two service places - is carried out by Fast Handling Devices. The operating range of the system spans one loading track, one empty track and one service position e.g. for transhipment to a cross conveyor or skid/pallet-system. The rail of the crane bridge is elevated on one side in order to show the cross conveyor operation.

The Fast Handling Devices can be moved over the whole length of the transhipment area in order to achieve redundancy. They are designed to adapt individually to varying configurations of transhipment plants. Also the storage lanes can be served by extending the bridge.

The loading units are picked up by a spreader which is equipped with telescopic pivots for varied container sizes as well as gripping pliers/grappler arms for swap bodies and semi-trailers. All typical container lengths (20', 24', 30', 40' and 49'), swap bodies (between 6.25m and 13.6m) and semi-trailers up to 13.6m can be transhipped automatically. The loading units can have a maximum weight of 42 tonnes.

After picking up the loading units by the Fast Handling Devices the bodies are transhipped to the feeder position for the internal transport. The cycle time of transhipment (from picking up a loading unit, via transport to the feeder position, then back to the picking position for the next loading unit) amounts to about 35 seconds for containers and 72 seconds for semi-trailers.

In the transhipment area there is no catenary installed. The train enters up to an exchange point. Then the train is moved by a switching engine or by a special train-push/pull-device through the transhipment area. The whole Fast Handling System is carried out by the following components:

- crane way,
- crane bridge,
- trolley with lifting gear,
- telescopic spreader,
- absolute distance measuring system,
- sensors and data transmission unit.

6.2 Transhipment and Internal Transport Devices

In this functional category the vehicles are equipped to serve both functions: transhipment and internal transport/transfer. They include Terminal Truck (Swap Body) and Self Loading AGV Robot, which are discussed below.

6.2.1 Terminal Truck with Lifting Device for Swap Bodies

This is special equipment with a hydraulic lifting system that can tranship and transport swap bodies of lengths from 7,150mm up to 8,130mm (according to DIN EN 284). It can also transport containers and move trailers and semi-trailers with a one-man-operation. One manufacturer's example is INNOVA. All safety measures and regulations have been taken into account in the design procedure to ensure a continuous and risk-free operation.

6.2.2 Self loading AGV Robot

The self loading Automatic Guided Vehicle (AGV) is a robot. It transports/ transfers boxes from one location to another, with free movement in all directions. It can navigate by reference to passive beacons set in the ground.

The movement of the AGV can be longitudinal with a normal run by symmetrical rotation of the wheels, or transversal by rotation of the wheels on a 90° angle. The vehicle can therefore draw in below a storage table with accuracy. The AGV robot is self loading and is able to handle boxes by itself. It can pick up a box from a storage table or set a box down on a storage table, by means of an auxiliary vertical move of the platform of the vehicle. The AGV can also be loaded or unloaded by means of a crane or any other vertical transhipment device.

6.3 Internal Transport Equipment

In this functional category the following systems can be listed:

- Shuttle Wagon (Navette)
- Multi Trailer System (MTS)
- Skid/Pallet (Longitudinal Conveyor)
- Skid/Pallet (Cross Conveyor)
- Moving Train
- Other Conveyor Concepts
- Bi-directional Rail mounted Shuttle “B+”
- Train Transfer and Positioning Devices

6.3.1 Shuttle Wagon (Navette)

The shuttle wagons are automatic and autonomous wagons, designed for the COMMUTOR concept to ensure with accuracy the longitudinal transfer of boxes along a rail track. For the COMMUTOR high flow application - as each overhead crane moves the boxes within its span–shuttle wagons are used when span changing is needed: they move the boxes from one span to another. The shuttle wagon is self propelled, electrically fed by a cable trolley situated on the rail-side and able to position itself with accuracy within a span. These shuttle wagons can be used for any other application, e.g. for the automatic transportation of boxes within a terminal or even between terminals.

6.3.2 Multi Trailer System (MTS)

The MTS is designed and developed by ECT, especially for the Delta Terminal (Rotterdam), where it is successfully employed in the main transportation system. The system basically consists of a heavy duty tractor coupled to a train of five trailers (wagons). The tractor is a customized 415 horsepower FTF design, capable of towing up to 400 tonnes. The FTF is equipped with an automatic coupler, operated from the driver’s cabin, for coupling and uncoupling complete trains.

Each trailer is fitted with two steerable four wheeled axes connected by means of a computer designed steering mechanism that results in the trailer’s exact tracking of the truck’s path. Each trailer may carry one 40’ or 45’ container or two 20’ containers with a total weight of up to 50 tonnes. The trailers are designed to be used in conjunction with chassis loaders on the crane. The MTS is in fact a buffer in itself, capable of accepting the fluctuations in crane cycle time without delay to the crane. This results in better crane productivity with fewer drivers necessary for transport per crane than a yard tractor/chassis operation. An average performance of 40 containers per crane per hour in Delta Terminal is achieved using two tractors per crane.

In the buffers, located in the stack, the MTS-trains are towed in by the tractor and uncoupled when lined up. The driver then picks another train from the buffer and proceeds to the crane in much the same way as is done in the tractor/chassis operation. The total savings in the transportation system costs of the MTS, compared to the conventional yard tractor/chassis system, is about 20% in ECT's situation. It requires more capital cost, but results in substantial savings in labour, maintenance, energy, tyres, less damage, safer handling and higher crane productivity.

6.3.3 Skid/Pallet (Longitudinal Conveyor)

Skid and/or Pallet Systems can be utilized for longitudinal movement of loading units or transport crosswise (perpendicular) to the rail track or other tracks in a terminal as well as in the application of crosswise transport of units in a Fast Handling System linking rail and road. The skid systems consist of passive frames to carry the loading units and guide ways which compose also the actuation system. The pallets are self propelled, but need guide-ways and power and data lines.

6.3.4 Skid/Pallet (Cross Conveyor)

Apart from longitudinal movement, a skid and/or pallet system can be used for the transport of loading units between fixed points or feeder-points. It allows quick transfer with high performance under automatic control. The pallet system takes over the loading units from the handling system on the rail track-side and moves them into the store or directly to the feeder position which is in the rail-road terminal and directly to the truck loading lane. The cross conveyor consists of single, electro-mechanically accelerated palettes controlled by the central processing unit. They operate on rails which are situated in the cross lane. One level beneath them, a second rail-system allows the retrieval of empty pallets. At the other end of the conveyor there is a crossbar lifting table to connect both transport systems and to allow movement of pallets in a circuit. In the middle of the lane a third crossbar lifting table is possible. The truck and train loading is disconnected and two circuits are running in opposite directions. An appropriate control and security system is integrated. The cross conveyor serves the following functions:

transport into the storage area,

transport to the feeder position for direct transhipment to the truck lane,

buffer for the speedy unloading of trains as well as

pre-sorting when reloading of the train.

6.3.5 Other Conveyor Concepts

The basic designs of conveyor concept were included:

- Equipment to equipment conveyor
- Internal transport conveyor
- Overhead conveyor

6.3.5.1 Equipment to equipment conveyor

This transhipment device is additional equipment in the transhipment activity, that can interchange containers between a harbour crane (or self-unloading ship) and the internal transport. The basic concept of this conveyor is to match the productivity of two pieces of equipment and to provide buffers where possible. Matson Terminals Inc. has developed a conveyor of this type to support the sea-side operations of a container terminal. This conveyor was installed in the company's container terminal in Los Angeles. The equipment is rubber tyred and follows the shore side crane automatically.

The main feature of this container conveyor is to bridge the gap between the yard crane and the vessel crane, allowing direct transfer of containers between the two equipments without chassis or straddle carriers. Provision was made to use the container conveyor between two yard cranes. This permits fast re-handling of containers from one area to another without intermediate handling.

Advantages:

Eliminates traffic interferences in the yard and under the crane

Reduces hoist travel

Improves crane productivity without major redesign in the crane structure

The rubber tyre conveyor can be assigned to different ship-cranes (one at a time)

Disadvantages:

It is additional equipment and that means additional purchase and maintenance costs.

It was designed for a special purpose (ship to quay transfer) but is not very efficient in other terminal activities in comparison with a straddle carrier. Note that a straddle carrier can be used - not so efficiently - to do the conveyor's job on the quay.

The primary container handler will be the yard crane. It will be matched to a vessel crane for vessel loading and discharging and, when not working on vessels, to a defined area for serving community truckers. The transtainer is used to service trucks during the times when the yard crane is working on the vessel or during peak periods when additional capacity is needed. It will operate under the yard crane so that containers handled will be accessible to both.

6.3.5.2 Internal transport conveyor

The internal transport conveyor is built to shift containers horizontally between the shore-side crane and a stacking crane (e.g. Container system Meeusen Consultants BV, Netherlands). This internal transport system is similar to the Longitudinal Skid Pallet system (discussed in section 6.3.3).

6.3.5.3 Overhead conveyor

The specific design has been developed by Translift GmbH and IFK Karlsruhe but similar conveyors have been developed by other designers too. It consists of an elevated crane way which is capable to carry a number of vehicles/ trolleys. The crane way is designed for straight line and bows. It is also possible to include switches. The vehicle is composed of a trolley with lifting gear and a telescopic spreader. A distance measuring system, sensors and a data transmission unit also have to be installed. It could be possible to consider the type of conveyor as "additional internal transport"

Another type of overhead conveyor combines with "internal transport conveyors" and transhipment devices to perform all the transport and handling activities on ship side. The crane way is built to reach over the quay wall to span the ship, which has to be moved in order to reach all the bays for containers.

6.3.6 Moving Train

The moving train supports the Krupp Fast Handling System (discussed in section 6.1). Its main advantage is that no further equipment for longitudinal movement of loading units is necessary and all loading units pass the transhipment plant automatically, moving on rail cars. Therefore the transhipment area can be very compact.

6.3.7 Bi-directional Rail mounted Shuttle “B+”

The bi-directional shuttle B+ is an automatic device designed for COMMUTOR.

The purpose is to provide dynamic storage of boxes. The device ensures:

Gripping of boxes situated on storage tables from underneath. The gripping and the setting down are performed by a vertical move of the main platform of the shuttle.

Fast moves of boxes on two perpendicular axes by moves of the main platform of the shuttle on a network of orthogonal rail tracks.

6.3.8 Train Movement and Positioning Devices

Train Movement and Positioning Devices assist the train operation in terminals. The main producers of this specific equipment are De Dietrich (France) and Windhoff (Germany). Remote-controlled locomotives are produced by many important companies specialized in shunting locomotives. The different concepts are available in the market:

- Semi-automatic fixed installation: is a system of chains and hooks that moves wagons or a group of wagons;
- Automatic fixed installations: they are special chariots in the space between rails which move groups of wagons or in some cases complete trains;
- Remote control locomotives move trains or train sections
- COMMUTOR train transfer and positioning devices

The main advantages of these devices are:

reduction of investment costs, through simplification of installations (mobile loading machinery, etc. are rendered unnecessary),

reduction of operating costs, since there is no equipment for skilled labour assigned to handling operations only, reduction of maintenance costs, through the use of rugged and sturdy equipment This equipment is in use in over 3,000 installations all over the world, in mines, petrochemicals, metal refineries, steelworks, agricultural co-operatives, cement works, container terminals, railway companies.

6.3.8.1 Semi-automatic fixed installations

With this system chains and hooks move wagons or group of wagons. The system is used in small installations and can be useful only in the case of a low quantity of wagons or groups of wagons. The cost of the equipment is very low. We list some kinds of this equipment:

SEMI-AUTOMATIC/SIDE CHAIN

Manual fixing of a chain to a hook on the side of the wagon, the chain being pulled by a rope alongside the track.

SEMI-AUTOMATIC/SIDE CARRIAGE

An electrical motor drive by means of gears and a system of ropes; the ropes drive a carriage which runs on a section member or rail alongside the track. A rigid bar or sling is manually fixed from this carriage to a hook on the side of the wagon.

SEMI- AUTOMATIC/BALLAST VEHICLE

An electrical motor drive by means of gears a system of ropes; the ropes drive a two-axle ballast vehicle on the main track, which is attached manually or automatically to the main coupling of the wagon. This is an uncommon application which is made for the handling of barges and other vessels alongside quays. The rope drives two carriages along a section member or rail along the quay, and the hawsers are mutually fixed to the carriages.

6.3.8.2 Automatic fixed installations

Special chariots in the space between rails move a group of wagons or in some case complete trains. The equipment is used in large terminals and shunting yards. The equipment is based on chariots driven by a system of ropes; the ropes drive a carriage which runs on an auxiliary track inside the main track.

Wagon axles are engaged by trolleys on the carriage activated by remote control. Electric motors and gears control the movements of the ropes.

The ends of the haulage cable are fixed to a low-level carriage, which runs inside the main track on an auxiliary track, or even in some cases on the rail feet. The carriage is fitted with retractable arms and rollers, of which the transverse motions of extension and retraction can be carried out at a predetermined point or by remote control at any location. The rollers engage the wheels of a wagon axle, so that the haulage force can be applied in either direction. All hooking, unhooking and control operations are carried out by remote control, without the need for personnel along the track at any stage of the marshalling operation. This arrangement is suitable for repetitive operations, (wagon formations of 1,500 tons and over), enables precise positioning, passage over a weight-bridge, feeding a rocker, etc., and is adaptable to most track gauges in use. It can obviously be included as part of a complete automation system. There also is an automatic pusher (pushing only), which consists of a unidirectional pushing device acting on the axles of the cars, without the use of hooks.

6.3.8.3 Traction Robots and Locomotives with Remote Control

Increasingly locos without a driver on board are employed; the locos are remotely controlled by an operator on fixed installations. Speed can be very low 2-6 km/h in order to present vehicles to a fixed installation for loading/unloading and 10+15 km/h for transferring trains in shunting yards. Different protocols of radio control are used and the robot can be equipped with automatic couplings. The cost of these robots is important and comparable with shunting locomotives. The main advantage is the possibility of safe-operation without a locomotive driver.

6.3.8.4 COMMUTOR Train Transfer and Positioning Devices

In the TECHNICATOME COMMUTOR process, the whole train must be moved and centred by means of positioning devices, so that each wagon is positioned in the middle of its span and right beneath its crane, before automatic handling can begin. One positioning device every 5 wagons is needed to have the whole train positioned. Several technological solutions have been developed, including:

- hydraulic (jack or motor),

- chain or cable drive, with hydraulic winch.

The device commonly used pulls or pushes on a part of the wagon. The positioning system must comply with the following main requirements:

Automatic operation: for the positioning of the whole train, as soon as the train is initially stopped in a correct range by the locomotive driver.

Security: any risk of interference with the elements of the bogie must be eliminated, especially when the operation starts after the train stop.

Strength: the device develops strength in relation to wagon rolling, slope, starting and acceleration, deceleration and braking, compression of the wagon couplings, efforts by spreader during automatic handling.

Speed: the devices have a sufficient speed to allow a total positioning time under 3 minutes for the train.

For a train of 750 m length, different kinds of positioning devices can be disposed along the rail track in order to optimise the investment and operation: long stroke positioning device at the head of the train and/or short stroke positioning devices for the other elements between head and rear of the train.

6.4 Stacking Devices

In this functional category the ITIP study (2001b) found the following systems:

- Portal Crane for Stacking
- One-Arm Crane (Stack Lifter)
- High-Rack Handling Device
- Mechanical Storage

6.4.1 Portal Crane for Stacking

The portal crane for stacking operations is very similar to the one designed for transhipment. In fact, in most cases the transhipment crane fulfils storage functions. This semi-gantry crane consists of the following components:

- Crane way,
- Semi Gantry,
- Trolley with turntable and hoisting machinery,
- Anti Sway Device,
- Telescopic Spreader,
- Control.

6.4.2 One-Arm Crane (Stack Lifter)

The O & K Stack Lifter is similar to a deck crane of container vessels. The stack lifter is able to serve all areas in the terminal such as quayside, train and road separately so while working they are not interfering with one another. The stack lifter consists of a foundation column, a basic jib, a top jib and a top turntable. The overall outreach between centre column and hoisting axle is 44.5m, but greater outreaches are possible. The operator’s cabin is situated beneath the hoisting gear under the top turntable. Each stack lifter serves 1255 TEU stacking spaces over the entire range of five container-tiers. On average 36 duty cycles per hour can be achieved.

6.4.3 High-Rack Handling Device for Shelf-Store

For short and middle term storage of containers, swap-bodies and semi-trailers within the Fast Handing Terminal a shelf store has been conceived as one possible element of the KRUPP Fast Handling System. In order to meet the varying capacity-requirements the shelf store is of modular design and can be configured according to the demand. It is composed of an end module on the left and right side of 16m length each and several middle modules. The middle modules are carried out with lengths of 16m and 32m alternatively. The shelf modules have from three up to six floors and from eight up to 16 columns. Due to this modular concept the capacity meets the requirements and allows an optimal utilisation of the area of the estate. The whole Shelf Storage has the following components:

- Shelf Store Hall,
- Hall for Cross Transport Device (Skid Pallet System),
- High Rack Handling Device with Transversal Bridge,
- Hoisting Bridge and Channel Vehicle with Telescopic Spreader.

7 Summary of the-state-of-the-art

The role of a terminal is crucial for intermodal door-to-door transport. Due to extra handling time and costs in a terminal compared to unimodal road transport, it is a big challenge for intermodal transport. Thus the terminal must be time and cost effective and reliable. To get a reliable service from a terminal it is important that the right transhipment technique is used. Another important feature of intermodal transport is unitised or containerised cargo. If the containerised cargo is standard i.e. ISO containers then the terminal operator can use a standard technique. But it is true that increasingly non-ISO cargo units such as swap bodies are being used in Europe as well as in the US. Thus, this is an extra issue that has to be taken into consideration to adopt a terminal transhipment technique. The problems of non-ISO containers include non-stack-ability as its superstructure is soft compared to ISO containers. Thus it requires extra care in handling and extra space in storing. In contrast, the ISO containers can be stacked up to 10 high. Thus, it requires less space for storage. On the other hand, swap bodies have advantages over ISO containers. The dimensions of swap bodies suit the standard pallets (ISO type 1), thus the total space of a swap body is fully utilised, which is the main cause of its popularity in Europe for continental transport. But, the ISO containers do not offer as great a volume when loaded with standard pallets and thus are less used Europe for domestic traffic. So, the importance of swap bodies cannot be denied. On the other hand, ISO containers are dominantly used in maritime and inland shipping and the vessels are built to fit ISO containers to the full extent and the terminals in worldwide ports are equipped with a standard handling technique. So, for some international trade in Europe the ISO containers will be used.

Apart from these two types of cargo units there are (semi) trailers with different dimensions (size and weight) in Europe as well as in the US. Intermodal train wagons are built according to national and international railway directives. Thus, an agreement between the national companies has to be agreed. Modalohr is a proven and patented concept that allows quicker and low cost horizontal transhipment between road and rail. To date it operates on a very restricted line of operations and has not yet achieved a wide acceptance.

Efficient terminal operation can be achieved through the integrated efforts of main three actors: the terminal operators themselves, the rail operators and the road transport operators. The terminal operator must be a part of total integrated transport chain, not just a cargo transfer station. A single optimal terminal design, layout and configuration cannot be suggested as there are many options each being effective in certain cargo transfer situations. The terminal's capacity limitations are mainly imposed by the capacity limitations of the rail sidings that is by the transhipment track sub-system rather than by the handling (sub-system) i.e. equipment capabilities, at least for the majority of terminal configurations with limited rail-rail transhipment. Thus, an effective utilisation of siding tracks can dramatically improve the performance on the rail side, but it may imply additional costs, which vary according to the handling technologies adopted. Thus, the choice of alternative technology and terminal design, layout and configuration are linked to rail operations and operators. On the other hand, the improvements of the rail operation are achieved through the complementary and comprehensive use of all operating forms (direct trains, feeder systems, shuttle-shuttle forms, liner trains, hub-and-spoke systems, full-load traffic). The terminal efficiency through road transport operator can be achieved in two ways: time savings at the gate and improved service quality. Most modern terminals are now achieving time savings at the gate. Thus the main thrust should be the continued improvement of service quality.

The key issue of terminal transhipment is to guarantee a timely and safe treatment of the transhipments. It is therefore necessary to develop rules for the sequence of operations and strategies for the direct or indirect loading. The transhipment functions can be broadly two types: inland and port terminal. In the port terminals mainly the ISO containers are transhipped (between rail/road and quay). However, a mixed port terminal can handle other cargo units as well. On the other hand, in the inland continental terminals all types of cargo units are transhipped. The transhipment functions in a typical rail terminal can be divided into four: railway operation, internal transport/buffer/storage, rail-side transhipment and roadside transhipment. Railway operation in the terminal includes functions such as entering into Reception Sidings and/or direct transfer to transhipment track by locomotive, (manual and/ auto) identification of train, wagon and/ITU, and lastly exit from the transhipment track by the mainline locomotive. The rail-side transhipment includes a) from/to rail, b) to/from buffer/internal means of transport, c) to/from storage place(s), d) to/from road vehicle, and e) direct rail-to-rail transhipment can be foreseen. Option (E) could be of interest and value in the context of intersecting corridors. In most terminals the "direct" transhipment is seen as advantageous, to avoid additional expenditure. However, the type of transhipment depends on the requirements of the network modes (clients) and is not a rule of the terminal. Thus flexibility is recommended in the face of varying shipper/receiver requirements and imperatives.

Internal transport and buffer may be required in complex terminals in case the operation procedures of rail wagon and trucks cannot be matched or the customers demand the terminal to work as buffer place. The internal transport can be performed by crane, conveyors, "sorting tables" or mobile equipment. Parallel to the rail-side transhipment, some functions may have to be carried out on the terminal yard area. The lorries can be linked with buffer or storage places and trains in either direction. Also, the road traffic has to be organised as Pre-Gate Inspection of transport ability, the gate procedure itself, the movement on driving paths and parking areas and the procedures in the driving and loading lane.

The transfer of loading units between different modes, through an improved system, must be less costly with improved reliability. With this objective there are many projects funded by the EC. The (IN.HO.TRA) project promoted specific (horizontal) transfer technologies for intermodal transport. Terminal operation demands online (real time) optimisation and decision (Steenken, et al, 2002). The ITESIC project was implemented to develop and demonstrate a one-stop-shop for intermodal freight transport in short and medium distance corridors by developing a working environment capable of covering the requirements of the logistic planners and operators. It attempted to fill up the gap between existing information systems that do not communicate to each other. Effectively, re-engineering the process of sending cargo to the corridors, eliminating, for instance, multiple efforts to send the same information to many parties including the maritime leg, the railway leg and the customs, and replacing it by a single procedure capable of delivering the information to all interested parties regardless of the mode of transport that they operate. The IRIS project investigated Rail, Road and Short sea modes on the basis of the three demonstrators of how trucks dominate the field of transport on short and medium distances and whether it can be exploited by intermodal rail transport. The Italian IT platform demonstrated at the Bologna inland terminal set out options to use an open architecture to integrate and facilitate the movement of information between various actors on site to improve efficiency and reduce delays, information loss and re-entry requirements. The project 'Improvement of transfer facilities of the Port Bou terminal' was implemented to upgrade the capacity of the terminal by acquiring some handling equipment. The feasibility study project 'CargoSpeed' is an innovative concept for the faster transfer of semi-trailers permitting rail freight to operate as a sustainable intermodal transport system with high-throughput and efficiency. It brings in Roll-On-Roll-Off efficiency to the road-rail sector and aims to halve the economic break-even distance to around 300 km.

The whole transhipment functions at rail-road terminals can be performed through four types of techniques: i) transhipment devices, ii) transhipment and transfer devices, iii) internal transport equipment, and iv) stacking devices. The transhipment device includes Fast Transfer Techicatome Commutor Handling Device and KRUPP Fast Handling Device. The Fast Transfer Techicatome Commutor Handling Device is composed of transhipment equipment that is designed and developed as loading units (container and swap body), rolling stock (wagon or truck) and the spreader. On the other hand, the Krupp Fast Handling Device is an automatic loading and unloading device for flat wagons. Its operating range spans one loading track, one empty track and one service position. The terminal trucks with hydraulic lifting devices are used for transhipment and transport of swap bodies, containers and trailers. On the other hand, the self-loading AGV Robot is used for transfer and transport of containers from one place to another. It navigates by reference to passive beacons set in the ground. Moreover, there are other internal transport equipments such as the shuttle wagon, and the multi-trailer system. Stacking devices include portal crane, one-arm crane, and high rack handling devices.

8 Transhipment techniques on the RETRACK corridor

8.1 Transhipment techniques

In relation to sea-rail transfer Retrack will have little or no direct bearing on the selection of trans-shipment technology. The main ports at Rotterdam use the full panoply of lifting and transfer equipment including gantry cranes working in multiple, automated guided vehicles for movement within terminals, front end loaders, straddle carriers and fork lift trucks. All of these are used in combination within the marine-rail interface. The high levels of automation already achieved in Rotterdam is notable as this sort of technology is probably going to be deployed in further terminal developments within the port.

In Constanza a similar position applies in that the port and proposed extensions already have a mix of terminal equipment (gantry cranes, front end loaders etc) in place and for the proposed extension at this end of the corridor.

At some inland terminals inspected along the corridor the option of tri-modal interchange is in place for the movement of containers between trains, trucks and inland shipping. This is the case in Dusseldorf, Duisburg, Worms, Mannheim, Ludwigshaven, Nuremburg, Vienna & Budapest. Ironically the exchenge of containers between water and other modes, whilst provided for with cranes in Nuremburg & Vienna has been less heavily used than anticipated so the tri-modal option may be less attractive than originally planned.

In all of the terminals visited along the corridor the operators of the terminal have elected to deploy a range of trans-shipment technologies and not confined their operation to any specific option. The mix of gantry and reach stackers is the most common model based on individual terminal throughput, configuration, equipment weight footprint and terminal foundation strength as well as the usual acquisition and operational choices.

For road to rail a similar situation applies. In Rotterdam the terminals inspected also deployed a mix of gantry cranes and reach – stackers to service the inter-modal traffic (ISO containers, 45' high cubes, trailers and swap bodies). Similar situations applied in most of the other terminals. Only one smaller terminal, Worms, relied completely on reach-stackers. This was a function of the terminal layout and size constraints. In none of the terminals was there any immediate interest in horizontal transfer technologies as this appears to be still largely undeveloped and untested in front line commercial service.

8.2 Cost related issues

In terms of the cost analysis of container handling systems the following general considerations apply:

- Definition of terminal productivity targets/production rates per hour or per day.
- Required stack size, stack handling capacity and location of stacks in relation to train loading/unloading pad areas
- Terminal configuration and point load weight limits
- Alternative equipment performance capabilities in terms of cost and physical performance to manage a planned/targeted production level
- Possible growth and expansion options
- Terminal command, control and communications systems
- Terminal IT and planning methods.

Planning models for terminal equipment need to reflect:

- The estimated number of cranes and other lifting equipment forecast for up to 30 years forward from commissioning with possible mid-life refurbishment and upgrading.
- Total terminal investment costs including infrastructure, yard pavement areas, rail tracks, maintenance and renewal costs
- Operating costs including fuel/energy consumption, maintenance, replacement and upgrade costs

- Number of hours per year for actual cargo operations, maintenance and any infrastructure modifications.
- Actual cargo throughput planned and achieved
- Recognition of applicable hours of operation per day/week.

The cost per move will be a function of all of the above plus the financial criteria the terminal owners/investors are required to respond to in terms of the cost of capital, sources of funds (private or state support), any operating subsidies and grants and possibly some non-accountable issues such as environmental cost measures such as noise abatement.

In relation to the terminals inspected the cost per container movement is directly linked to terminal throughput but no commercial tariffs were made available except in Vienna.

8.3 Noise related issues

Noise related issues were not identified as a key item in discussions with terminal operators along the corridor except in one terminal located deep within the urban area of Vienna. This terminal was previously an old style goods shed for the inter-modal transfer of goods & parcels between rail and local city delivery vehicles. The terminal has been modified to act as a container base for road-rail container, trailer and swap body traffic but still retains the cargo sheds on site for container stuffing and stripping. There is a heavy flow of HGV traffic in and out of the terminal during the hours of operation in addition to the container handling activity (a mix of gantry cranes and front end loaders). The cranes are electrically powered and rail mounted so do not generate a significant amount of noise when moving. The major noise generation is from containers being grounded, lifted on and off stacks (container reverberation and engine noise from mobile lifting equipment) and loaded on and off rail vehicles. HGV circulation is also a significant source of noise generation. There is also some noise from the flanges of rail vehicle wheels whilst being propelled in and out of the terminal.

Because the terminal function has changed and has over time become surrounded by residential dwellings the terminal has been constrained in terms of hours of operation with no over night working and restricted hours of operation over the weekend. This constraint will, with others rule out the use of the older terminal in Vienna on the grounds of inflexibility and the noise constraints.

All the other terminals inspected were in designated industrial areas or port areas well away from residential areas and no noise constraints applied.

8.4 ITESIC implications for Retrack

The primary objective of ITESIC was to develop and demonstrate a one stop shop for inter-modal freight transport in short and medium distance corridors capable of fulfilling the requirements of logistics planners (forwarders) and operators. The project applied IT technology and telematics support, re-engineered processes to satisfy users requirements and maintained a unified user interface and standards to facilitate harmonization at a European scale. The overarching part of the concept has been to consider the corridors as a unified transport system rather than a set of separate transport and logistics activities that occasionally come into contact. The ITESIC concept has been tested by users using simulation techniques to compare the approach with other models. It was also tested using demonstration methods in a laboratory environment. It is not known whether it was ever deployed into commercial demonstration activities during the life of the project or subsequently.

The ITESIC system effectively acted as an umbrella and became a single point of entry to all information required to manage the information flow associated with cargo in the corridors used during the project life. The project claims to have brought together:

- Shipping line and port interests,
- Logistics operators/forwarders
- Maritime agents
- Truckers
- Rail operators
- Depots/warehouses and terminals.

The system claims to fill the gap between existing systems that do not or cannot readily communicate. It recognises the whole logistics chain irrespective of direction (import/export/domestic). All players are able to communicate and the system claims to be able to forecast demand patterns. Replication into other corridors is also claimed as it eliminates the need to connect disparate systems.

The project is believed to have been completed in 2000. Evidence of adoption by a wider community of potential user has been elusive. In terms of corridor application the overwhelming need is to recognise that the corridors will have lateral links with cargo flows originating/terminating away from the corridor whilst using it for part of the cargo movement. The corridors are not surrounded by a cordon sanitaire and will need to reflect the requirement of remote users to connect and exchange information with actors along the line of route.

The IRIS project also developed a communications platform for use within terminals and cargo villages as a means of overcoming problems with different systems using different technologies, interfaces, protocols and technologies. It had similar objectives to the ITESIC initiative but has also had only limited application away from the demonstration point.

8.5 Recommended actions for rail transport operator on RETRACK corridor

To become more commercially attractive to cargo interests, shippers, receivers and those parties actually controlling cargo flows and making the freight payment rail has to address the following points:

- Reduce the cost base of the rail sector through the use of much improved asset management systems to drive up productivity

- Work the asset base more intensively with monitoring for the technical condition of the train formation in transit including security, crew condition and performance
- Condition monitoring of cargo in the rail sector of the transit for temperature, pressure, humidity etc with interventionist management in the event of a problem being identified
- Secure commercial gains through significant service reliability improvements and the analysis of variance against targets.
- Recognise what the competing modes are routinely capable of achieving and aim to outperform them using rail's inherent energy efficiency, weight, speed and controlled environment.
- Improve the overall management capability and skills base of the rail operating companies
- Ensure 24/7 responsiveness and credible management intervention in the event of service disruption and delays however caused.
- Develop better dialogue with shippers/customers in the planning of train services as an evolving process from cargo budget forecasts (-1year), progressive refinement of cargo plans, volumes and end destinations, link to train resource planning including crew, traction, freight wagons, terminal slots, pre and end haulage etc.
- Rail needs to move out of the – 48 hours permanent panic state onto a more rational and cost effective base
- Look into the option of variable train service offers (higher speed shorter formation loco hauled trains), priority inter-modal block trains, mixed inter-modal and general/bulk cargo trains offering slower but cheaper services.
- Exploit the green credentials of rail but maintain commercial viability. Green credentials do not yet pay the bills.
- Stop gold plating everything!
- Stop acting as a supply side monopolist.
- See Europe without national or railway territorial borders.

8.6 Recommended actions for road transport operator on RETRACK corridor

- Consider the long term sustainability of current methods and logistics patterns in the face of steeply rising fuel input costs and a wholesale dependency on one highly specific fuel input. Possible greater collaboration between road and rail co-modality but this needs receptivity to the concept by both modes.
- Consider the impact of the WTD, increasing congestion on inter-urban roads and the impact of this on reliability, productivity and cost
- Consider the impact of environmental limitations on access to cities, time, weight and noise bans

9 Conclusion

It is more unlikely to see innovative terminal technology in the short term by refinements and enhancements of existing kit (faster/cheaper/more reliable etc). Currently the horizontal transfer options are too expensive, untested/unproven and complex at this stage. The cost needs to drop by huge chunks to get into contention and then match reliability and availability.

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