Analysis and Comparison

for

Intermodal Transport Chains in European Markets: Handling and Transport Techniques

elaborated by
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Content

0. Executive Summary

Introduction:

- **Purpose and aim of this study**: To compare existing techniques for intermodal transport with regard to their environmental implications, the time and the possible cost expenses needed for new intermodal technology systems that are ready for market introduction.

- **Selection of technical systems that are ready for the market**: 1) RailRunner for bi-modal transport and 2) MODALOHR for semi-trailers without crane lifting re-enforcement.

- **Applied method: The calculations are based on a typical intermodal train model that** has been defined with the selected itinerary Hamburg (Germany) to Budapest (Hungary) and compares the carriage of the following intermodal unit load types: 45 ft. European (i.e. pal-let-wide) container; 40 ft. ISO-container; 20 ft. tank container; swap bodies; semi-trailers and roll-on roll-off rail applications (RoLa). Selected transport systems are compared based on these different loading units.

Results:

- RailRunner shows very good environmental qualities as far as CO_2 emission and energy consumption is concerned. It also shows an excellent ratio of total weight to payload and advantages vis-à-vis existing technologies especially when using 45 ft. or 40 ft. containers or semi-trailers.
    - RailRunner has an effective ratio of payload and tare weight of 2:1 with 45 ft. Euro containers, while a T5 has a 1,1:1 ratio, a TWIN car has a 1,3:1 ratio.
    - With a 40 ft. ISO container, RailRunner has a ratio of 2,3:1 auf, a T5 car of 1,6:1, a TWIN of 1,2:1.
    - The specific design of the RailRunner chassis always allows for the optimum use of train capacity as the tare weight of the rolling stock remains relatively low. This is especially advantageous when using semi-trailers. The ratio is 2,9:1, T5 1:1, TWIN 1,2:1.

- The environmental efficiency of the RailRunner system, based on the comparison of CO_2 emissions and energy consumption, proves effective especially when compared to 45 ft. and 40 ft. containers and semi-trailers.
    - When transporting 45'containers, RailRunner's energy consumption and CO_2 emission range between 30 % und 43 % higher efficiency when compared to "standard" rail cars.

- With RailRunner, 40' ISO container can be transported saving up to 45 % of CO_2 emissions and in energy consumption when compared to T5 and T4.2 railcars; and up to 35 % when put in comparison to the TWIN / Mega II. As with the 45 ft. container, the available loading capacity per train can be used more efficiently.

- Since the RailRunner system also hauls trailers, the environmental savings increase to 44 % (T5) and 53 % (TWIN) in case of 100 % train capacity utilization.

- In our model calculation from Hamburg to Budapest the net operational transport cost per loading unit (unit cost) for a T5-unit train or an “Ultralow” RORO unit train (35 units per train) is EUR 894. The cost for a tractor with semi-trailer, without considering any toll, amounts to 781 EUR compared to a loading unit transported with a RailRunner unit train (47 units) of 652 EUR. The RailRunner transport cost are 16% lower than trucking and 27% lower than with a T5 unit train. As unit cost in trucking for various volumes always stays the same, rail cost vary according to the actual transported units, however between 35 to 47 units a fleet of trucks requires significantly higher cost.

- In the exemplary calculation of our train itinerary the labour cost per transported unit with the Railrunner system was 9.55 EUR while for the T5 12.69 EUR and with the ‘Ultralow’ 11.84 EUR had been calculated, - the latter explicitly without any driver accompanying the cargo.

- The new RailRunner technology has another advantage when it is compared to existing intermodal rail solutions, which is the high total amount of transport units that can be carried with one block train. This is especially relevant with 45 ft. and 40 ft. containers as well as semi-trailers. While a T5 wagon can handle up to 35 units per block train of the above mentioned loading units and a MEGA II up to 38 units, the RailRunner can handle 47 units of 45 ft. containers as well as semi-trailers up to a length of 13.6 meters. A block train carrying only 40 ft. containers can even carry up to 52 units!

- Another remarkable advantage of the RailRunner system is that it easily can be integrated into existing intermodal transport systems. RailRunner can be fully comprised in existing terminals, thus enlarging the overall terminal capacity. The costs are relatively small.

- The costs of an intermodal terminal in Europe can total 8 million or 10 million EUR, while the concept of Modalohr can cost as much as 3 million EUR (includes concrete loading area). Yet, RailRunner terminals with comparable capacities have an estimated budget of only 2 million EUR.

- The MODALOHR concept leads to a relatively high tare ratio, because the tractor for transporting semi-trailers is included in the rail transport unit, resulting in high energy consumption and emissions relatively to the net payload shipped and is therefore, less efficient when it is used for transports of the “Rollende Landstrasse”, a concept that includes the transportation of the towing vehicle on the flat wagon. But if e.g. a political program asks for the shift

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of full truck + semi-trailer units from road to rail, offering funding for the intermodal system for environmental reasons, this system is workable. When it is used to transport only semi-trailers, Modalohr's environmental efficiency is comparable to that of a T5 car. Since the Modalohr wagon is rather expensive, it still needs a maximum capacity utilisation to be compatible to existing solutions such as T5 or MEGA II.

- The time needed for a single road to rail transfer of a unit load in an intermodal terminal is in average slightly higher when using new technologies (A crane move is 2.5 minutes per unit, Reach Stacker require 5 minutes and RailRunner and Modalohr between 3 and 4 minutes) But if the actual time needed for the transfer becomes part of the total transit and shipping time, both MODALOHR and RailRunner offer competitive solutions to conventional intermodal operations. However, both systems offer the possibility to simultaneously transferring several loading (4 to 5) units in parallel. Once this concept is realized, the actual transfer time needed will be much shorter than moves compared to conventional crane or reach stacker transfer.

- Regarding total cost, the MODALOHR concept carrying complete truck + trailer combinations cannot easily be economically compared to conventional container transport. Therefore, this technique can only be justified for specific transport situations, which are politically or socially requested and/or subsidised such as a particular mountain crossings or by passing traffic bottle-necks.

- Investment cost for presently used intermodal (IM) technologies range - depending on type of railcar used - between 2.2 to 3.1 million EUR per 700 m unit train. The Modalohr solution costs 7.5 Mio. EUR and for the comparable RoRo/RoLa "UltraLow" technique the investment would amount to 5.2 million EUR not including investments for trailers/chassis. The investment for a RailRunner unit train using comparable number of unit loads (35) as shipped with conventional IM railcars amounts to 2.9 million EUR which includes the required container chassis as part of the system. If the advantage of carrying more units 52 i/o 35 per train is considered the investment for RailRunner is 4.3 million EUR. When considering the latter case the costs of RailRunner are still fully competitive compared to existing intermodal techniques, because we calculated lower total operating costs, especially because of the reduced transfer cost, operational cost savings and better utilization of train slot capacity.

- Due to lower operating and significant lower terminal cost RailRunner is competitive when compared to existing intermodal transports even as the investment cost for a 35 unit are slightly higher.

- Both RailRunner and MODALHOR show specific advantages in situations where larger shipping volumes require transport into areas where there aren't any existing terminals.

- RailRunner is an especially interesting technology when transporting semi-trailers and on routes with higher cargo flows of containers using certain types of railcars. The transport towards Eastern European regions with their lack of an adequate terminal infrastructure should be a specifically advantageous market for RailRunner.

- RailRunner offers low terminal operating costs (equipment cost are about 200,000 EUR per start-up terminal capacity) and also reduced road and rail operating cost, because the road transport equipment is used more on rail than over the road than regular chassis or trailers and thus has lower tire and brake wear and can be depreciated over longer time periods. Some additional cost components are compensated by advantages and lower costs in rail operation (energy consumption, life cycle, etc.) and in overall systems costs (e.g. lower transfer costs).

1. Aim of the Study

The aim of this study contains an evaluation comparing different technical solutions in the European intermodal transport market with regards to their economical and ecological efficiency. The comparison covers techniques in current use and future technical concepts that are technically "mature" for market introduction. The study aims to find operation fields to enlarge and to intensify intermodal transport. Only those new techniques have been included that have shown their ability for market introduction and that can show sufficient data for an efficiency comparison. There are many more systems under discussion and/or development, but none can provide sufficient cost and efficiency data since these systems have never been operated under realistic conditions.

This study evaluates technical solutions concerning cost, time consumption and environmental aspects that are in commercial operation and that can be immediately introduced to the market. The method used is a model that sufficiently reflects the present European market conditions. The direct comparison is based on the main run (i.e. the long haul rail operation) and covers cost, time use per loading unit and environmental effects. New technologies are compared with those already existing and specific advantageous fields of operations for each specific technology are identified. The comparison is based on a typical intermodal transport itinerary that is applied to all types of loading units, intermodal transport as well as transfer systems.

2. The European Intermodal Transport Market

Intermodal transport is defined by a multimodal transport chain that moves freight in standardized transport units such as ISO containers, swap bodies and or trailers over the long distance part of the itinerary using mass transport modes (such as rail, inland waterway or deep sea ship) for the collective move of single units. The transfer between the mass transport mode and the road vehicle for the single unit transport is executed in specific transfer establishments, so called terminals.

Differentiation must be made between unaccompanied intermodal transports and accompanied intermodal transports. Accompanied intermodal transport carries complete truck + trailer combinations with trains or ships [Roll-on/Roll-off (RoRo) ferry boats]. Rail transport is operated using specific low platform or pocket railcars. A sleeping car is added to the train to accommodate those drivers that accompany their vehicle. Unaccompanied transport carries only loading units such as containers swap bodies and trailers (without truck). The cargo transfer is executed in terminals. This unaccompanied intermodal transport represents the biggest part of intermodal transport in Europe.

Most long-distance runs in intermodal transport in Europe are operated by rail. Two different types of operation in intermodal transport must be mentioned: 1) Hinterland transport between seaports and inland destinations and 2) continental transports that are operated mainly between Germany and Italy, and between France and Spain.[1] In addition, these countries have considerable national

[1] Please also see: EIA: Intermodal Transport in Europe, Brussels, 2005, Chapter 1

transport volumes in intermodal transport over both medium and long distances; mainly overnight services for urgent deliveries. Since 1980, the international intermodal transports are growing faster than national intermodal transport. Transport distances are smaller in national intermodal transport and road transport is more cost-effective in the distance segment of less than 600 km. Intermodal transport over shorter distances does exist, but mainly in the form of antenna movements where feeder trains over shorter distances carry the loading units to gateway terminals, ultimately changing over to long distance trains. Most European intermodal transport itineraries are North-South movements (often starting in the North European seaports). Since the European Union has enlarged its territory to the East European countries, specific growth potential can be identified on the East-West axis. Picture No. 1 shows the intensity of intermodal transport flows in Europe of 2004.

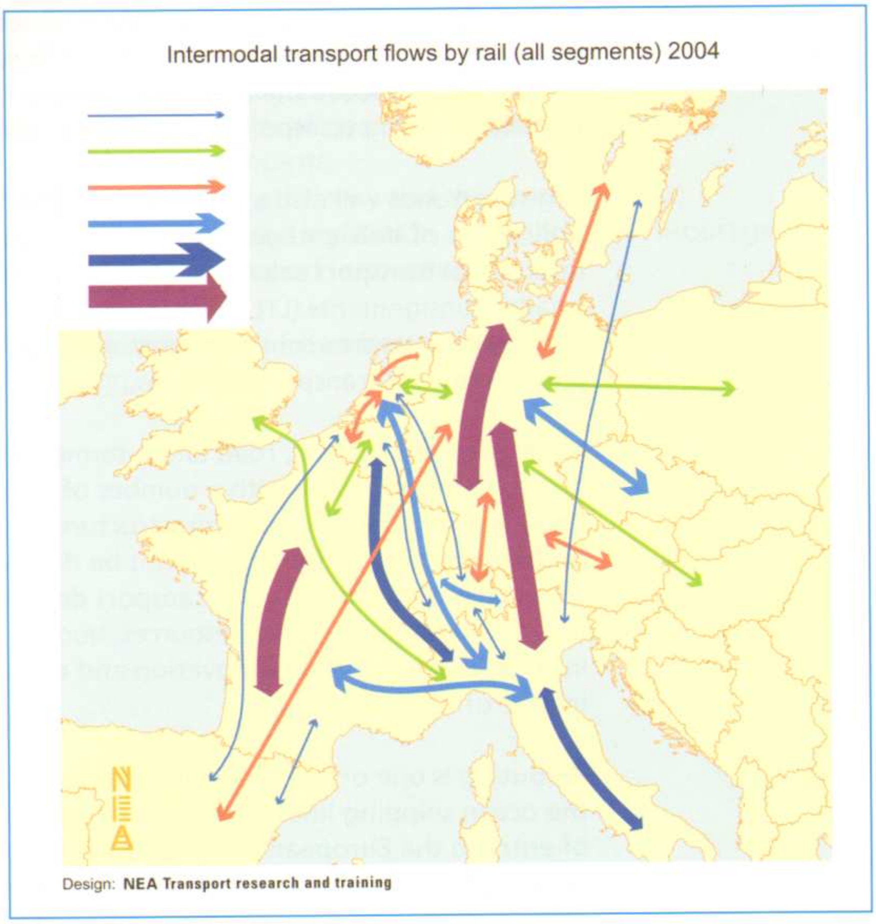

Figure 1: Intermodal Transports in Europe (Road / Rail). EIA: Intermodal Transport in Europe, 2005, S.17

Particular importance has to be mentioned for a special mode of intermodal transport namely the "Rolling Road" (Roll-on/Roll-off railcar) (USA: "Iron Highway"), in short in German: RoLa transport. In this transport technique, the entire road vehicle (either truck + semi-trailer or rigid truck + hanger) is loaded onto a special low platform railcar and transported over the rail to its destination region. In most cases, the driver accompanies his/her vehicle and stays in a sleeping or standard passenger car attached to the intermodal train. This special solution is not considered economically feasible on most itineraries due to the additional tare weight and the associated labour costs, which needs to be considered for an idle driver. This solution is limited to very specific transport corridors, mainly in transit through Austria or Switzerland in Alp Mountain crossing. Both countries have a specific political plan to reduce emissions from road traffic transferring through their mountain regions by providing subsidies and thus making RoLa commercially viable.

With regard to loading units, Swap bodies or containers, a large portion of intermodal units is designed to offer an internal width of 2.480 mm allowing 2 pallet loads 800 x 1200 mm to be stowed side by side.[2] ISO containers cannot offer such features, so that the European loading units (Swap bodies or domestic containers) have 4 % more space, but offer 20% more pallet utilization. The official figures from 2008 give a number of 381,423 swap bodies in TEU capacity of which 84 % of these have a Class C size – either 7,45 m or 7,82 m in length. A small part of this number 29,780 TEU is represented by tank containers. Furthermore, Europe operates 253,350 TEU of special containers with ISO length characteristics, but with a sidewall design that allows two pallets inside, side by side. Although 20' and 40' of these containers are still dominating, the pallet-wide 45 ft. container is steadily increasing its market share and totals today 49,072 TEU. It continuously replaces the 40 ft. container as it is better adapted to the specific requirements of European logistics. The European 45 ft. pallet-wide container will certainly play a larger role in future intermodal transport. However, this development is hampered by the lack of 90 ft. railcars, thus preventing this type of container presently finding optimum rolling stock when carried by rail.

Intermodal transport has increased its volume by 500% between 1988 and 2008 according to the European DIOMIS Study.[3] In 2007, national intermodal transport in Europe accounted for more than 7 million TEU. In international intermodal transport, plus hinterland transport from seaports is totalling approximately 10 million TEU. Comparatively, Europe totals approximately 17 million TEU, while the numbers for the US and North America were almost 25 Million TEU and 29 million TEU respectively.

Compared to the US, the European intermodal transport market is less dynamic and receives more political support and subsidies to meet the lower price competition of road transport with which intermodal transport carriers often have problems. As previously mentioned, many intermodal transport movements are only cost-competitive when a distance of more than 600 km is incurred, but this is, for most European states, already international traffic. In addition, international rail traffic in Europe is confronted with differing networks and transport conditions. As a result, adaptation measures are needed leading to increasing costs of rail transport and thus often result in further advantages for road transport. Furthermore, central European rail operations allow only for train lengths of 700 m, while for instance in the US rail operates train lengths of up to 2,440 m. This US rail cost advantage is increased by generally longer distances and the possibility to double-stack containers. Altogether, intermodal transport in the US has significant cost advantages that cannot be realized in Europe.

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[2] This „pallet-wide" feature ensures that 2 European standard pallets, measuring 1200 x 800 x 144 mm can be stored next to each other in the container, since the container is a few inches wider.

[3] Please see: Diomis 2 – Benchmarking Intermodal Rail Transport in the United States and Europe, Report No. 4, Paris, 2009, pp. 25 and following

Until 2008 intermodal transport in Europe experienced high annual growth rates mainly resulting from seaport hinterland container traffic. Notably, the global financial crisis has temporarily interrupted this growth and is likely to resume beginning 2010. In 2008 the intermodal terminals demonstrated some capacity restraints. We assume that, once the growth returns to the market, such bottlenecks will reappear, especially in conduct of seaport hinterland transport of containers: In consequence, the commercial actors will have in future to adapt their business strategy and the techniques in infrastructure operation to make intermodal transport quicker and more efficient.

When evaluating new technologies, especially the RailRunner solution, we have to keep in mind that the US market shows some distinct differences to the European markets and must be considered when such a new technique is to be implemented. The DIOMIS study (2008) provides details of these differences. While many US enterprises include all resources needed for an intermodal transport service offer, the European rail and road transport markets show a strict separation between infrastructure and operation, thus requiring a more complex business strategy. In most European countries private railways still have a small market share of only approximately 10%. In Germany and Italy, private operators move approximately 20% of all rail transport.

As mentioned, North American railroads can operate longer and heavier trains and thus offer a competitive advantage. The success of US intermodal transport is directly attributable to a train length of three times the length of the European systems, better tunnel profiles, and higher maximum axle loads compared to European rail operations. This translates into transporting more containers via double stack on many corridors. However, US rail networks consists of many single rail tracks requiring frequent acceleration and braking, thus reducing the average speed of intermodal operation – slower than the average speed in Europe. Therefore, the increase of transport capacity is a significant issue for the European intermodal transport markets. This will require not only changes in new administrative regulations, but also in innovative technologies and concepts.

3. Transfer and Transport Techniques in the European Union

3.1 Existing Techniques

Transport and transfer techniques used in Europe are similar in their basic features, thus allowing intermodal transport to operate in a compatible environment throughout Europe. Generally, new technical innovation cannot – or only with rather big financial and technical effort – be integrated into existing intermodal systems. Thus, such innovation always show, vis-à-vis the everlasting low cost competition from road transport, high risks of commercial introduction, which again reduce chances in finding competent sponsors for a start-up. Therefore, when innovative techniques are introduced, they should be capable of being integrated into existing structures and/or, if new infrastructure is needed, should require low capital investment. In addition they should also have a successful 'proof of concept'. As intermodal transport continues to grow offering more high capacity installations, new techniques and their market should be designed in a way that they can be commercially operated in small or niche markets to demonstrate their economic viability.

The following considerations introduce the environment of a "typical" intermodal operation in Central Europe. The model does not reflect the various special issues that might occur in other European areas, but is shown as a sample itinerary most typical for many European areas and intermodal transport operations.

Basically, any intermodal transport and logistic chain consists of a pre-carriage (dray), a main transport, a delivery carriage (dray) and two unit transfer operations. We assume a pre-carriage distance of 50 km to 100 km from supplier's warehouse to a departure terminal, and similar distances for delivery from arrival terminal to final destination. The main haul is done by rail with a minimum distance of 600 km and one or more border crossings. Furthermore, we assume that the border crossing or crossing into another rail network does not incur significant delays or complications. The train length available for railcars is 700 m, plus the locomotive(s). Both diesel motor and electrical traction are taken into account, especially when calculating the implications of such transport on the environment.

The intermodal transfer in a terminal is executed by reach stacker or by gantry crane (rail mounted or rubber-wheel supported). We calculated different models for transfers with reach stacker or cranes with the implication mainly related to their lifting capacity. A typical intermodal transport operation in Europe will request a maximum lifting capacity of 44 metric tonnes (Full loaded 13.6m intermodal Trailer).

This study concentrates on intermodal road-rail transport chains with rolling stock, loading units and transfer equipment (lifting devices) as described in the following chapters. The basic data is included in the model calculations and the technical comparison.

a) **Rolling Stock**

The rolling stock used for the main (rail) haul includes a train of 750 m length, offering 700 m of loading length with railcars. We assume the use of the most common railcars used in European intermodal transport. This configuration is compared to a commercial road vehicle of a 40 t total weight (mass) with a diesel engine and an emission characteristic of EURO III. The railcars are platform units that offer flexible use for containers, swap bodies and trailers.

		COFC	COFC	COFC	TOFC	T(ruck)OFC
TRANSPORT		Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train MEGA II (TWIN)	Block Train: T4.2 Waggons	ROLA Bombardier "Ultralow"
Max. Transport Length	meter	16,5	700,0	700,0	700,0	700,0
Length: Waggon / Trailer	meter	12,7	20,0	36,9	27,1	19,0
Max. Amout of Waggons	amount	1,0	35,0	19,0	25,0	21,0
Tare Weight Waggon / Trailer	tonnes	6,0	21,5	35,6	20,2	18,8
Tare Weight Traction Unit	tonnes	14,0	45,0	45,0	45,0	45,0
Travelling Speed	km/h	80,0	120,0	120,0	120,0	100,0

Table 2: Rolling Stock. Source: SGKV

The pocket railcar T5 is rather flexible and offers multiple fields of operation. It can carry trailers, swap bodies, and heavyweight containers offering a maximum payload of 68,5 (metric) tons. Thus, it can carry all typical loading units that occur in intermodal transport. Its specific design as T 4.2 gives the possibility to transport trailers with the (European) P 386 code that offer an inside loading height of 2,77 m (9ft. 3 in.). The important increase of inside loading height of 0,07 m (3 in.) has been achieved by a lowering the longitudinal beams at the location of the grappler arm (lifting) recess of the trailer or swap body.

The TWIN or similarly designed the MEGA II are developed on the basis of the T 2000 railcar that has until most recently been the best selling railcar for the carriage of trailers, swap bodies and containers in intermodal transport. This railcar is designed as a spine car with twin pockets. Low railcar tare weight (35 t), efficient ratio between rail car length and loading length, as well as low price are the advantages of this design. However, a specific problem occurs in operation. Twin units (either twin spine units or twin units with 3 bogies (one intermediate bogie) always create difficulties in achieving an optimum utilization of capacity length. Yet, this is also true of other railcar types that have not been discussed here in detail such as 80 ft. or 90 ft. (Lgjs and Sgrss) railcars. Such railcars would require in operation the loading of long containers (40 ft. or 45 ft.). Generally, such long containers are not always available in the transport market. Therfore, mostly they are stowed in the terminal at locations near to specific train slots which are able accommodating such units. This makes the operation more complicated.

Concerning the RoLa transport, the low platform height “Ultralow” railcar has been selected for the comparison. This railcar is already in use on trans-Alpine itineraries e. g. in Switzerland. Each railcar can accommodate a complete truck/tractor + trailer combination. This railcar has the typical problem of small diameter wheel sets (380 mm), which have much heavier abrasion (wear) than standard railcars with standard wheels. In consequence, this railcar needs significantly more maintenance, resulting in more costs and less availability of the railcar for commercial operation. The advantage of this specific railcar is its low tare weight of 17,5 t.

b) Loading Units

Specific intermodal loading units typical for European operation have been selected for comparison in this study. These are the 40 ft. ISO container and the European pallet-wide 45 ft. container. Additionally, 20 ft. tank containers that are used in the chemical and the foodstuff industry have been investigated, because they are of special interest due to their usually extreme heavy payload weight. Normally, their payload reaches more than 80% of the maximum gross weight. Other containers and swap bodies show, on average, a much smaller gross weight capacity use. Their normal actual weight, including cargo - based on a normal operation - generally reaches 12 t to 14 t per unit.

The use of RoLa is modelled with the use of complete truck/tractor + semi-trailer combinations using the special platform railcars that have been developed for such type of operation. Furthermore, we have taken into account semi-trailers comparing traditional and new transport technologies.

Loading Units (LU)		40 ft High Cube	45 ft EU Domestic	Swap Body	20 ft Tank	Semi Trailer	Tractor Unit + Trailer
Length	meter	12,2	13,7	7,8	6,1	13,5	16,5
Tare Weight	kg	4,0	4,8	4,6	4,2	4,6	20,0
Max. Payload	kg	26,5	25,7	18,0	29,3	22,0	22,0
Avg. Payload	**kg**	**13,0**	**14,0**	**16,0**	**26,0**	**14,0**	**14,0**

Table 3: Technical data of loading units; based on SGKV research results

c) Transfer Equipment

Common transfer equipment considered in this study is a rail mounted gantry crane lifting 44 tons and a LINDE reach stacker with comparable lifting capacity. The purchase and maintenance costs of such equipment are very high. There are, however, some new technical solutions in intermodal and bi-modal transport that can operate without such costly transfer equipment. A direct comparison of the investment costs with such solutions would theoretically be interesting, but is not realistic because such new techniques imply new construction and certification of such systems and need to compete against existing solutions used in practice. Completely new developed and designed systems are exceptional. Because established intermodal terminals (including those with heavy weight lifting equipment) already use an invested infrastructure, any comparison with a completely new systems would create numerous problems (not only of a theoretical nature), namely as such terminals that are already existing and operational would have to be expensively modified or totally scrapped in order to allow for a realistic comparison.

Cargo Handling - Techn. Data		Cantry Crane	Reach Stacker
Tare Weight	tonnes	250,0	77,0
Handling Capacity (max.)	per hour	60,0	30,0
Handling Capacity (avg.)	per hour	25,0	12,0
Lifting Capacity	tonnes	44,0	44,0
Energy Utilisation	Liter / 100 km	n/a	20,0
	KWH	5,6	11,3
CO2 Emission	kg per hour	3,4	29,4
	per l.u.	0,1	2,5
Investment Costs			
Hardware	EUR	3.000.000,00	500.000,00
Real Estate	EUR	6.750.000,00	6.750.000,00

Table 4: technical data and costs of intermodal transfer equipment

3.2 New Technologies

When including new intermodal technologies into the comparison, we must consider that such systems must have the capability of being seamlessly integrated into existing intermodal transport systems or must enlarge their operational scope according to various market needs. Systems that are completely new and require total or partial replacement of actual ones normally have no chance of implementation as rail and intermodal transport systems in Europe are very well established. They have a sophisticated and established infrastructure that has been built over decades with conside able investments. Completely new systems outside this infrastructure would lead to risks of premature obsolescence within these established systems – risks that no investor is prepared to bear.

New systems must be looked at from different angles: 1) the view of unit transfer and 2) the view of operations. Intermodal transfer with the use of cranes or reach stackers is currently standard in most markets. A meaningful new technology that aims of being a realistic alternative to current practice must not consider a new transfer system as such, but must combine transfer and transport operations as an integrated solution, like existing bi-modal systems. This will widen intermodal transport applications by additional offers at such places that are not yet equipped with any or inadequate terminal infrastructure. The bi-modal technology can thus be a good alternative to existing systems for cargo handling, especially in case there is no infrastructure for cargo handling implemented and the relatively high investment cost would hinder the implantation of adequate cranes or reach stackers. Furthermore, the transport/transfer interface can be improved with regard to simplicity and the actual transfer time required. Another intermodal solution to look at could be a system transferring complete non-reinforced, non-lift able road vehicles with their running gear. Such a system would be interesting for the transport of trucks, and truck-trailer-combinations (like those hauled on the Iron Highway), that today dominate European road transport. Such solutions would have a greater influence to the intermodal transport markets.

Bi-modal technologies that combine transport and cargo transfer in an innovative way have been used and tested in Europe on different occasions. Below, we describe some systems that have attempted to optimize transfer and transport in such innovative way.

Road Railer: Designed and manufactured by Wabash National Corporation, USA. This system had been initially a semi-trailer with an additional pair of rail wheels attached as a special designed road vehicle. The system was meant for intermodal transport. Compared to RoLa or trailer transported-in-pocket cars, this system did not require the use of a specific railcar. But the system originally needed very special semi-trailers that ultimately could not be imported from the US into Europe in large numbers. The current version used in the US no longer consists of semi-trailers with rail wheels, but operates the rail journey on a special bogie. This system is rather similar to the RailRunner technique, yet the loading units are heavier due to all required securing and locking components that are built into the semi-trailer. This technology is used in large numbers and on a broad scale in the US, including various types of trailers and has shown its feasibility. The same is true for RailRunner. However, the Road Railer system, during its use in Europe, showed some serious defaults and therefore was not able to become commercially feasible. Road Railer's much higher tare weight leads to serious infringements with the possible payload required and thus reduced its commercial attraction for European markets. All attempts to introduce the Road Railer system on a large scale in Europe (e. g. with the company BTZ) have not shown commercial success and have been abandoned. Thus, we do not include this technology in our comparison.

Kombirail: Kombirail is a combination of two bi-model technologies - the system "Kombitrailer" designed by Ackermann-Fruehauf and "Semirail" designed by Talbot. This system consists of semi-trailers that underneath their support structure attach to a bogie at both ends and as such change to a freight railcar to be operated as a train on rail. The development of the system has been stopped. The main reason for this cessation was the fact that the semi-trailer was 950 kg (almost 2,000 lbs.) heavier than comparable road vehicles. Furthermore, Kombirail included a complex coupling technique that did not show successful operation in day-to-day use. This system and other systems of rather similar design never developed beyond a prototype stage. Some additional doubts were expressed about the feasibility of these systems and capabilities of being integrated into existing intermodal transport systems.

Additional bi-modal systems such as:

- *TransTrailer designed by Transfesa,*
- *Multitrailor designed by Tabor,*
- *Combitrans designed by Intermotra,*
- *Rail-Trailer designed by Sambre et Meuse / Kaiser,*
- *Coda-E designed by Stork Alpha Engineering in co-operation with Netherlands Railways*

are no longer in operation or were not developed beyond the prototype stage. For example, **Multitrailor** needed a special high yield steel king pin in the semi-trailer for its coupling system. As such solution was not approved in the US because of the inherent safety risks and because it could not be proven that a common semi-trailer had sufficient king-pin rigidity to meet the forces implied, this product did not reach general acceptance.

Road Railer, which is limited to trailer operation only, today serves a limited and specific segment of the US market and therefore has some significance, but compared to the total intermodal transport market size in the country it is a niche product. Therefore, the advanced **RailRunner** solution, which has been expanded to the transport of international and domestic container is currently the only bi-modal technology that truly has a wide-range commercial viability. The RailRunner technology is used in the US and in future will also be designed and manufactured for use in India.

As mentioned before, alternate technologies focus on intermodal transport operation of non-lift able road vehicles (which is the great majority of vehicle in Europe). Few different systems have been suggested, but only the **Modalohr** system is in practical use. Other possible solutions could not find market approval and subsequently an investor willing to go beyond a test cycle. Insofar, all these technical suggestion cannot provide data about practical use – such data are needed for any realistic comparison.

CargoBeamer: A new system to be mentioned and developed in Germany, concentrates on quick transfer of intermodal loading units from road to rail, but requires specially designed, rather expensive terminals. Any larger market entry would need a complete new terminal network (in addition to the already existing network). This would result in very high investment costs with doubtful return on the investment. Similarly, the **WTT** system has built a model terminal near the city of Soltau, Germany and as of January 2010 both systems have not found any customer for commercial application.

CargoSpeed: A suggestion based on a 2004 technical study. It is also only in its prototype phase.

Flexiwagon: Invented in Sweden and in principle a similar system than Modalohr. Neither CargoSpeed nor Flexiwagon are currently in commercial use.

The German Promotion Centre for Intermodal Transport (SGKV) in Berlin, Germany, has made a survey on all these systems in the Framework of its 'InHoTra study'. This survey has been translated into English and can be studied at in the office of SGKV.

Therefore, there are only two technical systems that have been introduced into the market and have supplied sufficient data to be compared to existing commercial solutions, namely **Modalohr** and **RailRunner**. Thus, we include only these new techniques in our following comparison.

The **Modalohr** technique has been in use for a number of years, mainly on RoLa corridors between France and Italy. While the so called "RoLa" transports the towing vehicle in addition to the semitrailer as one unit (a transport solution used mainly on alpine rail connections), recently new connections were established that transport only the semi-trailer, so each Modalohr wagon can carry up to two trailers with 13.6 m of length. This system requires a special terminal, which mainly consists of a flat, ground level area with asphalt coverage, built-in rails, and some fixed installed low maintenance transfer supports and mechanics. The Modalohr system needs a specific low platform twin spine car with short coupling in the centre, enabling the horizontal roll-on roll-off (RoRo) transfer of standard European trailers within the existing European rail gauge or plate profile. The railcar platform is so close to the rail that the railcar can carry standard semi-trailers with 4 m (13 ft.) corner height within the railway gauge of the existing network (UIC GB 1). Also, intermodal transport can be operated on the main trunk lines in South and West Europe which generally cannot accommodate the normal intermodal transport combination of a standard semi-trailers lifted into a pocket railcar as this operation requires a more

Figure 5: Loading a Truck with Modalohr. http://www.modalohr.com

generous rail gauge that these Western and Southern European trunk line can offer. The railcar is equipped with standard bogies so that it has similar maintenance characteristics as a traditional railcar. The transfer of the road vehicle onto this railcar is carried out by the same truck that brings the road vehicle to the terminal. The system does not require additional specific transfer equipment.

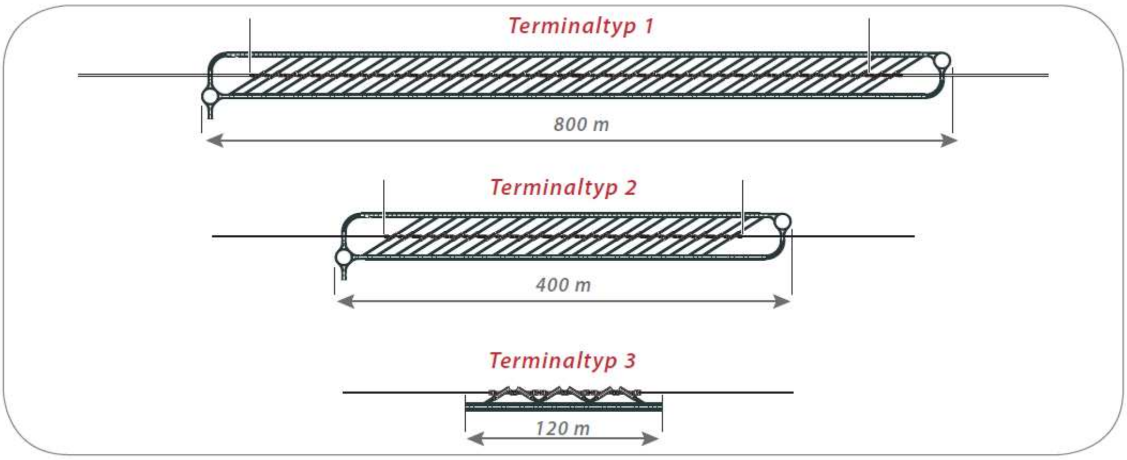

Figure 6: Modalohr Terminals- http://www.modalohr.com

Compared to bi-modal systems, Modalohr has the advantage of using standard semi-trailers, which need not to be modified or strengthened. But the terminal investment with its specific built-in rails and support as well as mechanics for terminal operation are costly and cannot be easily integrated into established transfer systems and/or terminals.

RailRunner: An advanced bi-modal system developed in the US which executes the transfer between road and rail using a slightly modified semi-trailer which is coupled to bogies having a unique air suspension. This technical concept is referred to as the Terminal Anywhere™ solution and consists of only three elements: a Chassis, an Intermediate bogie, and a Transition bogie.

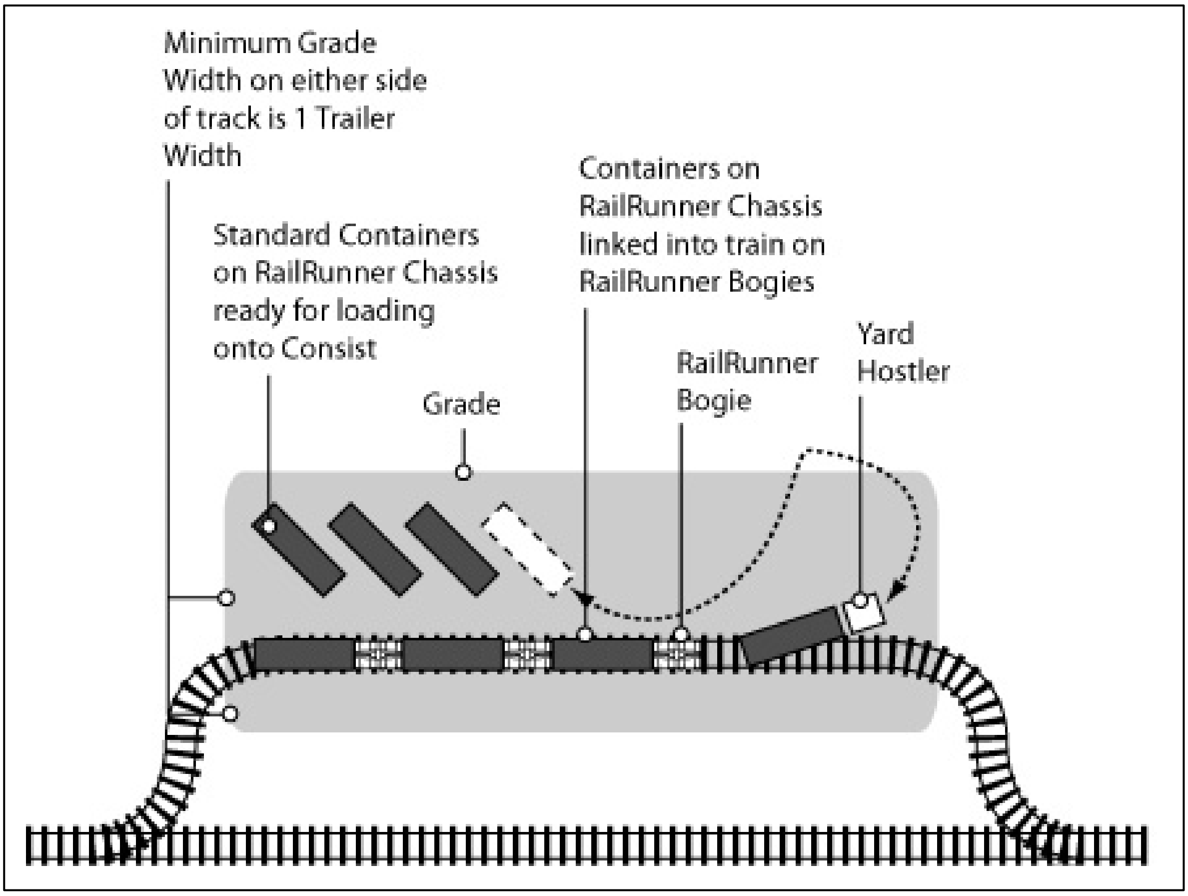

Figure 7: rail-runner concept. Source: http://www.RailRunner.com

The basic concept involves a container chassis that carries the loading unit which can be operated both in road and in rail traffic, thus abandoning the need for a specific railcar in rail operation. Each chassis is uniquely specifically adapted to a certain type of loading unit. The chassis are fully operational on road and rail and can be used for standard containers and/or swap bodies. The European transport market shows some significance for 40 ft., 45 ft. containers and swap bodies. In the intermodal terminal the intermediate rail bogies with air suspension are coupled to the front and rear of the chassis with the loading units on board. The air suspension then lifts the loaded chassis which then is carried by the bogies during rail operation, performing as an articulated rail car. A third element is the so-called Transition bogie that couples the lead loaded chassis with the locomotive or a regular railcar. As a result of this concept the RailRunner systems requires only a minimum investment for the terminal, since the terminal needs only a rail connection to the rail network, some level-grade road pavement and sufficient space for train building and road vehicle movement and parking (parking lot quality).

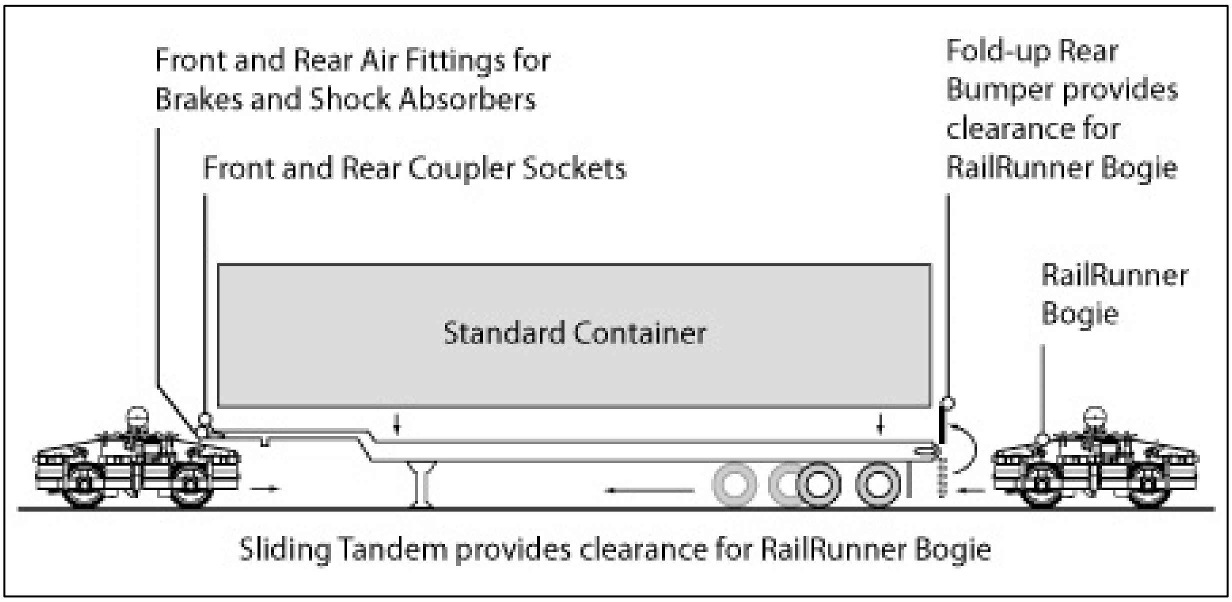

Figure 8: RailRunner terminal. Source: http://www.RailRunner.com

The following chart shows the technical details of the innovative concepts[4]:

New Approaches		TOFC Rail Runner Semi-Trailer (45 ' Chassis)	COFC Rail Runner 20 ' HD Chassis	COFC Rail Runner 45 ' Chassis	COFC Rail Runner 40 ' Chassis	T(ruck)OFC Modalohr Waggon
Block Train Length	meter	700,0	700,0	700,0	700,0	700,0
Length of Waggon	meter	14,7	10,5	14,7	13,3	33,0
Max. number of Waggons	amount	47	66	47	52	21 / 42
Tare Weight per Waggon	tonnes	7,6	4,2	4,8	4,0	42,0
Tare Weight Traction Unit	tonnes	45,0	45,0	45,0	45,0	45,0
RR IU Bogie Tare Weight	tonnes	6,6	6,6	6,6	6,6	n/a
Amount of Bogies per Train	amount	48,0	67,0	48,0	53,0	n/a
Travelling Speed	km/h	120,0	120,0	120,0	120,0	120,0

Table 9: innovative concepts for intermodal transport. Source: SGKV

Both systems, Modalohr and RailRunner, can be implemented as a stand-alone solution with specific features concerning the possibility of terminal expansion. Old terminals or sites with access or siding rail tracks can easily be enlarged or re-vitalised. This is certainly competitively advantageous for the RailRunner, but may also be realized, in a more limited way, for Modalohr. When compared to traditional intermodal transport terminals, both systems can use terminals that are easier and less expensive to install.

If we directly compare RailRunner and Modalohr, we find that both offer a less expensive and easily installed alternative to crane-equipped terminals. However, Modalohr requires (other than RailRunner) a very heavy concrete track to organize the transfer. This high-end concrete track will create higher costs. This heavy duty pavement is not required for a RailRunner terminal since it does not incur such high loads. This is a notable RailRunner advantage.

[4] The tare weights of the RailRunner technology for the European market were estimated, based on the American models, since it is not yet operating in Europe. Actual figure may differ slightly from those given.

4. Comparison of costs, time needed and environmental implications of existing and new technologies

4.1 Train run and itinerary model

For a meaningful comparison of existing and new concepts for intermodal transport and transfer, we need a common model itinerary, and a set of comparable model trains that are conceived following identical criteria.

The comparison will cover new bi-modal and intermodal technologies and various loading units, including those very specific for intermodal transport as complete truck + trailer combinations or semi-trailers. The selected itinerary must:

a) have more than 700 km distance in the main rail run, as commercial competition against road transport can be guaranteed with such transport distances;

b) have border crossing traffic that includes at least two European countries;

c) be specifically interesting for the new and fast growing transport markets within Europe that have emerged after the enlargement of the European Union;

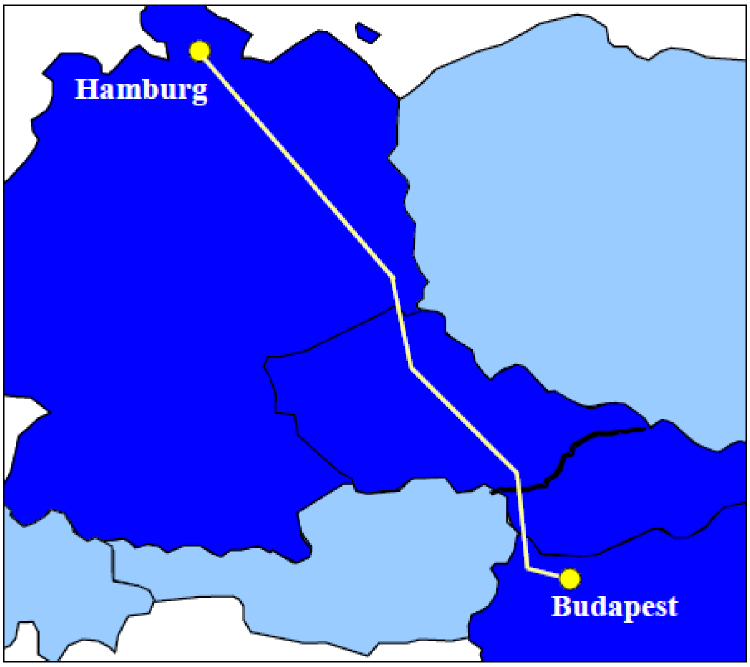

Figure 10: Model connection. Source: PACT: Combined CO2 Transport Reduction, 2003, pg. 37

d) not include difficult topographic features such as the Alps mountain crossings, because such itineraries require specifically high operational measures and may include many operational variations that do not allow for a useful comparison for this study.

Due to the argument mentioned before we did not include any intermodal Alps crossings, in this study. Although the routes are relevant to the European market, they imply too many variables which hinder a comprehensible comparison. Bi-modal transport via the Alpine corridor also has been successfully operated with the Road Railer system equipment in the past. The system worked, but was abandoned as mentioned before.

The model itinerary selected starts in Hamburg (Germany) and crosses four countries, ending in Budapest (Hungary) for a total distance of 1 168 km. This route is used today on a regular basis with high frequency, mainly for the carriage of ISO containers and European swap bodies. Normally, trailers and truck + trailer combinations are not carried on this route, but we wish to offer a complete comparison and have included such units in the model.

All comparative calculations only include the main run and the transfer operation in the terminal. Pre-carriage and final delivery (drayage) costs are included in the study, but as they are almost identical for each of the compared intermodal techniques they are not part of the comparison details.

The concept of model trains has a usable train length of 700 m (+ space for locomotive) which is typical for Germany and most European rail networks. This model train length forms the basis for calculation of a model set of loading units, maximum number of platform railcars and other rolling stock and for the total number of loading units that can be accommodated in our model train. We base any comparison on loading units, because trailers generally show a differing length characteristic and higher tare weight when carried via intermodal transport. The model trains show a maximum payload according to their composition and the loading units carried (calculated with their average loading weight, not with their maximum gross weight capacity) and a certain total tare weight of all components including the traction unit. The model considers train operations with typical average capacity use of 75 %, but also compares figures for a 100 % capacity operation.

		Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner Semi-Trailer (45 ' Chassis)	Rail Runner 20 ' HD Chassis	Rail Runner 45 ' Chassis	Rail Runner 40 ' Chassis	Modalohr Waggon
Block Train / Truck Netto Length	meter	16,5	700,0	700,0	700,0	700,0	700,0	700,0	700,0	700,0	700,0
Length of Waggon / Trailer	meter	12,7	20,0	36,9	27,1	19,0	14,7	10,5	14,7	13,3	33,0
Max. Anzahl der Waggons / Trailer	amount	1,0	35,0	19,0	25,0	35,0	47,0	66,0	47,0	52,0	21,0
Tare Weight per Waggon / Trailer	tonnes	6,0	21,5	35,6	20,2	18,8	7,6	4,2	4,8	4,0	42,0
Tare Weight of Traction Unit	tonnes	14,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0	45,0
RR IU Bogie Tare Weight	amount	0,0	0,0	0,0	0,0	0,0	6,6	6,6	6,6	6,6	0,0
Number of Bogies per Train	amout	0,0	0,0	0,0	0,0	0,0	48,0	67,0	48,0	53,0	0,0
Travelling Speed	km/h	80,0	120,0	120,0	120,0	100,0	120,0	120,0	120,0	120,0	120,0

Table 11: model trains – basic data for their composition. Source: SGKV

The table shows the model trains that have been arranged according to the type of loading unit. Also, a European road vehicle with 40 t total gross weight (mass) and an EURO III emission characteristic has been modelled. Looking at the results we have to keep in mind that such road vehicle can carry a maximum of only one or two loading units, depending on length and weight. Once the transport volume becomes bigger, the economics for any mass transport mean greatly improve.

The model calculation starts with a maximum number or loading units (LE = containers, swap bodies) and rolling stock (bi-modal chassis, railcars) directly related to the maximum usable train length (for complete truck/trailer-combinations we used a length of 16.5 m). This creates the basic data per model train. Starting from there, we count the average payload per loading unit in metric tons (specified to the type of loading unit), which then results in a given total gross weight for the road vehicle or train. This "average" payload per loading unit takes into account the experience and statistical data available to the author of the study based on market conditions and the basic values that are considered by the International maritime Organization (IMO). Furthermore, we considered the actual number of loading units based on an average use in train capacity of 75 % as it is standard practice in European intermodal transport.

THE DETAILED CALCULATION OF ALL MODEL TRAINS CAN BE FOUND IN ANNEX 1

45 ft. European container in COFC mode

The European (pallet-wide) 45 ft. container is calculated presuming it is being transported on the following railcars T5, TWIN, T4.2 and compared to standard road vehicle (16.5 m trailer) and a 45 ft. chassis of the RailRunner system as a new technology. The RailRunner technique shows, compared to T5 and TWIN railcar, a better ratio between average payload and total gross weight transported (please also compare environmental effects). Furthermore, the maximum payload per modelled block train is at 1,207 metric tons, much higher as with conventional solutions. In all such cases we must use a heavy duty locomotive adding some additional weight to the train. The ratio of maximum payload and total tare is very advantageous with the RailRunner solution. It is 2:1, while the other systems offer a much worse ratio of 1.3:1 (see table 11 b).

40 ft. ISO container in COFC mode (No double stack service in Europe)

Carrying 40 ft. ISO containers on the same type of railcar as used for 45 ft. container the RailRunner solution again demonstrates a much higher payload per train: RailRunner offers 1,377 t of payload, T5 railcar offers 927 t of payload and TWIN railcar 1,006 t of payload. Again, the ratio between total gross weight and payload is much better with RailRunner. RailRunner provides the best ratio of 2,2:1, while the other types of rail rolling stock have ratios of 1,1:1 and 1,4:1.

20 ft. tank containers in COFC mode

Transporting heavy tank containers with RailRunner on rail requires an increased number of bogies per train but in comparison, RailRunner and conventional railcars demonstrate similar loading values. T5 and TWIN railcars offer actual additional capacity in our model however their ratio of gross weight to payload is less than that of RailRunner. This is particularly true when comparing a tractor + semi-trailer combination on a train with T4.2 railcars which also showing a disadvantage in loading length when operating heavy tank units compared to RailRunner. The reason for this rather balanced picture is the very high payload capacity of tank containers carrying liquids in bulk. Our calculation is based on the 20 ft. HD (Heavy Duty) chassis concept of RailRunner to operate such high weights. This concept is yet not commercially available. However, based on our experience the chemical industry generally operates very high container weights in intermodal transport; so, we did not model a comparison with less loaded tank containers. We understand that with different and lower weight categories the RailRunner system will use other types of chassis, which will be better adapted to this type of operation. In such cases, RailRunner will again show advantages such as already experienced with 45 ft European containers and 40 ft. ISO containers, as the technology makes better use of the loading length than current technologies. Furthermore, the RailRunner HD type and the normal LD (Light Duty) chassis give better values than current intermodal railcars of 60 ft., 80 ft., 90 ft. length, like Lgjs or Sgrss railcars: These railcars very often make inefficient use of their available loading length when transporting 20' or 40' containers and thus create higher portions of dead weight.

Swap body in COFC mode

The tare weight and loading length advantage of RailRunner is only partially comparable with standard IM applications when using low weight and short swap bodies on so-called Kombi-Chassis. Altogether, the efficiency data of all transport means are rather similar and once the swap body gets heavier, the advantages of RailRunner become more realizable. Only the single Tractor + semi-trailer cannot match a mass transport system.

Semi-trailer in TOFC mode

Compared to intermodal transport with semi-trailers in TOFC mode, RailRunner shows a very good ratio of total gross weight to payload. The ratio is 2.68:1, i.e. nearly three times as good as conventional trailers presently transported in conventional IM transport. Semi-trailers are an integral part of the RailRunner system; - this mode of transport shows very remarkable weight advantages. Conventional techniques must transport the semi-trailer and additionally the weight of a railcar, so they are carrying much more gross weight. Therefore RailRunner is especially efficient with semi-trailers in intermodal transport. Also, the Modalohr technology can be used to transport semi-trailers. The efficiency of the system, which has its cargo handling technology integrated into the wagon, is similarly negative as a T5 or MEGA II railcar.

Semi-trailer + truck in RoLa/RoRo

If an operator wishes to carry complete combinations of truck/tractor + semi-trailers in European intermodal transport, the ‘Ultralow’ railcar as a conventional mode and the Modalohr technique for a comparison offer available solutions. Modalohr offers higher capacity, while Ultralow shows less tare weight and will be preferred for lower traffic volumes. Such road-vehicle-combinations in intermodal transport carry considerably more tare weight than conventional intermodal systems using standard loading box type units. Because they also show lower payloads per train, any comparison would show extremely different and widely incomparable values to those with containers. These modes of operation create a considerable efficiency loss as energy consumption is concerned, because of the additional truck or tractor weight carried. The Modalohr system shows an efficiency deficit when considering train loading length and the ‘Ultralow’ system has the advantage of a low tare weight when compared to Modalohr. Both modes render inferior commercial values when put in relation to other non-accompanied intermodal transports, which is due to the massive dead weight of the loading unit plus tractor.

The bi-modal RailRunner system can only be indirectly compared to a semi-trailer RoRo/RoLa transport with a truck/tractor + trailer combination carried on rail, because such transports are very special. They are feasible only on very few itineraries, in most cases only under fringe conditions that incur political influence on transport market conditions. The Modalohr manufacturer offers, seeing these reasons, mainly solutions with a carriage of the semi-trailer only, without driver accommodation and without tractor transport, which offer a limited database for comparisons since the services were only introduced recently (see Semi-trailer in TOFC mode for the comparison of semi-trailer transports).

Summing up, the ratio of maximum payload to tare weight of the system is as follows:

Capacity Utilization (100%)
Ratio - Payload (t) : Tare weight (t)

	Truck EURO III, 40 t	Block Train: T5 Wagons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Wagons	ROLA Bombardier "Ultralow"	RailRunner Semi-Trailer (45 ' Chassis)	RailRunner 20 ' HD Chassis	RailRunner 45 ' Chassis	RailRunner 40 ' Chassis	Modalohr Wagon
45' Euro	1,28	1,13	1,35	1,17	-	-	-	2,05	-	-
40' ISO	1,32	1,16	1,40	1,20	-	-	-	-	2,28	-
20' Liquid HD	1,46	2,57	3,09	2,66	-	-	2,53	-	-	-
Swap Body	0,90	1,58	1,90	1,64	-	-	-	-	1,55	-
Trailer	-	0,97	1,16	1,00	-	2,86	-	-	-	1,00
Truck	-	-	-	-	1,10	-	-	-	-	0,50

Table 11 b: ratio of maximum payload to tare weight. Source: SGKV calculation

4.2 Comparison of environmental effects

In the following we compare the environmental effects of the different intermodal transport techniques with regards to their energy consumption and CO_2 emission. All models of CO_2 emissions from environmental effects include complex calculations that cover, inter alia, the type of fuel (diesel motor fuel or electrical energy in rail traction on practical all European trunk lines) and the energy mix in the various rail networks. Such a detailed calculation, also including the need for additional research, would be beyond the possibilities of this study. So, this study refers to well established calculation models that are publicly available today. In addition, all individual calculations would need, as a basic input, the energy consumption of the various locomotives used in European freight transport. Such values are neither provided by the manufacturers nor obtainable from neutral studies. But recently a calculation tool has been developed which consider as input the energy consumption of locomotives.

One of the existing models with sufficient complex structure can be found under www.ecotransit.org. This software tool has been developed by leading operators in intermodal transport in Europe. It allows a precise routing in intermodal transport with a selection of the transport service operator. Consumption values and country specific energy mix figures are already built into the model and will be automatically taken into consideration when respective calculations are made.

The problem inherent to this model, similar to all readily available models, is selecting the correct train model for calculating energy consumption and CO_2 emission. It also assumes a train model with a fixed total weight (mass) that cannot be altered during the calculation. However, when new bi-modal techniques like RailRunner are analyzed, the ratio between payload and total gross weight (mass) is a decisive figure for any meaningful comparison. We decided to compensate this problem by replacing the actual weight of the train by a "modelled weight". This is calculated as follows:

a) First the relation between payload and total weight (the "ratio") is calculated,

b) this relation (i.e. the ratio) is transferred into a scale that values the maximum (i.e. the most disadvantageous situation) with the above value,

c) finally, this scaled ratio will be applied to all differing payload cases and reduced with the most advantageous ratio for the compared intermodal transport techniques.

The "modelled train weight" will only be used for the calculation of CO_2 emission and energy consumption while our other comparison between the different transport modes is based on the actual payload per train. By this method the different ratios between actual payload and total gross weight can be included our calculation model.

DETAILS OF THESE CALCULATIONS ARE REPRODUCED IN ANNEX 2.

Furthermore, the calculation of the block train transport will differentiate between diesel traction (D) and electrical traction (E). Electrical traction can be based on differing energy mixes with differing CO_2 emissions according to the actual types of power stations used and this has been included in our model.

As environmental concerns are discussed, we also must take into account the noise and rumbling (ground vibration) of rail transport. Such unwanted impacts are much higher than those created by road traffic. First assumptions about possible noise and vibrations have been developed for RailRunner by operation experts from the Technical University Berlin, Professor Hecht. The conclusions indicate that the actual construction of RailRunner bogies create less noise while driving through curves when compared to conventional platform railcars. In addition the experts conclude that the hydraulic attenuation and the used air suspension may reduce vibrations by 50% compared to standard bogies.

Completing the calculations we considered that the transfer operations using either crane or reach stacker will consume additional energy. This part of the total energy consumption is nearly completely eliminated with RailRunner, except for some tractor operation during assembly or disassembly of trains. The energy consumption during drayage is similar with RailRunner to any other analyzed intermodal technique.

The emission calculations in our model only relate to the transport of the intermodal unit loads by rail. The total balance sheet of energy consumption will show that the RailRunner system saves even more energy because they do not need the building of sophisticated terminals or the manufacture of heavy transfer equipment. The RailRunner system needs some larger service area for parking and maneuvering the intermodal trailers, and this might decrease the energy savings slightly. Overall, the energy balance of RailRunner is much better that that of conventional intermodal transport.

<u>45 ft. (pallet wide) container in COFC mode</u>

When comparing 45 ft. container (which is of increasing importance to European intermodal transport), the T5 platform railcar generates the most disadvantageous ratio between available gross weight and payload. RailRunner shows a much better ratio of 1,6:1. All these values refer to the total train run on the model itinerary from Hamburg to Budapest.

Intermodal platform railcars with 90 ft. loading length are designed for an optimal use of 45 ft. containers, but are currently very rare. When no 45’ containers are available the same car is generally used for 40’ units and this also holds true for other existing platform railcars (80’ or 60’), which even offer less possibility for improving utilization of their loading length when carrying 45 ft. boxes. Bimodal systems such as RailRunner show advantages as they can be optimized or adapted to all transport length variations needed in the intermodal market transporting containers.

If a given amount of payload has to be carried, RailRunner can make use of its positive ratio of gross weight to payload. This will create an advantage of 30% to 43% compared to conventional railcars; the exact amount will depend on the type of vehicle and the degree of capacity used. This advantage of RailRunner is similar in diesel or electrical traction of rail transport. The direct comparison to road transport can only be made with theoretical restrictions. If only one single loading unit must be shipped road transport is the most effective and no one would select using a train. However in mass transport, a large fleet of road vehicles would be needed over a long distance and any advantage of a single truck transport will immediately be lost. For this reason in our analysis we have multiplied the values for road operation by a factor of 35. This represents the number of road vehicles that would be equal to the capacity of a (European) block train composed of T5 railcars. This ratio is then used for all further comparisons. Applying such a ratio, road transport cannot match the economic advantage of a block train going over the model distance.

Loading unit: 45 ' EU-Container	c.u.: 75%	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	0,65%	57,05%	69,03%	59,24%
Co2 Emission per Tonne Payload	kg [D]	0,65%	56,98%	68,94%	59,16%
Energy Usage per Tonne Payload	kwh [E]	n/a	57,05%	69,03%	59,24%
Co2 Emission per Tonne Payload	kg [E]	n/a	57,03%	69,05%	59,26%
Loading unit: 45 ' EU-Container	**c.u.: 100%**	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	0,70%	62,04%	73,14%	64,07%
Co2 Emission per Tonne Payload	kg [D]	0,70%	62,06%	73,14%	64,08%
Energy Usage per Tonne Payload	kwh [E]	n/a	68,69%	73,14%	65,09%
Co2 Emission per Tonne Payload	kg [E]	n/a	62,00%	73,09%	64,04%

Table 12: RailRunner savings in energy consumption and in emission compared to conventional intermodal transport systems when carrying 45 ft. containers. Source: SGKV

<u>40 ft. container in COFC mode</u>

When analyzing and comparing 40 ft. high cube container operations (specifically a seaport hinterland operation), RailRunner will again offer positive values when compared to present IM applications. RailRunner continues showing very positive gross weight/payload ratios resulting in an advantageous value of 0.65 when calculating the T5 railcar (which is a rather heavy rail car). The weight ratios will improve with the availability of more optimized container carrying cars, but still stay advantageous for RailRunner.

The RailRunner is similarly energy efficient as already seen with the transport of 45 ft. containers. RailRunner saves 45% in CO_2 and fuel compared to operation of T5 or T4.2 railcars, and RailRunner shows 35% better effectiveness even when compared to TWIN or Mega II railcars (which offer more loading length than T5 or T4.2). As with the 45 ft., RailRunner makes most efficient use of the loading space available; other than with conventional intermodal transport techniques where mostly some empty space/slots remain which cannot be utilized.

Loading unit: 40 ' ISO-Container	c.u.: 75%	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	0,63%	54,42%	65,62%	56,46%
Co2 Emission per Tonne Payload	kg [D]	0,63%	54,46%	65,62%	56,46%
Energy Usage per Tonne Payload	kwh [E]	n/a	54,39%	65,62%	56,46%
Co2 Emission per Tonne Payload	kg [E]	n/a	54,39%	65,62%	56,46%
Loading unit: 40 ' ISO-Container	**c.u.: 100%**	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	1,81%	59,72%	70,18%	61,67%
Co2 Emission per Tonne Payload	kg [D]	1,81%	59,72%	70,18%	61,67%
Energy Usage per Tonne Payload	kwh [E]	n/a	59,72%	70,18%	61,67%
Co2 Emission per Tonne Payload	kg [E]	n/a	59,72%	70,18%	61,67%

Table 13: RailRunner savings in energy consumption and in emission compared to conventional intermodal transport systems when carrying 40 ft. containers. Source: SGKV

20 ft. tank container in COFC mode

RailRunner offers a solution for the transport of very heavy 20 ft. containers that has not yet been tested in the market. When introduced and operated, RailRunner will demonstrate similar values in energy consumption and emission compared to conventional intermodal transport systems when carrying the same amount of cargo over the same distance and itinerary. RailRunner will need an optimized, shorter chassis (20 ft. HD concept). This will increase the tare weight resulting in a ratio of tare and payload similar to that in conventional intermodal transport. If containers with lower weight are carried, RailRunner can use lighter weight types of chassis. This might lead to an advantage of the RailRunner system, because the number of vehicles that can be included in the block trains is increased. In addition, the total tare weight of the chassis could be reduced.

The following table compares RailRunner HD with conventional intermodal transport when operating very heavy containers:

Loading unit: 20 ' Tank-Container	c.u.: 75%	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	2,30%	101,08%	113,72%	103,50%
Co2 Emission per Tonne Payload	kg [D]	2,30%	101,08%	113,72%	103,50%
Energy Usage per Tonne Payload	kwh [E]	n/a	101,08%	113,72%	103,50%
Co2 Emission per Tonne Payload	kg [E]	n/a	101,08%	113,72%	103,50%
Loading unit: 20 ' Tank-Container	**c.u.: 100%**	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	2,38%	100,88%	111,07%	102,86%
Co2 Emission per Tonne Payload	kg [D]	2,38%	100,88%	111,07%	102,86%
Energy Usage per Tonne Payload	kwh [E]	n/a	100,88%	111,07%	102,86%
Co2 Emission per Tonne Payload	kg [E]	n/a	100,88%	111,07%	102,86%

Table 14: RailRunner savings in energy consumption and in emission compared to conventional intermodal transport systems when carrying 20 ft. tank containers. Source: SGKV

Again, comparing single truck road transport and considering a total fleet of 35 road vehicles, a block train over the model distance is much more competitive than conventional trucking.

If we enlarge our comparison and include additional types of railcars, we can see that only the 60 ft. Sgns railcar can carry tank containers with a total weight of 34 t over a European rail track with D characteristic. All other platform railcars must either reduce the total weight (Reducing payload) per tank container to 30 t or can only accommodate one single container per railcar. Swap bodies of the 7 m length and 20 ft. containers for general cargo operate normally with smaller payloads. But RailRunner will show advantages when heavier and longer unit loads, for instance 7.82 m or 30’ containers are used, because the negative impact from longer chassis is reduced. The problem with the RailRunner chassis for heavy containers is caused by the need to provide a rather long chassis design even for shorter containers, because of connectivity needs in train assembly. If we introduce longer tanks, e.g. 30’ or tank swap bodies of 7.45 to 7.82 m length, this specific disadvantage factor is reduced. The use of larger and longer tanks is a market trend. In block trains that contain some single heavy loaded containers comparable analysis for RailRunner with very heavy containers is equally negative to conventional intermodal transport, but each additional less heavy container and a more uniform loaded train creates an advantage for the RailRunner system.

Swap body

RailRunner is competitive even with low weight swap bodies showing rather comparable values to present intermodal technologies. The RailRunner solution will become more efficient with a higher capacity use of the block train as number of loading units increase as well as for the average tonnage per loading unit.

The comparison of RailRunner with conventional intermodal transport for the transport of swap bodies shows rather similar values over all:

Loading unit: Swap Unit	c.u.: 75%	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	2,16%	101,61%	119,20%	104,89%
Co2 Emission per Tonne Payload	kg [D]	2,16%	101,61%	119,20%	104,89%
Energy Usage per Tonne Payload	kwh [E]	n/a	101,61%	119,20%	104,89%
Co2 Emission per Tonne Payload	kg [E]	n/a	101,61%	119,20%	104,89%
Loading unit: Swap Unit	**c.u.: 100%**	RR / Truck	RR / T5	RR / TWIN	RR / T4.2
Energy Usage per Tonne Payload	kwh [D]	2,24%	101,36%	115,94%	104,13%
Co2 Emission per Tonne Payload	kg [D]	2,24%	101,36%	115,94%	104,13%
Energy Usage per Tonne Payload	kwh [E]	n/a	101,36%	115,94%	104,13%
Co2 Emission per Tonne Payload	kg [E]	n/a	101,36%	115,94%	104,13%

Table 15: RailRunner savings in energy consumption and in emission compared to conventional intermodal transport systems when carrying swap bodies. Source: SGKV

Semi-trailers (TOFC)

When comparing semi-trailers, the RailRunner concept shows very significant advantages in energy consumption and CO_2 emissions. In TOFC operation each shipment includes the tare weight of the trailer plus the weight of the carrying railcar. RailRunner reduces this additional railcar weight and provides significantly better efficiency in energy consumption and emission values. The ratio of payload to gross weight is much better than with conventional intermodal transport. Compared to conventional intermodal transport, the RailRunner system grants savings of sometimes more than 50%.

The Modalohr technology has a similar efficiency as T5 or MEGA II railcars. It is however necessary that the system has very high capacity utilization, since the wagons with their built-in cargo handling technology are rather heavy and only a high utilization of the cars can compensate for this.

Loading unit: Semi-Trailer	c.u.: 75%	RR / Truck	RR / T5	RR / TWIN	RR / T4.2	Modalohr
Energy Usage per Tonne Payload	kwh [D]	n/a	37,94%	46,55%	39,50%	39,36%
Co2 Emission per Tonne Payload	kg [D]	n/a	37,94%	46,55%	39,50%	39,36%
Energy Usage per Tonne Payload	kwh [E]	n/a	37,94%	46,55%	39,50%	39,36%
Co2 Emission per Tonne Payload	kg [E]	n/a	37,94%	46,55%	39,50%	39,36%
Loading unit: Semi-Trailer	**c.u.: 100%**	RR / Truck	RR / T5	RR / TWIN	RR / T4.2	Modalohr
Energy Usage per Tonne Payload	kwh [D]	n/a	43,97%	52,55%	45,56%	45,41%
Co2 Emission per Tonne Payload	kg [D]	n/a	43,97%	52,55%	45,56%	45,41%
Energy Usage per Tonne Payload	kwh [E]	n/a	43,97%	52,55%	45,56%	45,41%
Co2 Emission per Tonne Payload	kg [E]	n/a	43,97%	52,55%	45,56%	45,41%

Table 16: RailRunner savings in energy consumption and in emission compared to conventional intermodal transport systems when carrying semi-trailers. Source: SGKV

Truck/tractor + Semi-trailer (RoLa/RoRo)

It already was mentioned before that RoLa/RoRo rail transports carry the complete road vehicle (truck + trailer) on railcars, shipping a maximum gross weight ratio and thus cannot be seriously compared to intermodal transport transporting regular loading units. Wherever such transports are operated, they are subsidized for political reasons otherwise they would not be a viable economic consideration.

By including this type of transport technique, we analyzed conventional 'Ultralow' technique and Modalohr as the innovative technique. 'Ultralow' has less tare weight, thus providing better efficiency in emission values. However, the loading capacity per block train of this system is limited. So, the advantage only works when limited numbers of units are transported (The trains operated will be shorter due to heavier loads, e.g. tractors + trailers). If larger number of units need to be carried per block train operation, the Modalohr system with its greater capacity per block train, will be more efficient. One Modalohr train can carry the same amount of road vehicles as 2 sometimes 3 trains with 'Ultralow' RoLa railcars.

The Modalohr concept can only operate with semi-trailers, either with or without a towing vehicle. The latter will increase its capacity and efficiency. However, extra terminal expenditure for the transfer of the semi-trailers onto the swinging platform must be added and in this case most if not all advantage of the system is lost (presuming infrastructure with cranes or reach stackers is available and need not be built). Even when a direct comparison with the other concepts is not possible with the RoLa, we can easily assume that the high portion of tare weight together with the high prices for the low platform railcars will result in considerable disadvantages to conventional intermodal transport and also to the RailRunner technology. The RoLa concept is mainly used in crossing the Alps and done mainly for environmental and political reasons and heavily financed through governmental subsidies. When transporting merely semi-trailers without a towing vehicle, the RailRunner presumably has advantages (as described before) on the alpine routes also.

Drayage is not a part of the comparison model because the economic and technical conditions are rather similar with all techniques. The following table gives an example of such a calculation based on one pre-carriage or final delivery over the road:

First and Last Leg	Model Calculation	
Distance (one way)	km	48
CO2 Emission	kg	45
Energy Utilisation	kwh	170

Table 17: Energy consumption and emissions in drayage operation. Source: SGKV

It may be mentioned at this point, that with RailRunner no additional chassis for drayage will be needed at either end of the rail haul when containers are transported in COFC transport.

4.3 Comparison of travel time requirements

The total time needed in our modelled itinerary is calculated for the distance from Hamburg to Budapest and includes both transport and transfer time.

Transfer time per loading unit in a terminal with some 60 % capacity use will use 2,4 minutes per crane transfer and 5 minutes per reach stacker transfer. These are approximate values because the transfer time needed will greatly depend upon the capacity utilization of the terminal at the moment the transfer has to be executed. A terminal with a momentary low capacity use may do transfers in 2 minutes, while the same terminal when confronted with 95% capacity use may generate waiting times and other delays of up to 55 minutes per loading unit. Our values are average figures with a moderate capacity utilization of the terminal. Based on our calculation, RailRunner will need an average transfer time of 3 minutes per loading unit, but is quoting a time needed for a coupling operation of 4 minutes and 3 minutes for de-coupling. Terminal management may achieve even shorter coupling time by using intelligent operation software or other supporting measures (guides). In addition, RailRunner can assemble several units simultaneously in parallel operation. The Modalohr and the 'Ultralow' concept give some 50 to 60 minutes for the composition of a block train, but with fewer units. [5]

The train speed can only be an assumption value and would be equal to all intermodal modes (although RailRunner has the potential of higher speed applications). Therefore, rail travel time is not differentiated in our calculations. Indeed, some transport systems may be able to operate at higher rail track speeds than others, but railway network characteristics in Europe with their specific speed limits, curvature and other restrictions results in similar required travel time periods. The general logistical conditions in Europe require a day A (Departure) to a day C (arrival) operation and such schedule can practically be achieved with all techniques in intermodal transport. The following table therefore illustrates only the differences in transfer times:

[5] Please compare: Betriebskostenvergleich und Investitionskostenvergleich zweier RoLa-Systeme [comparison of operational and investment costs of two RoLa-Systems], Bern, 2003, pp. 14 and following

	Route : Hamburg - Budapest, Length of main leg: 1168,2 km. http://www.ecotransit.org/								
	Time Requirements		Truck Fleet (35 VEHICLES) EURO III, 40 t / 60 t	Block Train:T5 Waggons	Block Train: MEGA II (TWIN)	Trailer Train: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner 40 ' Chassis	Modalohr Waggon
	Number of Loading Units (100% Capacity Utilisation)	Number	1,0	35,0	38,0	25,0	35,0	47	21,0
	Number of Loading Units (75% Capacity Utilisation)	Number	1,0	27,0	29,0	19,0	27,0	36,0	16,0
	Cargo Handling: Reach Stacker	Minutes per loading unit	5,00	5,00	5,00	5,00	//	//	//
	Cargo Handling: Gantry Crane	Minutes per loading unit	2,40	2,40	2,40	2,40	//	//	//
	Cargo Handling: Other	Minutes per loading unit	//	//	//	//	2,80	3,00	3,00
100 % c.u. / 2x handling	Total Time Reach Stacker / Other	Minutes	10,00	350,00	380,00	250,00	196,00	282,00	126,00
	Total time: Gantry Crane / Other	Minutes	4,80	168,00	182,40	120,00	196,00	282,00	126,00
	Time per loading unit:Reach Stacker vs. Other	Minutes	10,00	10,00	10,00	10,00	5,60	6,00	6,00
	Time per loading unit: Gantry Crane vs. Other	Minutes	4,80	4,80	4,80	4,80	5,60	6,00	6,00
75 % c.u. / 2x handling	Total Time Reach Stacker / Other	Minutes	10,00	270,00	290,00	190,00	151,20	216,00	96,00
	Total time: Gantry Crane / Other	Minutes	4,80	129,60	139,20	91,20	151,20	216,00	96,00
	Time per loading unit:Reach Stacker vs. Other	Minutes	10,00	7,71	7,63	7,60	4,32	4,60	4,57
	Time per loading unit: Gantry Crane vs. Other	Minutes	4,80	3,70	3,66	3,65	4,32	4,60	4,57

Table 18: models of time needed. Source: SGKV

In a first analysis, the comparison of all technologies shows that RailRunner requires additional time, but this is relative as to the total number of total unit loads (47). If we calculate the total time needed (i.e. 2 transfers + 1 transport operation) for one unit, operating an entire block train, we see that the per-unit-value with RailRunner is rather similar to a reach stacker based transfer operation. Using crane transfer, we might see no specific advantage in time, possibly a slight advantage for the crane. Modalohr is rather similar to RailRunner in regard to time consumption, but its high tare weight will over-compensate its slight transfer cost advantage.

Because of its high payload capacity per block train RailRunner's efficiency in train cost is similar or more efficient than conventional intermodal transport techniques. Its time factor for train assembly (Transfer) is, to a small degree advantageous compared to reach stacker transfers when high volumes of cargos are moved. If the trains and terminals show less capacity utilization this advantage would reduce. In this case, crane transfer would be quicker because operation travel over the train can be easier optimized; on the other hand, cranes are very expensive in investment and maintenance and thus amortization can only be realized in terminals with considerable high transfer volumes. According to our analysis, RailRunner would generate comparable transfer efficiency and offer less expensive investment and maintenance costs for both small and large transfer volumes. Generally, RailRunner train assembly time can be looked at rather independent from terminal utilization, because it can be affected by the tractor bringing the trailer/chassis to the terminal, thus does not require any other transfer mean. Also a RailRunner operation would most likely be realized in an existing terminal at a track of less utilization and thus would be able to operate independent. This would fit well into the operational concept of RailRunner as it gears to a closed loop operation and controlled fast turn-around moves of the equipment.

With regard to time consumption, the RoLa with 'Ultralow' and Modalohr transfer systems are competitive with other systems. Yet these systems show greatly reduced payload/units per block train, so any comparison of time consumption per block train provides very limited operational and economical value.

Both RailRunner and Modalohr offer the possibility of parallel loading times (Transfers), i.e. several semi-trailers can be simultaneously be transferred. In a terminal with 400 m loading length RailRunner/Modalohr can transfer three to five semi-trailers simultaneously. This is an advantage in time use, because a crane or reach stacker must work in sequential order. Modalohr needs additional loading time for the closing and securing of the swinging platform and trailers. Such action will be done semi-automatically in the RailRunner application which is supervised by the same officer who assists with the individual dispatch. Insofar, RailRunner operates with less personal than the other systems. Simultaneous transfer of multiple loading units in parallel requires intelligent planning and co-ordination, but offers a definite advantage that can be maximized if the operator and his clients wish to do so.

4.4 Comparison of cost

The most significant advantage of bi-modal transport systems, specifically of units that need not be lifted, is the fact that they do not need a fully equipped terminal and a crane. Calculated below are the investment and operating costs of a crane equipped terminal and/or a terminal that is operated by reach stacker.

A standard terminal operator would have to spend in average 150 EUR per square meter for a total area of 45 000 square meters (40 000 square meters for operation + 5000 square meters for parking, roads, buildings). Therefore, the operator must spend 6.75 million EUR. Using an interest rate of 6 % would yield annual real estate financing costs of 405 000 EUR. Furthermore, the terminal operator needs to purchase a crane for 3 million EUR and one reach stacker for 500,000 EUR. The crane would be depreciated over a 30 year useful life resulting in annual depreciation and interest expense of 193,000 EUR. The reach stacker will be depreciated over a five year useful life and cost 136,000 EUR per year. Further costs will be created by the need for maintenance (approximately 200,000 EUR per year) and about 720,000 EUR per year for personnel, assuming the need for 12 employees with an annual salary + social charges of 60,000 EUR. Also, we must include 100,000 EUR per year for miscellaneous expense. Total annual cost for a small terminal (1 crane, 1 reach stacker) thus arrives at 1,750,000 EUR. If this terminal handles 100 000 loading units per year, the costs of handling per load would be 17.50 EUR, if we calculate with a smaller volume of 50,000 loading units per year the costs per loading unit transfer will rise to 35 EUR.

These amounts can differ considerably, e. g. with the real estate spending. If the terminal is operated with a reach stacker only, the costs are lower, but the reach stacker requires much more time per transfer and will become inefficient once the terminal begins handling larger volumes. The costs for terminal infrastructure maintenance will increase sharply if a reach stacker is used for large volume operations. In this case several stackers and more personnel are needed, which would also require more organizational planning and dispatch efforts. Conflicting interference can easily occur and efficiency will drop. Therefore, reach stackers would be mainly feasible for smaller terminals. Thus, the economic decision to utilize a reach stacker or crane is mainly contingent upon the number of loading units forecast.

A minimum equipped terminal for a RailRunner or Modalohr applications can be realized with annual costs between 1 million and 2 million EUR (Modalohr with a slightly higher amount) including both real estate and infrastructure. This is the significant advantage of these new technologies. If we compare investment needs of RailRunner and of Modalohr (both much less expensive than conventional terminals), we find that only Modalohr adds some extra costs for the installation of a heavy duty concrete track for its transfer operation. RailRunner’s terminal requirements need not include such extreme terminal specifications.

Notably, Europe is largely covered by a well equipped terminal infrastructure and does not require many new terminals. Many existing terminals have expansion plans to improve their current capacity. The new technologies become very advantageous when no intermodal transport infrastructure is available and new terminals have yet to be built. In these cases new technologies offer considerable cost advantages.

At the beginning of the study we have explained that the intermodal transports on the East-West-axes are especially promising markets. The East European countries currently do not offer many terminal options. Existing older terminals often have limited crane capacity and cannot transfer heavier containers as well as 40 ft. and 45 ft. containers, semi-trailers and swap bodies. New transport applications on these axes normally require new terminal equipment. The new technologies for intermodal transport can thus be used to avoid the need for new large terminals or even the need to enlarge existing terminals, avoiding high costs and complicated administrative approval processes RailRunner offers an especially easy to install solution for expanded capacity because intermodal transport is simple in its terminal design and does not require a specific interface to existing transport systems.

New technologies should permit integration into existing intermodal transport systems and their infrastructure. However, if new infrastructure is needed, this should ideally be a low budget solution, because in the beginning additional intermodal transport corridors in Europe are confronted with low volumes in the start-up phase. So, any new solution should allow efficient intermodal transport, even with lower traffic volumes. RailRunner can efficiently serve both low and high traffic volumes. After preparing only one rail track in an existing, possibly older and/or abandoned terminal (Also useable rail siding will work) with a flat level-grade road-rail surface RailRunner can begin operation. The track must lead into the trunk line network. The track might be (in Europe) equipped with catenaries for electric train traction. Using RailRunner, this doesn't matter as RailRunner can fully operate its transfer and assembly operations under catenaries as well.

Investment costs mentioned in our analysis do not relate to locomotive and tractor because any other intermodal system needs these components as well. We therefore only considered the investment for standard semi-trailers that might cost 20,000 EUR. A T5 platform railcar or a T4.2 railcar will cost approximately 88,000 EUR, and the MEGA II will cost 120,000 EUR. A Modalohr railcar totals 356,000 EUR, and the Ultralow from Bombardier will cost 145,000 EUR per railcar. In table 19 we compare the costs for a 40 ft. chassis with equipment from RailRunner and show container chassis, intermediate bogie and the transition bogie that couples to the locomotive.

Locomotive and tractor for semi-trailer movement are not included in the comparison, because these are typically leased. Otherwise, locomotion costs are normally included in the train traction cost so that this does not lead to a specific investment need.

				Lkw 40 t	T5	MEGA II	T4.2	Railrunner 45 ' chassis	Modalohr	"Ultra Low"
Investment	Trailer / Waggon		EUR	20.000,00 €	88.000,00 €	120.000,00 €	88.000,00 €	28.000,00 €	356.000,00 €	145.000,00 €
	RR Bogie Intermediate		EUR	0,00 €	0,00 €	0,00 €	0,00 €	53.500,00 €	0,00 €	0,00 €
	RR Bogie Transition		EUR	0,00 €	0,00 €	0,00 €	0,00 €	56.500,00 €	0,00 €	0,00 €
Block Train	Waggon / Chassis /		Number	1	35	19	25	52	21	36
	RR Bogie Intermediate		Number	0	0	0	0	52	0	0
	RR Bogie Transition		Number	0	0	0	0	1	0	0
	Total Costs	**per TRAIN**	**EUR**	**20.000,00 €**	**3.080.000,00 €**	**2.277.657,27 €**	**2.200.000,00 €**	**4.294.500,00 €**	**7.476.000,00 €**	**5.220.000,00 €**
	Total Costs	**per 45' Unit**	**EUR**	**20.000,00 €**	**88.000,00 €**	**60.000,00 €**	**88.000,00 €**	**82.586,54 €**	**356.000,00 €**	**145.000,00 €**

Table 19: Comparison of investment costs for rolling stock. Source: SGKV

The semi-trailer begins with low investment costs of 20,000 EUR. Purchasing a complete set to operate an intermodal transport train (consisting of 35 T5 railcars) this would total 700,000 EUR. Additionally, trucks might cost 80,000 EUR - 100,000 EUR per unit, or be leased.

The rolling stock for rail operation leads in conventional intermodal transports to investment needs of 2,200,000 to 3,100,000 EUR for the block trains set of 35 units. The Modalohr solution is exceptionally costly with 7,500,000 EUR. Similarly, Ultralow is as costly as a block train set and would be priced at 5,200,000 EUR. These results enforce our basic statement that both Modalohr and Ulltralow (RoLa) systems can only be financed for very specific (niche) applications when the full amortization costs for purchasing the rail rolling stock are politically supported and justified.

RailRunner requires an initial investment of 4,294,500 EUR per 52 unit block train and 2.9 Million EUR for 35 units. But, it must be noted that the RailRunner semi-trailers can be used both in road and in rail transport and in case of container transport no additional chassis for dray to or from the terminal is needed, which reduces the overall investment cost calculation. In case of trailer investments such 52 units at costs of 20,000 EUR each do not need to be purchased in addition to rail wagons thus RailRunner would save 1,040,000 EUR compared to conventional intermodal trailer transport. The RailRunner solution still would be slightly more costly than the compared IM alternatives.

If we alternatively adapt the calculation to 45 ft. containers moving in a block train, the high investment costs of RailRunner per unit become even lower (similar to T5 and T4.2 investment), while the investment costs with Modalohr and ‘Ultralow’ continue to show high costs per unit. Furthermore, when considering the very low terminal operating costs of RailRunner required for the unit load transfer (depending on capacities required only yard hostlers, service trucks and one fork lift to move the idle bogies will be needed) we arrive at excellent competitive values for RailRunner. The value for one set of these listed items is about $200,000 and this value can be transferred to European conditions without too many alterations (for a set which can handle between 20.000 and 30.000 units per year).

The following cost table highlights the operation costs for both a single road vehicle and for a block train. The train operating costs relate to conventional and to new technologies of intermodal transport. The new techniques normally offer lower transfer costs. In handling of intermodal loading units, we have to consider that the terminals in Germany are subsidized so that the German market price per handling might be half of the amount in other European countries.

			Truck	Train
Transport Costs	Track Costs	EUR per km	0,00 €	20,00 €
	Trucking	EUR per hour	37,50 €	19,75 €
	Overheads / Other	EUR per LU and Day	75,00 €	75,00 €
Cargo Handling	Germany	EUR per LU	23,00 €	23,00 €
	Europe	EUR per LU	46,00 €	46,00 €

Table 20: Operation costs road vehicle. Source: SGKV

Additionally, the operator of the RailRunner system will provide the drayage company with the container chassis which is one of three elements of RailRunner's Terminal Anywhere solution and thus allows the drayage operator to save chassis leasing costs.

Wages and salaries (including taxes and social charges) are calculated for a 160 h operation and a lump sum overhead of 10% resulting to 24 EUR per hour, both for operators of transfer equipment and for truck drivers. Other overheads may be added. Special charges must be paid for night shift, weekend, and overtime work. Such charges differ greatly, and must be individually applied to all solutions. Therefore, these cost positions are not part of the comparison.

Labor Costs: Single Trip Hamburg - Budapest			Truck 40 t (x35)	T5: Container Transport	Ultralow: Full Truck Transport	Rail Runner 40 '
Transport	Manpower	amount	1	1	1	1
	Hourly Wage	EUR	24,00 €	24,00 €	24,00 €	24,00 €
	Avg. Transport Time	hours	21	14	14	14
Cargo Handling	Manpower	amount	1	1	1	1
	Hourly Wage	EUR	24,00 €	24,00 €	24,00 €	24,00 €
	Time: 2x Cargo Handling	hours	0,08	4,50	3,27	4,70
Additional Costs	Manpower	amount	1	0	0	0
	Hourly Wage	EUR (reduced)	18	0	0	0
	Time requirements	hours	16	0	0	0
Total Costs	Single Trip, 2 x Cargo Handling	EUR	793,92 €	444,00 €	414,40 €	448,80 €
Loading units		tonnes	1	35	35	47
Costs per loading unit		EUR	793,92 €	12,69 €	11,84 €	9,55 €

Table 21: Model of hourly costs for work force. Source: SGKV

The above calculation compares a road vehicle, a block train carrying containers, a block train carrying semi-trailers and RailRunner. In some cases intermodal transport is accompanied by a driver, or a driver has to stay and sleep overnight on board of the vehicle. We have assumed that this would be paid at a reduced lump sum payment.

The highest costs are generated on our model itinerary for single truck road transport with a total of 793.92 EUR. This high amount is due partly to industry regulations, meaning either one has to pay for a 2nd driver or the truck driver has to stop during the total travel twice to have his required rest periods of eight hours each. The above table shows this under additional costs.

While the T5 block train initially seems equal to an 'Ultralow' block train, we understand that the latter system has a much higher portion of tare weight to carry. The cost values can financially not justly be compared with each other. However, we can assure that based on our calculation for the itinerary, the transport of container will be much more efficient than the transport of single truck +

trailer vehicles, especially, because we did not consider any additional cost for the accompanying tractor drivers for such transport or the required resting period.

RailRunner total cost per train and trip will total 448.80 EUR, slightly higher than ‘Ultralow’ and T5, but when comparing this on a unit basis considering a RailRunner train can carry more payload (in tonnage, or in number of loading units) the cost per ton is only 9.55 EUR. If the block train operator uses its full possible capacity the RailRunner solution is fully competitive to existing container transport and may provide cost advantages. The comparison per loading unit is based on an 80 % capacity utilisation. It is clear that a full utilisation of 100 % would give the RailRunner technology an even further cost advantages over existing technologies.

5. Summary

The study compares conventional, well established techniques of intermodal (IM) transport operating over a model itinerary from Hamburg to Budapest. The comparison refers to environmental effects and costs, travel times required as well as to overall costs. The comparison is based on a modelled train operation.

The following new technological concepts are already available for commercial use in intermodal transport: The Modalohr concept which mainly aims at transporting semi-trailers without lifting capability and the bi-modal RailRunner technology, which offers with its special bogies, chassis and/or trailers an alternative to the classic lift-on lift-off transfer of unit loads by crane or reach stacker in intermodal transport.

The environmental effects are valued by CO_2 emissions and the energy consumption. RailRunner offers here very good values because the system shows a very efficient ratio of total gross weight to payload in rail movements. The advantages vis-à-vis existing intermodal transport solutions are especially high with the intermodal transport of 40 ft. and 45 ft. containers and semi-trailers. This advantage even increases with better utilization of train design capacity. Another considerable advantage is the feasibility and capability of the RailRunner system to be integrated into existing IM freight transport systems. The system can, without any problems, be integrated into existing terminal infrastructures and thus enlarge terminal capacity. Only one track or siding is required for truck access, which also may easily be realized with abandoned terminals and single rail sidings for reuse. The only requirement is that the rail track is accessible by road vehicles and offers even level-grade surface for train assembly. The rail track may also be equipped with overhead catenaries as this would not impair RailRunner's transfer abilities. Additionally, its system costs are low. Modalohr shows some of these features as well, but includes an expensive and somewhat time consuming transfer technique and very expensive rolling stock. Modalohr originally aimed at intermodal transport of complete truck + trailer combinations. This includes a much higher proportion of tare weight to be carried on rail and results in high values for CO_2 emissions and energy consumption per ton payload. This makes Modalohr less attractive and efficient. But if, e. g. for political reasons, the shift of complete commercial road vehicles from road to rail is a desired or mandatory issue, Modalohr may be used.

The time needed for the unit load transfer (Train assembly or unit movements) can be higher with RailRunner, but its overall time budget stays competitive with Modalohr or conventional intermodal transport solutions. If the new technologies of RailRunner and Modalohr transfer their loading units simultaneously in parallel operation, they may even be better with regard to the transfer times needed.

Considering costs the technique of Modalohr aims at niche markets. This intermodal transport of complete commercial road vehicles (Truck + Semi trailer) should only be regarded as viable in specific operations and under special circumstances that make optimal use of these abilities, e. g. in some trans-Alpine corridors. If RailRunner costs are compared to those of normal conventional intermodal transport costs with containers and/or trailers, they prove to be a fully competitive solution. The investment costs for the rollings stock may be slightly higher, but the fact that RailRunner does not require expensive terminal infrastructure fully compensates for this. Both RailRunner and Modalohr operate with minimum required terminal investments. This means RailRunner technology is especially highly competitive in markets which do not have a good or insufficient intermodal terminal infrastructure and capacity. Modalohr is efficient only if political issues demand strictly the intermodal transport of complete commercial vehicles with truck and trailer, but this operation if commercially compared will need considerable subsidies. Modalohr can also be used to transport semi-trailers without the towing vehicle. In this case, its environmental efficiency can be compared to that of existing technical solutions, rendering it competitive, yet without special advantages to other railcars. Only if no equipment for cargo handling is available, the Modalohr solution becomes more effective, since no investment in cranes or reach stackers is necessary.

The RailRunner concept is specifically interesting in the logistics market for semi-trailer operation, and offers solid advantages in container transport especially comparing container carriage with some of the currently used railcar types. We conclude that very high potentials exist for RailRunner in the corridors involving Bulgaria, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia, Czech Republic, Hungary, and Turkey.

Modalohr shows its specific advantage vis-à-vis bi-modal solutions in its ability to carry conventional semi-trailers which do not need any modifications, but terminal investment and terminal operation are complicated, and the investment needed for rail equipment is very expensive and the system is difficult to be integrated into the existing freight transport rail systems. The total investment (Terminal and equipment) needed and the high maintenance costs result in an expensive operation. Although RailRunner requires a specific semi-trailer, this semi-trailer includes only minimum alterations compared to conventional road vehicles, especially when compared to semi-trailers with structural reenforcement for lift-on lift-off operation. As such semi-trailers today are used more extensively they can be depreciated in shorter time periods and thus these additional costs do not matter as much when compared to the savings the RailRunner system offers during rail operation (maintenance, energy consumption, life cycle costs) and its low systems costs (High number of units per train, cheap and easy transfer cost).

When we take the model itinerary from Hamburg to Budapest as shown in this study and include the need for interim rest periods got truck drivers during long distance road operation, and include the transfer costs of intermodal transport, the operation of 35 single road vehicles is much more expensive than operating a block train. Such a block train would complete this itinerary in 14 h (time needed for transport operation only), and road transport will require approximately 21 h. The operation of RailRunner's Terminal Anywhere solution would be slightly more expensive than a block train composed of T5 or Ultralow railcars (additional costs are resulting from the fact that a RailRunner block train consists of 47 compared to 35 loading units with T5), but the cost are much lower when compared per actual transported ton and/or unit load.

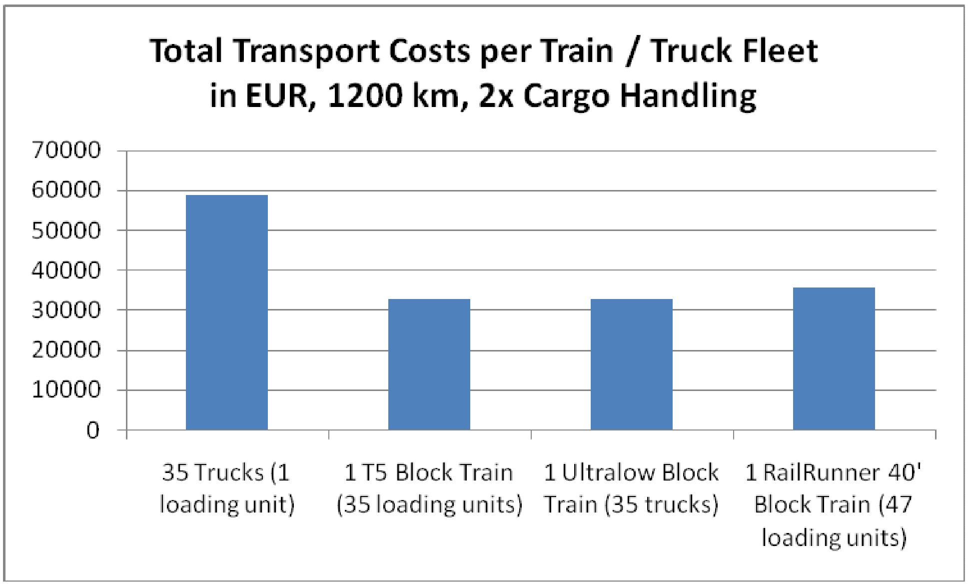

Table 22: Comparison of total transport costs per transport technology. Source: SGKV

If transport costs are calculated per loading unit we realize that the RailRunner technique incurs transport costs lower than 800 EUR per unit in our model calculation, while all other train concepts result in transports costs well over 900 EUR per unit. Also in this table the 'Ultralow' concept does not include the fact of the high tare weight (additional energy cost) as well as the additional costs for drivers accompanying the transport.

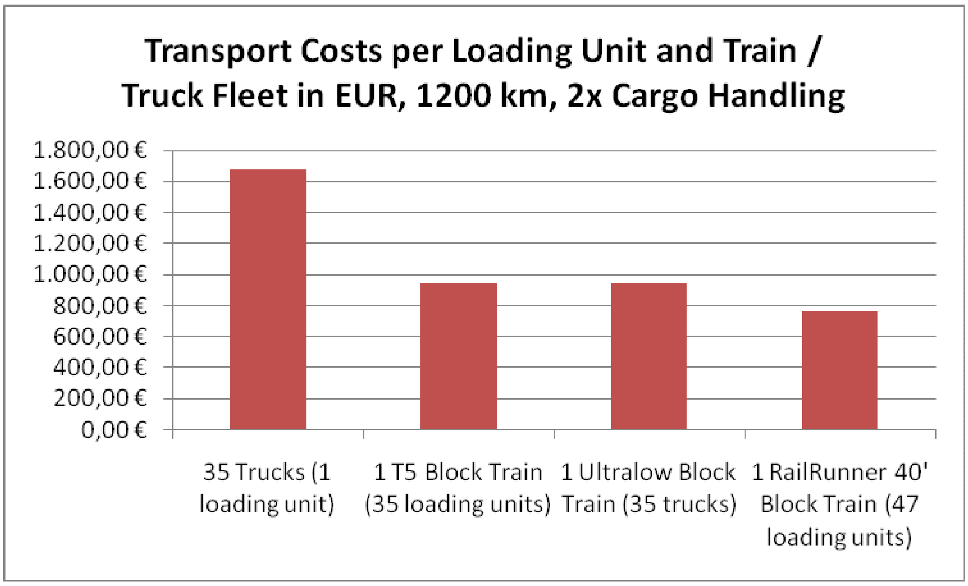

Table 23: Comparison of total transport costs per loading unit. Source: SGKV

The following graph shows the total CO_2 emissions per trip for the total modeled itinerary per (metric) ton payload, comparing 40’ and 45’ containers for each technology using block trains and assuming a75% and alternatively 100% capacity use per train.

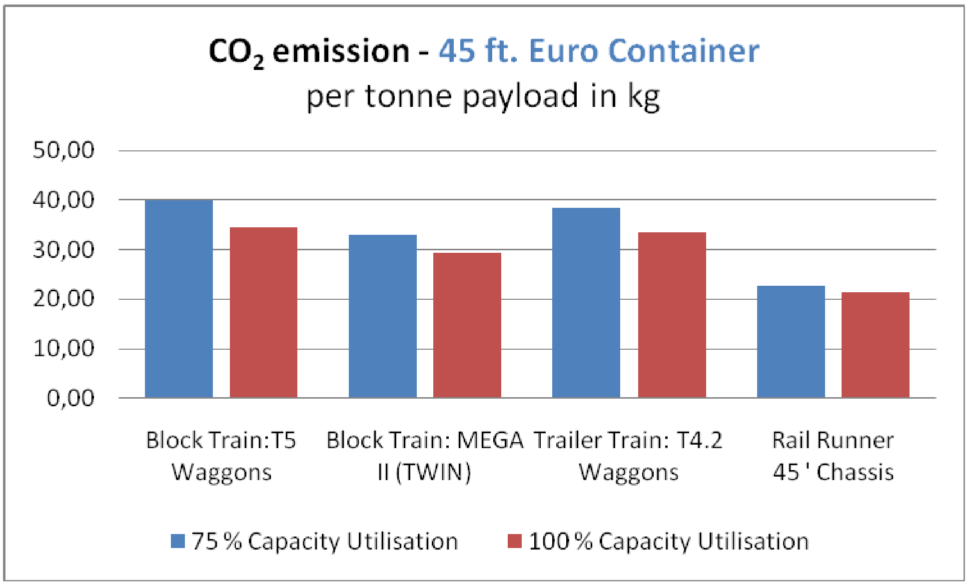

Table 24: Comparison of CO2 emission per (metric) ton payload when using 45 ft. pallet wide containers. Source: SGKV

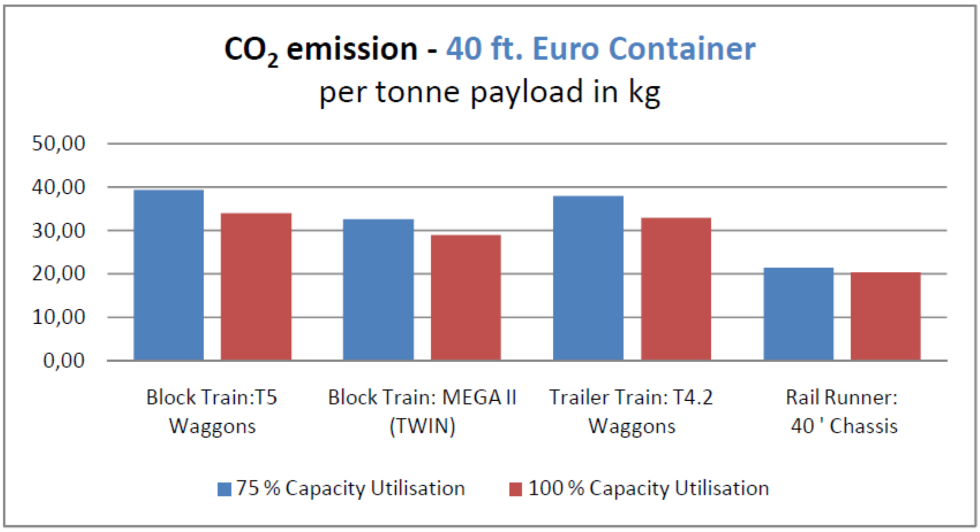

Table 25: Comparison of CO2 emission per (metric) ton payload when using 40 ft.ISO containers. Source: SGKV

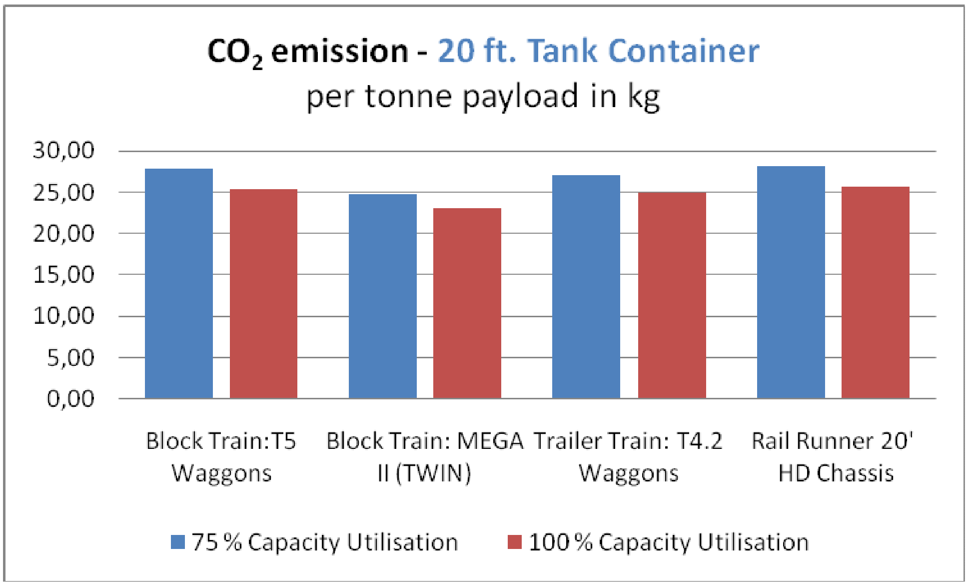

Table 26: Comparison of CO2 emission per (metric) ton payload when using 20 ft. tank containers. Source: SGKV

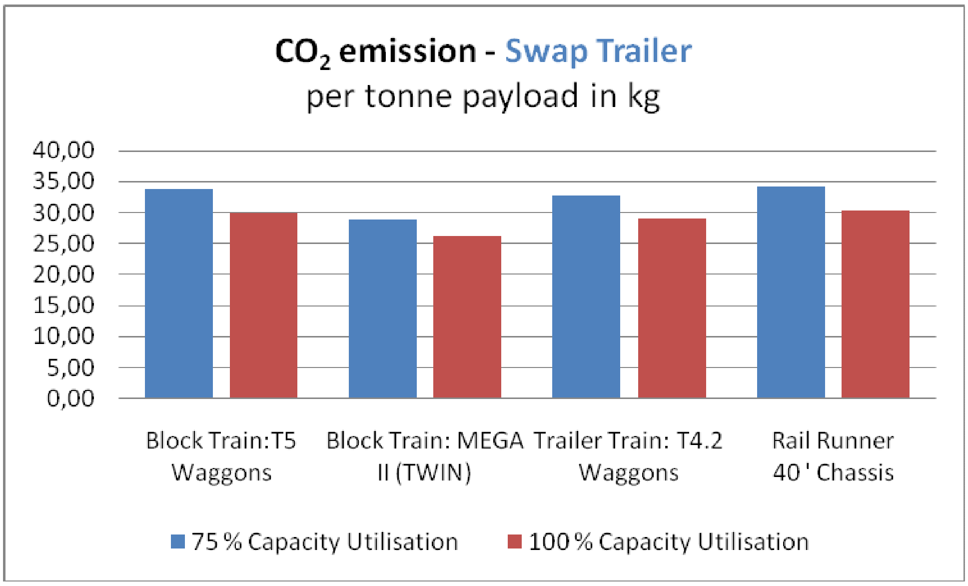

Table 27: Comparison of CO2 emission per (metric) ton payload when using swap bodies. Source: SGKV

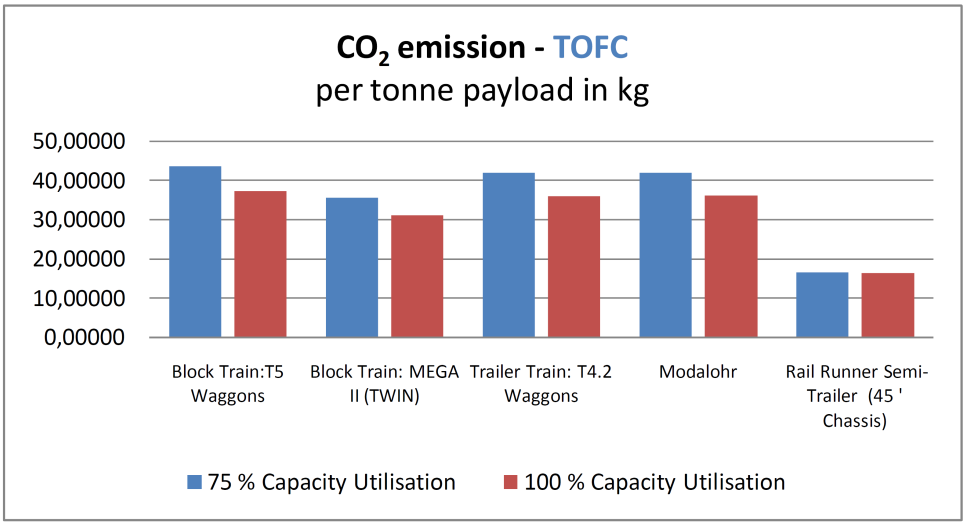

Table 28: Comparison of CO2 emission per (metric) ton payload when operating semi-trailers in intermodal transport. Source: SGKV

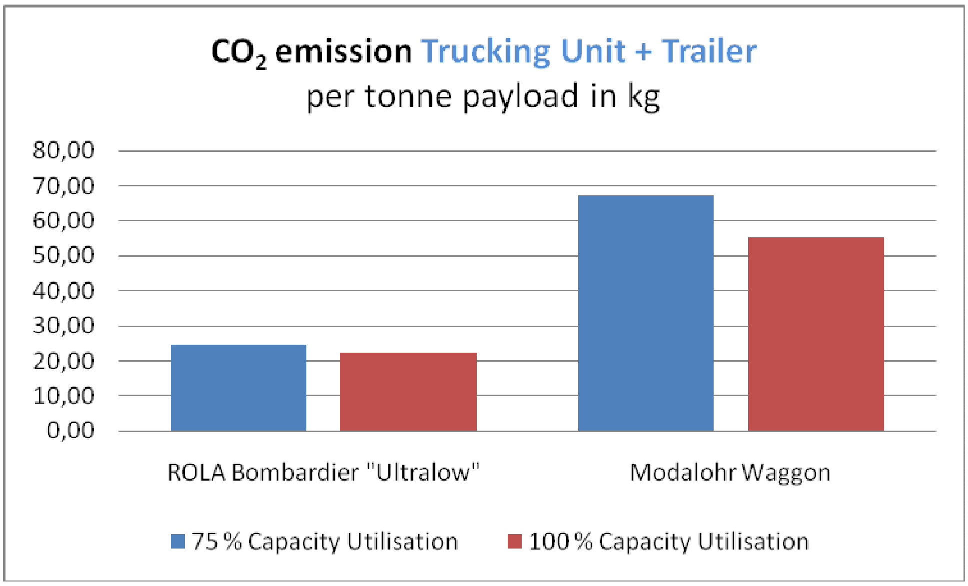

Table 29: Comparison of CO2 emission per (metric) ton payload when operating RoLa. Source: SGKV

6. Additional publications

- Ecoplan : Betriebskostenvergleich und Investitionskostenvergleich zweier RoLa-Systeme, Bern, 2003
- UIC: DIOMIS 2 - Benchmarking Intermodal Rail Transport in the United States and Europe, Report Nr. 4, Paris, 2009
- RailRunner: RailRunner Benefits vs. Other European Intermodal Rail Transport Modes, Hand-out, Lexington 2009
- SGKV e.V.: RailRunner – Feasibility on European Rail Itineraries, Frankfurt M., 2006
- IFEU: Verbrauch, Emissionen, Materialeinsatz und Kosten von Binnenschiffen, Flugzeugen und Schienenfahrzeugen, Heidelberg, 2008
- IRU: Vergleichende Analyse von Energieverbrauch und CO_2-Emissionen im Straßengüterverkehr und Kombinierten Verkehr Schiene/Straße
- Deutscher Bundestag: CO_2-Bilanzen verschiedener Energieträger im Vergleich, Berlin, 2007
- SGKV e.V.: Szenarien zum Verkehr mit Italien, Frankfurt M., 2000
- PACT: Combined Transport CO2 Reduction – Final Report, Gentilly / Frankfurt M./ Roitham, 2003
- EIA: Intermodal Transport in Europe, Brussels, 2005
- CO_2 / energy calculator: http://www.ecotransit.org/
- CO_2 / energy calculator (truck only): http://was.schenker.nu/ECO/EKSelectionForm.asp

Annex 1 – Modelled train calculations – Tables

The model calculation orientates itself based on type of loading units and it calculates trains using domestic 45' EURO Container, 40' ISO Containers, 20' tank container, swap bodies and semi-trailer for transport in RoRo/RoLa. For each unit load we only use the type of equipment capable of transporting that type of load.

Calculation starts with a maximum number or loading units (containers, swap bodies) and rolling stock (trailers, railcars, road vehicles with 16,5 m length)) per maximum possible and usable length of a train for the selected itinerary. This creates the basic data per modelled train. The train speed is a theoretical value based on the maximum possible speed and then considering the specific conditions and restrictions of the route.

Then we calculate the average payload per loading unit in metric tons (specified to the type of loading unit) to provide a given total weight of a road vehicle or train. The "average" payload per loading unit is based on the experience of the author with the specific market conditions and includes the basic values that IMO normally considers. Furthermore, we assume an average capacity of 75% per train, which represents a value based on experience in European intermodal transport.

LU	Parameter	Unit	Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner Semi-Trailer (45 ' Chassis)	Rail Runner 20 ' HD Chassis	Rail Runner 45 ' Chassis	Rail Runner 40 ' Chassis	Modalohr Waggon
LU: 45 ' EU-Container	Max. Amount of Loading Units	amount	1,0	35,0	38,0	25,0				47,0		
	Tare Weight per Loading unit	tonnes	4,8	4,8	4,8	4,8				4,8		
	Max. Payload per Unit	tonnes	25,7	25,7	25,7	25,7				25,7		
	Avg. Payload per Unit	tonnes	14,0	14,0	14,0	14,0				14,0		
	Total Tare Weight	tonnes	20,0	797,5	720,7	550,0				587,4		
	Max Payload (100 % Capacity Utilisation)	tonnes	25,7	898,8	975,8	642,0				1.207,0		
	Avg. Payload (75 % Capacity Utilisation)	tonnes	19,3	674,1	731,9	481,5				905,2		
	TOTAL WEIGHT (75% Capacity Utilisation)	**tonnes**	**39,3**	**1.471,6**	**1.452,6**	**1.031,5**				**1.492,6**		
	TOTAL WEIGHT (100% Capacity Utilisation)	**tonnes**	**45,7**	**1.696,3**	**1.696,5**	**1.192,0**				**1.794,4**		

Table A 1: Model trains carrying 45 ft. containers. Source: SGKV

LU	Parameter	Unit	Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner Semi-Trailer (45 ' Chassis)	Rail Runner 20 ' HD Chassis	Rail Runner 45 ' Chassis	Rail Runner 40 ' Chassis	Modalohr Waggon
LU: 40 ' High Cube ISO Container	Max. Amount of Loading Units	amount	1,0	35,0	38,0	25,0					52,0	
	Tare Weight per Loading unit	tonnes	4,0	4,0	4,0	4,0					4,0	
	Max. Payload per Unit	tonnes	26,5	26,5	26,5	26,5					26,5	
	Avg. Payload per Unit	tonnes	13,0	13,0	13,0	13,0					13,0	
	Total Tare Weight	tonnes	20,0	797,5	720,7	550,0					602,8	
	Max Payload (100 % Capacity Utilisation)	tonnes	26,5	926,8	1.006,2	662,0					1.377,0	
	Avg. Payload (75 % Capacity Utilisation)	tonnes	19,9	695,1	754,7	496,5					1.032,7	
	TOTAL WEIGHT (75% Capacity Utilisation)	**tonnes**	**39,9**	**1.492,6**	**1.475,4**	**1.046,5**					**1.635,5**	
	TOTAL WEIGHT (100% Capacity Utilisation)	**tonnes**	**46,5**	**1.724,3**	**1.726,9**	**1.212,0**					**1.979,8**	

Table A 2 : Model trains carrying 40 ft. containers. Source: SGKV

LU: 20 ' Tank-Container		Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner Semi-Trailer (45 ' Chassis)	Rail Runner 20 ' HD Chassis	Rail Runner 45 ' Chassis	Rail Runner 40 ' Chassis	Modalohr Waggon
Max. Amount of Loading Units	amount	1,0	70,0	76,0	50,0			66,0			
Tare Weight per Loading unit	tonnes	4,2	4,2	4,2	4,2			4,2			
Max. Payload per Unit	tonnes	29,3	29,3	29,3	29,3			29,3			
Avg. Payload per Unit	tonnes	26,0	26,0	26,0	26,0			26,0			
Total Tare Weight	tonnes	20,0	797,5	720,7	550,0			763,7			
Max Payload (100 % Capacity Utilisation)	tonnes	29,3	2.050,3	2.226,0	1.464,5			1.933,1			
Avg. Payload (75 % Capacity Utilisation)	tonnes	22,0	1.537,7	1.669,5	1.098,4			1.449,9			
TOTAL WEIGHT (75% Capacity Utilisation)	**tonnes**	**42,0**	**2.335,2**	**2.390,2**	**1.648,4**			**2.213,6**			
TOTAL WEIGHT (100% Capacity Utilisation)	**tonnes**	**49,3**	**2.847,8**	**2.946,7**	**2.014,5**			**2.696,9**			

Table A 3: Model trains carrying 20 ft.tank containers. Source: SGKV

LU: Swap Body		Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner Semi-Trailer (45 ' Chassis)	Rail Runner 20 ' HD Chassis	Rail Runner 45 ' Chassis	Rail Runner 40 ' Chassis	Modalohr Waggon
Max. Amount of Loading Units	amount	1,0	70,0	76,0	50,0					52,0	
Tare Weight per Loading unit	tonnes	4,6	4,6	4,6	4,6					4,6	
Max. Payload per Unit	tonnes	18,0	18,0	18,0	18,0					18,0	
Avg. Payload per Unit	tonnes	16,0	16,0	16,0	16,0					16,0	
Total Tare Weight	tonnes	20,0	797,5	720,7	550,0					602,8	
Max Payload (100 % Capacity Utilisation)	tonnes	18,0	1.260,0	1.368,0	900,0					936,0	
Avg. Payload (75 % Capacity Utilisation)	tonnes	13,5	945,0	1.026,0	675,0					702,0	
TOTAL WEIGHT (75% Capacity Utilisation)	**tonnes**	**33,5**	**1.742,5**	**1.746,7**	**1.225,0**					**1.304,8**	
TOTAL WEIGHT (100% Capacity Utilisation)	**tonnes**	**38,0**	**2.057,5**	**2.088,7**	**1.450,0**					**1.538,8**	

Table A 4: Model trains carrying swap bodies. Source: SGKV

LU			Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner Semi-Trailer (45 ' Chassis)	Rail Runner 20 ' HD Chassis	Rail Runner 45 ' Chassis	Rail Runner 40 ' Chassis	Modalohr Waggon
LU: Semi Trailer	Max. Amount of Loading Units	amount		35,0	38,0	25,0		47,0				42,0
	Tare Weight per Loading unit	tonnes		4,6	4,6	4,6		4,6				4,6
	Max. Payload per Unit	tonnes		22,0	22,0	22,0		22,0				22,0
	Avg. Payload per Unit	tonnes		14,0	14,0	14,0		14,0				14,0
	Total Tare Weight	tonnes		797,5	720,7	550,0		361,8				927,0
	Max Payload (100 % Capacity Utilisation)	tonnes		770,0	836,0	550,0		1.034,0				924,0
	Avg. Payload (75 % Capacity Utilisation)	tonnes		577,5	627,0	412,5		775,5				693,0
	TOTAL WEIGHT (75% Capacity Utilisation)	**tonnes**		**1.375,0**	**1.347,7**	**962,5**		**1.137,3**				**1.620,0**
	TOTAL WEIGHT (100% Capacity Utilisation)	**tonnes**		**1.567,5**	**1.556,7**	**1.100,0**		**1.395,8**				**1.851,0**

Table A 5: Model trains carrying semi-trailers. Source: SGKV

LU			Truck EURO III, 40 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	TOFC: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner Semi-Trailer (45 ' Chassis)	Rail Runner 20 ' HD Chassis	Rail Runner 45 ' Chassis	Rail Runner 40 ' Chassis	Modalohr Waggon
LU: Traction Unit and Semi-Trailer	Max. Amount of Loading Units	amount					35,0					21,0
	Tare Weight per Loading unit	tonnes					20,0					20,0
	Max. Payload per Unit	tonnes					22,0					22,0
	Avg. Payload per Unit	tonnes					14,0					14,0
	Total Tare Weight	tonnes					703,0					927,0
	Max Payload (100 % Capacity Utilisation)	tonnes					770,0					462,0
	Avg. Payload (75 % Capacity Utilisation)	tonnes					577,5					346,5
	TOTAL WEIGHT (75% Capacity Utilisation)	**tonnes**					**1.280,5**					**1.273,5**
	TOTAL WEIGHT (100% Capacity Utilisation)	**tonnes**					**1.473,0**					**1.389,0**

Table A 6: Model trains carrying truck + semi-trailer combinations. Source: SGKV

Annex 2 – Calculation of CO_2 emissions and energy consumption – tables

A well established model calculation with satisfactory complexity is shown in www.ecotransit.org. This software tool has been developed in co-operation of some of the leading operators of intermodal transport services in Europe. The model allows selecting a precise routing in intermodal transport with a given IM transport mode. Country specific consumption models and applicable energy mixes per country have been included and been considered in our model.

However, the software tool creates the same problem as any models calculating the energy consumption and CO_2 emission currently in discussion, namely the realistic modeling of the actual train weight. The model train uses a given total weight (mass) and this value cannot be changed. However, with new techniques such as RailRunner, especially the favorable ratio between overall train weight and maximum payload, there is a decisive weight advantage for said technology. We therefore have remodeled the calculation by considering a "model weight" per train. This "model weight" is calculated as follows:

- First the relation between payload and total weight (the "ratio") is calculated,
- then this relation (i.e. the ratio) is transferred into a 'normalized' scale that values the maximum (i.e. the most disadvantageous situation) with the value 1.
- Finally this scaled ratio will be applied to all differing payload cases, and the various intermodal transport techniques with an advantageous ratio will be valued with less than 1.

The result shows a "model weight". This model weight will only be used to calculate the actual CO_2 emission and the energy consumption, while in case of comparing the differences between the various transport modes we recalibrate the weight and used the actual real payload. By doing so the various ratios between payload and total weight could be included in the existing model.

Furthermore, we differentiate between diesel motor (D) and electric traction (E). When using electric traction the various country specific energy mixes with their related specific CO_2 emission are considered. The latter values are included in the model as well.

Route : Hamburg - Budapest, length of main leg: 1168,2 km. http://www.ecotransit.org/

Loading Unit	Section	Parameter	Unit	Truck Fleet (35 VEHICLES) EURO III, 40 t / 60 t	Block Train T5 Waggons	Block Train: MEGA II (TWIN)	Trailer Train: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner 45 ' Chassis
Loading Unit: 45 Foot EU-Container	MODELLING DATA	Payload: 75% utilisation	t	19,3	674,1	731,9	481,5		905,2
		Payload: 100 % utilisation	t	25,7	898,8	975,8	642,0		1.207,0
		Total weight 75%	t	39,3	1.471,6	1.452,6	1.031,5		1.492,6
		Total weight 100 %	t	45,7	1.696,3	1.696,5	1.192,0		1.794,4
		Ratio (75%): Total weight / payload	Factor	n/a	2,2	2,0	2,1		1,6
		Equalisation (75%)	Factor	n/a	1,0	0,9	1,0		0,8
		Model total weight (75%)	t	39,3	1.471,6	1.320,6	1.012,2		1.127,4
		Ratio (100%): Total weight / payload	Factor	n/a	1,9	1,7	1,9		1,5
		Equalisation (100%)	Factor	n/a	1,0	0,9	1,0		0,8
		Model total weight (100%)	t	45,7	1.696,3	1.562,8	1.172,7		1.413,5
		Block Train Equivalency Factor	Trucks	35,0	1,0	1,0	1,0		1,0
	75 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	434.644,0	172.694,2	154.966,9	118.808,0		132.308,9
		CO2 Emission [D]	t [D]	104,0	41,3	37,1	28,4		31,6
		ELECTRIFIED: Energy Consumption [E]	kwh [E]	//-//	161.331,7	144.770,8	110.990,4		123.603,5
		Co2 Emission [E]	t [E]	//-//	26,9	24,1	18,5		20,6
		Energy Consumption per Tonne Payload	kwh [D]	22567,19	256,18	211,74	246,75		146,16
		CO2 Emission per Tonne Payload	kg [D]	5397,20	61,27	50,64	59,00		34,91
		Energy Consumption per Tonne Payload	kwh [E]	n/a	239,33	197,81	230,51		136,55
		CO2 Emission per Tonne Payload	kg [E]	n/a	39,91	32,96	38,40		22,76
	100 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	501.511,5	199.109,5	183.377,5	137.709,2		165.885,1
		CO2 Emission [D]	t [D]	120,1	47,6	43,9	32,9		39,7
		ELECTRIFIED: Energy Consumption [E]	kwh [E]	//-//	168.008,5	171.312,1	126.648,6		154.970,6
		Co2 Emission [E]	t [E]	//-//	31,0	28,5	21,4		25,8
		Energy Consumption per Tonne Payload	kwh [D]	19529,26	221,53	187,92	214,50		137,44
		CO2 Emission per Tonne Payload	kg [D]	4674,84	52,96	44,94	51,29		32,87
		Energy Consumption per Tonne Payload	kwh [E]	n/a	186,93	175,55	197,27		128,40
		CO2 Emission per Tonne Payload	kg [E]	n/a	34,48	29,25	33,38		21,38

Table B1: Energy consumption and CO_2 emission with operation of 45 ft. containers. Source: SGKV

Route : Hamburg - Budapest, length of main leg: 1168,2 km. http://www.ecotransit.org/

Loading Unit: 40 Foot EU-Container

Section	Parameter	Unit	Truck Fleet (35 VEHICLES) EURO III, 40 t / 60 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	Trailer Train: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner: 40 ' Chassis
MODELLING DATA	Payload: 75% utilisation	t	19,9	695,1	754,7	496,5		1.032,7
MODELLING DATA	Payload: 100 % utilisation	t	26,5	926,8	1.006,2	662,0		1.377,0
MODELLING DATA	Total weight 75%	t	39,9	1.492,6	1.475,4	1.046,5		1.635,5
MODELLING DATA	Total weight 100 %	t	46,5	1.724,3	1.726,9	1.212,0		1.979,8
MODELLING DATA	Ratio (75%): Total weight / payload	Factor	n/a	2,1	2,0	2,1		1,6
MODELLING DATA	Equalisation (75%)	Factor	n/a	1,0	0,9	1,0		0,7
MODELLING DATA	Model total weight (75%)	t	**39,9**	**1.492,6**	**1.343,2**	**1.027,2**		**1.206,2**
MODELLING DATA	Ratio (100%): Total weight / payload	Factor	n/a	1,9	1,7	1,8		1,4
MODELLING DATA	Equalisation (100%)	Factor	n/a	1,0	0,9	1,0		0,8
MODELLING DATA	Model total weight (100%)	t	**46,5**	**1.724,3**	**1.593,0**	**1.192,7**		**1.529,9**
MODELLING DATA	Block Train Equivalency Factor	Trucks	35,0	1,0	1,0	1,0		1,0
75 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	434.640,5	175.159,6	157.694,3	120.594,5		141.611,1
75 % Capacity Utilisation	CO2 Emission [D]	t [D]	104,0	41,9	37,7	28,9		33,9
75 % Capacity Utilisation	ELECTRIFIED: Energy Consumption [E]	kwh [E]	//-//	163.700,6	147.318,9	112.660,0		132.293,9
75 % Capacity Utilisation	Co2 Emission [E]	t [E]	//-//	27,3	24,6	18,8		22,1
75 % Capacity Utilisation	Energy Consumption per Tonne Payload	kwh [D]	21885,22	251,99	208,96	242,89		137,12
75 % Capacity Utilisation	CO2 Emission per Tonne Payload	kg [D]	5234,14	60,26	50,01	58,14		32,82
75 % Capacity Utilisation	Energy Consumption per Tonne Payload	kwh [E]	//-//	235,51	195,21	226,91		128,10
75 % Capacity Utilisation	CO2 Emission per Tonne Payload	kg [E]	//-//	39,30	32,57	37,86		21,37
100 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	190.984,7	202.431,1	187.022,1	140.018,3		179.614,5
100 % Capacity Utilisation	CO2 Emission [D]	t [D]	45,7	48,5	44,8	33,5		43,0
100 % Capacity Utilisation	ELECTRIFIED: Energy Consumption [E]	kwh [E]	//-//	189.112,3	174.717,1	130.805,9		167.796,9
100 % Capacity Utilisation	Co2 Emission [E]	t [E]	//-//	31,6	29,2	21,8		28,0
100 % Capacity Utilisation	Energy Consumption per Tonne Payload	kwh [D]	7212,41	218,42	185,86	211,51		130,44
100 % Capacity Utilisation	CO2 Emission per Tonne Payload	kg [D]	1726,32	52,28	44,49	50,63		31,22
100 % Capacity Utilisation	Energy Consumption per Tonne Payload	kwh [E]	//-//	204,05	173,63	197,59		121,86
100 % Capacity Utilisation	CO2 Emission per Tonne Payload	kg [E]	//-//	34,05	28,97	32,97		20,33

Table B2: Energy consumption and CO2 emission with operation of 40 ft. containers. Source: SGKV

Route : Hamburg - Budapest, length of main leg: 1168,2 km. http://www.ecotransit.org/

Loading Unit	Section	Parameter	Unit	Truck Fleet (35 VEHICLES) EURO III, 40 t / 60 t	Block Train:T5 Waggons	Block Train: MEGA II (TWIN)	Trailer Train: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner 20' HD Chassis
Loading Unit: 20 Foot Tank Container	MODELLING DATA	Payload: 75% utilisation	t	22,0	1.537,7	1.669,5	1.098,4		1.449,9
		Payload: 100 % utilisation	t	29,3	2.050,3	2.226,0	1.464,5		1.933,1
		Total weight 75%	t	42,0	2.335,2	2.390,2	1.648,4		2.213,6
		Total weight 100 %	t	49,3	2.847,8	2.946,7	2.014,5		2.696,9
		Ratio (75%): Total weight / payload	Factor	n/a	1,5	1,4	1,5		1,5
		Equalisation (75%)	Factor	n/a	1,0	0,9	1,0		1,0
		Model total weight (75%)	t	42,0	2.335,2	2.253,4	1.629,0		2.225,5
		Ratio (100%): Total weight / payload	Factor	n/a	1,4	1,3	1,4		1,4
		Equalisation (100%)	Factor	n/a	1,0	1,0	1,0		1,0
		Model total weight (100%)	t	49,3	2.847,8	2.808,4	1.995,0		2.708,7
		Block Train Equivalency Factor	Trucks	35,0	1,0	1,0	1,0		1,0
	75 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	172.442,99	274.153,08	264.546,07	191.238,68		261.267,93
		CO2 Emission [D]	t [D]	41,28	65,62	63,32	45,77		62,54
		ELECTRIFIED: Energy Consumption [E]	kwh [E]	//-//	256.115,33	247.140,41	178.656,24		244.077,95
		Co2 Emission [E]	t [E]	//-//	42,73	41,24	29,81		40,73
		Energy Consumption per Tonne Payload	kwh [D]	7.849,91	178,28	158,46	174,11		180,20
		CO2 Emission per Tonne Payload	kg [D]	1.878,91	42,67	37,93	41,67		43,13
		Energy Consumption per Tonne Payload	kwh [E]	//-//	166,55	148,03	162,66		168,35
		CO2 Emission per Tonne Payload	kg [E]	//-//	27,79	24,70	27,14		28,09
	100 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	202.530,88	334.328,87	329.704,19	234.216,50		318.003,76
		CO2 Emission [D]	t [D]	48,48	80,02	78,92	56,06		76,12
		ELECTRIFIED: Energy Consumption [E]	kwh [E]	//-//	312.331,90	308.011,49	218.806,36		297.080,89
		Co2 Emission [E]	t [E]	//-//	52,11	51,39	36,51		49,57
		Energy Consumption per Tonne Payload	kwh [D]	6.914,68	163,06	148,11	159,93		164,50
		CO2 Emission per Tonne Payload	kg [D]	1.655,06	39,03	35,45	38,28		39,37
		Energy Consumption per Tonne Payload	kwh [E]	//-//	152,33	138,37	149,41		153,68
		CO2 Emission per Tonne Payload	kg [E]	//-//	25,42	23,09	24,93		25,64

Table B3: Energy consumption and CO2 emission with operation of 20 ft.tank containers. Source: SGKV

Route : Hamburg - Budapest, length of main leg: 1168,2 km. http://www.ecotransit.org/

Loading Unit	Section	Parameter	Unit	Truck Fleet (35 VEHICLES) EURO III, 40 t / 60 t	Block Train:T5 Waggons	Block Train: MEGA II (TWIN)	Trailer Train: T4.2 Waggons	ROLA Bombardier "Ultralow"	Rail Runner 40 ' Chassis
Loading Unit: Swap Trailer	MODELLING DATA	Payload: 75% utilisation	Tonnes	13,5	945,0	1.026,0	675,0		702,0
		Payload 100 % utilisation	Tonnes	18,0	1.260,0	1.368,0	900,0		936,0
		Total weight 75%	Tonnes	33,5	1.742,5	1.746,7	1.225,0		1.304,8
		Total weight 100 %	Tonnes	38,0	2.057,5	2.088,7	1.450,0		1.538,8
		Ratio (75%): Total weight / payload	Faktor	n/a	1,8	1,7	1,8		1,9
		Equalisation (75%)	Faktor	n/a	1,0	0,9	1,0		1,0
		Model total weight (75%)	Tonnes	33,5	1.742,5	1.612,7	1.205,7		1.315,3
		Ratio (100%): Total weight / payload	Faktor	n/a	1,6	1,5	1,6		1,6
		Equalisation (100%)	Faktor	n/a	1,0	0,9	1,0		1,0
		Model total weight (100%)	Tonnes	38,0	2.057,5	1.953,0	1.430,6		1.549,2
		Block Train Equivalency Factor	Trucks	35,0	1,0	1,0	1,0		1,0
	75 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	137.650,33	204.567,76	189.328,15	141.544,12		154.409,57
		CO2 Emission [D]	t [D]	32,95	48,96	45,32	33,88		36,96
		ELECTRIFIED: Energy Consumption [E]	kwh [E]	3.674,11	191.108,34	176.871,41	132.231,30		144.250,28
		Co2 Emission [E]	t [E]	0,61	31,89	29,51	22,06		24,07
		Energy Consumption per Tonne Payload	kwh [D]	10.196,32	216,47	184,53	209,69		219,96
		CO2 Emission per Tonne Payload	kg [D]	2.440,54	51,81	44,17	50,19		52,65
		Energy Consumption per Tonne Payload	kwh [E]	n/a	202,23	172,39	195,90		205,48
		CO2 Emission per Tonne Payload	kg [E]	n/a	33,74	28,76	32,69		34,29
	100 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]	156.140,67	241.548,44	229.278,44	167.953,32		181.879,44
		CO2 Emission [D]	t [D]	37,37	57,82	54,88	40,20		43,53
		ELECTRIFIED: Energy Consumption [E]	kwh [E]	//-//	225.655,90	214.193,19	156.902,93		169.912,79
		Co2 Emission [E]	t [E]	//-//	37,65	35,74	26,18		28,35
		Energy Consumption per Tonne Payload	kwh [D]	8.674,48	191,71	167,60	186,61		194,32
		CO2 Emission per Tonne Payload	kg [D]	2.076,28	45,89	40,12	44,67		46,51
		Energy Consumption per Tonne Payload	kwh [E]	n/a	179,09	156,57	174,34		181,53
		CO2 Emission per Tonne Payload	kg [E]	n/a	29,88	26,13	29,09		30,29

Table B4: Energy consumption and CO2 emission with operation of swap bodies. Source: SGKV

Route : Hamburg - Budapest, length of main leg: 1168,2 km. http://www.ecotransit.org/

Loading Unit: Semi-Trailer TOFC				Truck Fleet (35 VEHICLES) EURO III, 40 t / 60 t	Block Train:T5 Waggons	Block Train: MEGA II (TWIN)	Trailer Train: T4.2 Waggons	Modalohr	Rail Runner Semi-Trailer (45 ' Chassis)
Loading Unit: Semi-Trailer TOFC	MODELLING DATA	Payload: 75% utilisation	Tonnes		577,5	627,0	412,5	693,0	775,5
		Payload 100 % utilisation	Tonnes		770,0	836,0	550,0	924,0	1.034,0
		Total weight 75%	Tonnes		1.375,0	1.347,7	962,5	1.620,0	1.137,3
		Total weight 100 %	Tonnes		1.567,5	1.556,7	1.100,0	1.851,0	1.395,8
		Ratio (75%): Total weight / payload	Faktor		2,4	2,1	2,3	2,3	1,5
		Equalisation (75%)	Faktor		1,0	0,9	1,0	1,0	0,6
		Model total weight (75%)	Tonnes		1.375,0	1.216,7	943,3	1.590,5	700,5
		Ratio (100%): Total weight / payload	Faktor		2,0	1,9	2,0	2,0	1,3
		Equalisation (100%)	Faktor		1,0	0,9	1,0	1,0	0,7
		Model total weight (100%)	Tonnes		1.567,5	1.423,9	1.080,7	1.821,5	925,6
		Block Train Equivalency Factor	Trucks		1,0	1,0	1,0	1,0	1,0
	75 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]		161.423,63	142.835,39	110.736,61	186.728,45	82.239,78
		CO2 Emission [D]	t [D]		38,64	34,19	26,51	44,69	19,68
		ELECTRIFIED: Energy Consumption [E]	kwh [E]		150.802,85	133.437,62	103.450,76	174.442,75	76.828,87
		Co2 Emission [E]	t [E]		25,16	22,26	17,26	29,11	12,82
		Energy Consumption per Tonne Payload	kwh [D]		279,5	227,8	268,5	269,4	106,0
		CO2 Emission per Tonne Payload	kg [D]		66,90476	54,52682	64,25533	64,49398	25,38295
		Energy Consumption per Tonne Payload	kwh [E]		261,1	212,8	250,8	251,7	99,1
		CO2 Emission per Tonne Payload	kg [E]		43,57143	35,51035	41,84600	42,00142	16,53053
	100 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]		184.022,93	167.168,30	126.873,31	213.839,75	108.660,93
		CO2 Emission [D]	t [D]		44,05	40,01	30,37	51,18	26,01
		ELECTRIFIED: Energy Consumption [E]	kwh [E]		171.915,25	156.169,56	118.525,75	199.770,29	101.511,65
		Co2 Emission [E]	t [E]		28,69	26,06	19,78	33,33	16,94
		Energy Consumption per Tonne Payload	kwh [D]		239,0	200,0	230,7	231,4	105,1
		CO2 Emission per Tonne Payload	kg [D]		57,20357	47,86186	55,21404	55,39345	25,15329
		Energy Consumption per Tonne Payload	kwh [E]		223,3	186,8	215,5	216,2	98,2
		CO2 Emission per Tonne Payload	kg [E]		37,25357	31,16982	35,95789	36,07474	16,38097

Table B5: Energy consumption and CO2 emission with operation of semi-trailers. Source: SGKV

Route : Hamburg - Budapest, length of main leg: 1168,2 km. http://www.ecotransit.org/

Loading Unit	Section	Parameter	Unit	Truck Fleet (35 VEHICLES) EURO III, 40 t / 60 t	Block Train: T5 Waggons	Block Train: MEGA II (TWIN)	Trailer Train: T4.2 Waggons	ROLA Bombardier "Ultralow"	Modalohr Waggon
Loading Unit: Trucking Unit and Trailer	MODELLING DATA	Payload: 75% utilisation	Tonnes					577,5	346,5
		Payload 100 % utilisation	Tonnes					770,0	462,0
		Total weight 75%	Tonnes					1.280,5	1.273,5
		Total weight 100 %	Tonnes					1.473,0	1.389,0
		Ratio (75%): Total weight / payload	Faktor					2,2	3,7
		Equalisation (75%)	Faktor					0,6	1,0
		Model total weight (75%)	Tonnes					772,5	1.273,5
		Ratio (100%): Total weight / payload	Faktor					1,9	3,0
		Equalisation (100%)	Faktor					0,6	1,0
		Model total weight (100%)	Tonnes					937,2	1.389,0
		Block Train Equivalency Factor	Trucks					1,0	1,0
	75 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]					90.693,44	149.507,63
		CO2 Emission [D]	t [D]					21,71	35,79
		ELECTRIFIED: Energy Consumption [E]	kwh [E]					84.726,31	139.670,86
		Co2 Emission [E]	t [E]					14,14	23,31
		Energy Consumption per Tonne Payload	kwh [D]					157,04	431,48
		CO2 Emission per Tonne Payload	kg [D]					37,59	103,28
		Energy Consumption per Tonne Payload	kwh [E]					146,71	403,09
		CO2 Emission per Tonne Payload	kg [E]					24,48	67,26
	100 % Capacity Utilisation	DIESEL [D]: Energy Consumption	kwh [D]					110.031,97	163.067,21
		CO2 Emission [D]	t [D]					26,34	39,03
		ELECTRIFIED: Energy Consumption [E]	kwh [E]					102.792,48	152.338,30
		Co2 Emission [E]	t [E]					17,15	25,42
		Energy Consumption per Tonne Payload	kwh [D]					142,90	352,96
		CO2 Emission per Tonne Payload	kg [D]					34,20	84,48
		Energy Consumption per Tonne Payload	kwh [E]					133,50	329,74
		CO2 Emission per Tonne Payload	kg [E]					22,27	55,02

Table B6: Energy consumption and CO2 emission with operation of truck + semi-trailer combinations. Source: SGKV