Improved Performance of European Long Haulage Transport

Haide Backman
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PREFACE

The EXTRA project, initiated by Swedish and Finnish industry, has been carried out to support the improvement of the road transport system in Europe. The economic, environmental and safety benefits of extended heavy vehicle combinations has been studied and indicated by use of authentic transport information. The following organisations and their representatives have contributed to the accomplishment of the project financially and/or by the provision of expertise and data services. Financial support has also been received from the Swedish Agency for Innovation Systems (VINNOVA).

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Harri Rumpunen Confederation of Finnish Industry and Employers/
Finnish Forest Industries Federation
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Dennis van Tilburg Vos Logistics
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The project has also been supported by the Dutch Ministry of Transport, Koninklijk Nederlands Vervoer (KNV) and the Transport en Logistiek Nederland (TLN).

Trip data collection and processing in the Netherlands has been performed by NEA Transport Research and Training on partnership and consultant basis.
Anders Lundqvist has served as chairman of the project-managing group and Haide Backman as secretary. Project manager was Rolf Nordström.

TFK Transport Research Institute expresses its sincere thanks to everyone who has taken part in this project.

Stockholm in May 2002
TFK Transport Research Institute

Leif Andersson
Managing Director
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SUMMARY

In international long haulage transport within the EU articulated vehicles, usually called semi-trailer combinations, are dominant. Their regular loading capacity, of about 85 m$^3$ and 26 tonnes is provided by a 13.6 metre long semi-trailer (the maximum total weight being 40 tonnes or 44 tonnes if the cargo consists of a 40-foot ISO container). Also road trains, consisting of a lorry and a centre-axle trailer, are used. The maximum loading capacity is approximately 96 m$^3$ and 26 tonnes.

The modular concept practised in Sweden and Finland since 1997 is based on the CEN standardised 7.82-metre long unit load carrier and the 13.6-metre long semi-trailer being the longest single vehicle allowed in EU. The maximum length of this combination of "modules" is 25.25 metres. All cargo units in the system are well adapted for rail transport in combined transport either as single vehicles or as separate load carrier units. The combination is built on existing vehicles and load carriers available in large quantities on the European continent.

This study shows that the modular concept will change and improve the logistic system on the European continent. To fill up the extra loading capacity co-operation between hauliers and forwarders will be performed. Cargo units for the intended destination can be exchanged between companies.

Authentic transport data was used in the study as basis for the analyses. The established utilisation ratio of the loading units was applied as a restriction in the main analyses of the effect of modular concept. In practise this means that the loading units were reorganised but not the cargo.

On average the reduction of number of trips was approximately 32 %, fuel consumption was reduced by approximately 15 % and the cost savings about 23 %. Also the NOx would drop by about 15 %. The variation of the results from the studied companies is small.

The consequent advantage concerning environmental aspects, congestion, road wear and road safety is also described in the report.

The goods transportation by road in Europe was recently estimated to increase by at least 38 percent until 2010 in the EU White Paper "European transport policy for 2010: time to decide". This was considered to be the outcome even if all listed measures to increase the market share of rail and sea transport were implemented. Improved efficiency in all transport modes is crucial. New more efficient ways to combine already existing transport modules could be one of the solutions to improve the road freight system and to curb its social costs. It will also become a tool to limit the growth of the road traffic product.
1 INTRODUCTION

The maximum authorized dimensions that are allowed for national and international traffic and the maximum weights and dimensions that are allowed for certain vehicles in international traffic were prescribed in the EU Council Directive 96/53/EC of May 25th 1996. As result of the "modular concept" introduced in this directive Sweden and Finland were permitted to retain the longer lengths for vehicles operating in national traffic. In principle all Member States were allowed to apply the modular concept. The Council, however, called upon a report from the Commission whether the modular concept is possible to use by Member States other than Finland and Sweden and if this would be justified and could significantly affect international competition in the transport sector. Pending receipt of this report the other Member States did not intend to introduce or extend generally in their territory the modular approach (see Council minutes extract in chapter 1.1).

The modular concept implies road trains consisting of combined EU-directive vehicle modules. The maximum road train length in Sweden and Finland hence had to be extended to 25.25 metres. Foreign hauliers on the continent this way are enabled to extend their vehicle combinations with an available extra trailer for additional capacity at the border to Sweden or Finland.

![Vehicle configurations illustrated by Volvo](image1.png)

Figure 1-1 Vehicle configurations illustrated by Volvo

The articulated vehicle (i.e. semi-trailer combination) can be extended from 16.5 metres to 25.25 metres by adding a trailer with 7.82 metres load length. This gives the extra loading capacity of over 50% in both volume and weight compared to a road train. A dolly carrying a 13.6 metre semi-trailer may replace a road train trailer in the same situation. This will give the increase in loading capacity of about 40% in volume and 60% in weight. This way there is no discrimination from the Swedish and Finnish hauliers using larger and heavier vehicle combinations toward the other EU hauliers. Assuming that sufficient freight is available for the extra capacity the continental transport companies can contribute to and benefit from the cost, energy and environmental saving system practised in Sweden and Finland during their operation there. Advantages can be achieved without any increase in road wear, as the maximum axle loads allowed are the same.

It is accordingly believed that an increase in maximum vehicle length would significantly improve transport efficiency for the whole of Europe. Furthermore it could promote a reduction of traffic congestion along many transport corridors on the continent. Less shipments saves road space, need of drivers and motor vehicles. A reduced amount of
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shipments means that many tonne-kilometres would be saved which is the same as savings of fuel and road wear and reduction of pollution and also less pollution.

1.1 BACKGROUND

Articulated vehicles, composed of a tractor and a semi-trailer, are dominant in international traffic within the EU. Their regular loading capacity, of about 85 m$^3$ and 26 tonnes is provided by a 13.6 metre long semi-trailer. Also road trains, consisting of a lorry and a trailer, are used. In recent years a relatively short trailer for this combination, built like a cart with a centre "axle" in the form of a bogie, has become customary on the continent (stiff draw bar trailers or centre axle trailers). The loading capacity of the road train combination is dependent on the type of trailer used and the length of the draw bar between the cargo units. In general the maximum loading capacity for a road train is 26 tonnes in weight. The maximum loading capacity in volume is approximately 96 m$^3$ ($15.36 \times 2.55 \times 2.46 = 96.35$). If the cargo consists of a 40-foot ISO container the total weight of the semi-trailer combination may be 44 tonnes in international transports.

The most common combination for national transports in Sweden, Finland and Norway are road trains. The trailers combined with load-carrying lorries in these road trains have different lengths and axle configurations. For international transports the same vehicles are used as in the rest of Europe.

The system practised in Sweden and Finland since 1997 is based on the CEN standardised 7.82-metre long unit load carrier and the 13.6-metre long semi-trailer being the longest single vehicle allowed in EU. The maximum length of this "module" combination is 25.25 metres. All cargo units in the system are well adapted for combined transport on rail in either as single vehicles or as separate load carrier units. The modular combination is built on existing vehicles and load carriers available in large quantities on the European continent.

In the statements for entry in the minutes of the Council meeting in 1996 for the EU Council Directive 8702/96 ADD 1 regarding the adoption of 96/53/EEG article 4.4 b the following was said:

"The "modular concept" referred to in Article 4(4)(b) was introduced into this Directive to take account of the situation in the two new EU Member States whose legislation at the time of adoption of the Directive, bearing in mind particular geographical, economic and environmental conditions, had for a long time authorized the circulation in their territory of road trains whose length far exceeded that permitted under Community legislation.

The Council calls upon the Commission to submit as soon as possible a report on the implications of the derogation provided for in Article 4(4)(b) of this Directive, to enable it to assess whether its possible use by Member States other than Finland and Sweden would be justified and could significantly affect international competition in the transport sector, bearing in mind also the principles of harmonization and stabilization of the dimensions of road vehicles for the transport of goods.

The Council invites the Commission to submit to it, if necessary, on the basis of the evaluation of that report, appropriate proposals for the amendment of this Directive. Pending receipt of the above, Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal and the United Kingdom state that they do not intend to introduce or extend, according to the circumstances concerned, generally in their territory the modular approach as described in Article 4(4)(b)."
The report requested by the Council and directed in this writing has not yet been submitted. The EU White Paper "European transport policy for 2010: time to decide" has presented 60 measures for increasing efficiency in transports. The main objective is to increase the market share for rail and sea transport. If all measures are implemented, the increase for road transport between 1998 and 2010 is said to be 38%. This development is illustrated in Figure 1-1 where it is seen that the expected result on road transport of all EU White Paper measures, is very small (the red part in the chart).

The White Paper recognises that this means revitalising the railways and improving quality in the road transport sector for instance by modernisation of the way in which road transport services are operated.

The modular combination system could be one such improvement, which also supports the suggested use of larger vehicles with standardised swap bodies and semi-trailers in intermodal transports.

![Goods transport development in EU15 1970-2010, billion tonne-km, according to the EU White Paper](image)

**Figure1-2  Goods transport development in EU15 1970-2010, billion tonne-km, according to the EU White Paper**

1.2 OBJECTIVE

The objective of this study was to demonstrate and to confirm the possible benefits from an efficient and environmentally adapted cargo and vehicle modular system for heavy vehicle combinations on the European continent.

1.3 INTERESTED PARTIES

Interested parties are mainly composed of three designated categories; the public, decision-makers at national level (authorities, governments) and at the EU level.
2 SCOPE AND LIMITATIONS OF THE STUDY

In the initial phase of the project it was decided to focus on transport routes with the following characteristics:

- International transports
- Full truck loads (FTL)
- On highways
- Non-stop (direct) transports

Another limitation is that the project only aims to improve the road transport system. No considerations have been taken to the possible interchange with inter-modal corridors.

The modular combination system on the European continent is intended for use on the big transport corridors connecting main industrial areas, included in what is often called the Road Class System. On arrival to their destinations the modular combinations will be divided into regular EU-vehicles adapted for local distribution and compiling of goods for long haulage transport.

To illustrate the potential benefits of longer vehicle combinations the following factors have been considered as most appropriate for analysis:

- Energy consumption (kWh, kg, litre)
- Environmental impact (CO₂-emissions)
- Transport costs
- Road space utilisation
- Road wears (number of equivalent 10-ton axles)
- Road safety (number of vehicles and drivers on the road)

The study has focused on modular unit loads, which have weight and dimensions in compliance with the EU Directive 96/53. The following unit load combinations were selected as most relevant (total combination length / total load length):

- 16.5 m / 13.6 m (semi-trailer)
- 18.75 m / 7.82 m + 7.82 m (lorry and trailer combination, i.e. road train)
- 25.25 m / 7.82 m + 13.6 m (lorry and semi-trailer combination)
- 25.25 m / 13.6 m + 7.82 m (semi-trailer and trailer combination)

The Swedish National Road Administration describes the modular system on their web-site (http://www.vv.se/yrkestraf/regler/gods/vikt_dimension/2525eng.htm) as shown in figure 2-1 on the next page calling the modules building bricks.
Building bricks
The modular system normally contains the parts shown in the picture below
7,82 m swapbody, 13,6 m semitrailer, dolly, truck, trailer

When the building bricks are put together the result will normally be the shapes below

Speed criteria's
Truck with two trailers is basically speed limited to 40 km/h. Demands for an authorised speed of 80 km/h for the upper road train is that:

- it only have two joints (with a full trailer as the rearmost part, the speed limit will still be 40 km/h
- any steered axle but the front steering axle have to be blocked when the speed exceeds 40 km/h
- it must be possible to turn maximum without the super structures are turning
- The height of the rearmost trailer must not exceed 4.0 meter.

Demands for an authorised speed of 80 km/h for the bottom road train (truck + dolly + semitrailer) is that:

- both dolly and semitrailer are equipped with ABS brakes
- The fifth wheel on the dolly is placed on bearings.

Figure 2-1 The transport units recognised as building bricks
The "Modular concept" was also illustrated with the following picture and it was stressed that that the concept basically is very simple.

Figure 2-2 The basically very simple "Modular concept" illustrated

In words it means that when in the present situation a haulier can choose among three alternative combinations in a certain transport operation, in the "module world" there are five alternative combinations to choose. Importantly: the module concept gives us two more alternatives (IV and V), that are larger and more economical, but it does not take away any existing alternatives (I - III). So there is no need to use a bigger combination in cases where an existing combination is more economical.

In the modular combination system the larger alternatives (IV and V) can easily be switched over to other alternatives in the "module world".
3 METHOD

The analyses in the project contain a data compiling process and analysis of the potential for the module combinations used by specific transport companies. The results from the analyses are presented as fuel consumption, number of trips, and transport cost for both the modular combinations as well as for the present EU-vehicles.

An important principle has been to use real transport data as a basis for the analyses. In order to accomplish this a method with the following steps has been applied:

- definition of required data
- selection of data providing sources
- selection of transport corridors
- selection of observation period
- conversion factor calculation
- data processing
- analysis

DEFINITION OF REQUIRED DATA

In order to satisfy the object of authentic freight information for the study a certain data quality was required. When the data gathering started, it was however discovered that the lowest level of available trip data in some cases was not detailed enough. The freight information had to be transformed to fit the proposed structure of the basic trip records.

Per trip the following data was needed:

- cargo characteristics:
  - weight of the cargo
  - volume of the cargo (m³, pallets)
  - commodity
  - origin and destination (or: corridor)
  - date
- characteristics of the transport vehicle used:
  - loading capacity (ton, m³, pallets)
  - fuel consumption (litres per kilometre)
- derived figures:
  - fuel consumption (number of litres)
  - space occupancy
SELECTION OF DATA PROVIDING SOURCES
The focus of this research has been the possibilities of extra loading volume if longer vehicle combinations are used. Current statistics indicate that the share of shipments of voluminous goods is high and increasing. This development will probably continue, which means that there will be a further demand for voluminous loading capacity. Furthermore the collected data should provide an accurate reflection of the transport sector.

To fulfil the requirements of this study a representative haulier company should have the following characteristics:
• (for a large part) specialised in transport of voluminous cargo
• large (expressed in number of performed trips)
• operating internationally
• availability and accessibility of trip records.

Two Dutch and one Danish company were selected as data providing sources. Two of them are professional haulier companies and the third, which is a shipper, is using an independent operator. These companies are described in Chapter 4.

SELECTION OF TRANSPORT CORRIDORS
A limited number of suitable transport corridors have been selected with the following characteristics:
• substantial transport volume
• international transport
• on highways (interpreted as: more than 90% of the corridor is highway)
• non-stop transport
• full truckloads

The selection of transport corridors is described more in detail in Chapter 4.

OBSERVATION PERIOD
Actual trip records have been collected during a three month period from February until March 2001, allowing for a sufficient amount of transport data to be analysed.

CONVERSION FACTOR CALCULATION
The first sample of trip records indicated that not all required data was available directly from the transport documents. For example information about weight, volume, pallets or commodity could be lacking. The missing data had to be calculated by use of similar records having the additional information. This process is explained in the appendix.
DATA PROCESSING AND ANALYSES

In the main analyses of the effect of the modular concept the only restriction applied was the utilisation ratio of the loading module units. In practise this means that the loading units were reorganised but not the cargo.

Analyses made with other restrictions and scenarios are accounted for in separate reports. These reports also include simulations by extrapolation based on statistics of regional and national goods flow data on continental main transport corridors estimating the full advantage of the modular concept.
4 DATA PROVIDING SOURCES

4.1 DATA PROVIDER A

One of the companies found in the search for data-providing sources was an international transport and logistics provider in the Netherlands here called data provider A.

Data provider A operates on a large road network on the European continent. The main corridors are shown in the figure below marked with arrows.

![Figure 4-1 Data provider A's five major flows of road transport marked red](image)

**SELECTED TRANSPORT CORRIDORS**

Of the transport corridors data provider A operates on five were selected for the study. These are fairly long distance major flows of international road transport illustrated with red arrows in figure 4-1.

The selected corridors were:

- Belgium-West to France-North-West (1) (400 km) (Int. region code 7 to 9)
- Germany-Ruhr-area to France-North-West (2) (650 km) (13 to 9)
- England-North to France-North-West (3) (750 km) (15 to 9)
- The Netherlands-South to France-South-East (4) (850 km) (4 to 10)
- Sweden-South to France-North-West (5) (1750 km) (18 to 9)
FREIGHT INFORMATION PROVIDED BY DATA PROVIDER A

Available trip records from data provider A contained the following basic records:

- Week
- Client
- Commodity
- Tonnes transported (number of cubic metres/pallets)

By use of, among other things, a sample allotment of 300 CMR documents from data provider A the necessary weight/volume conversion factors were developed.

Together with other available information the following result was achieved:

- Week ➔ Period
- Client ➔ Destination area and origin
- Commodity ➔ Commodity group
- Number of cubic meters ➔ No of trips and type of vehicle

In total over 24,000 trip records recorded during the determined investigation period were provided by data provider A. Of these 3,841 were made on the selected routes or corridors and used in the calculations.

4.2 DATA PROVIDER B

As a representative for the group of lightweight cargo data provider B volunteered to supply freight information for the study.

Data provider B is a Danish company. The international road transport operations made for data provider B in Europe are performed by several independent operators. Trip record information was recorded and processed for the project by the division management.

SELECTION OF TRANSPORT CORRIDORS

The product distribution performed for data provider B by contracted hauliers has four major flows of road transport, which are illustrated with red arrows in the picture below. During the data collection and processing stage it was decided to include also the freight flow between the Netherlands South to Belgium.

The four selected transport corridors thus were:

- The Netherlands South to Belgium (2) (437 km)
- The Netherlands South to Denmark (3) (541 km)
- The Netherlands to Switzerland (4) (670 km)
- The Netherlands South to France Central (5) (805 km)
FREIGHT INFORMATION SUPPLIED BY DATA PROVIDER B

As the freight information from data provider B operations was for only one commodity group, insulation material, the variation was small. Transports are in general made with lorry and trailer combinations because of the available loading volume. The number of required trip records was thus much smaller.

The trip records contained the following basic information:

- Date
- Origin
- Destination
- Commodity
- Number of cubic meters
- Number of trip kilometres

By use of the determined conversion factors and additional information conversions were made with the following result:

- Date -> Period
- Origin -> Area
- Commodity -> Commodity group
- Number of cubic meters
- Number of trip kilometres
- Type of vehicle

During the determined investigation period 39 transports with full truckloads (FTL) were recorded and provided by data provider B for the calculations.
4.3 DATA PROVIDER C

Another road haulier with a similar type of operation as A in the Netherlands volunteered to provide trip data.

Data provider C is also a logistic service provider in the Netherlands operating on a large road network on the European continent. The main corridors are shown in the figure below and marked with arrows.

**SELECTION OF TRANSPORT CORRIDORS**

Data provider C has three major international flows of road transport, which are illustrated with red arrows in the figure 4-3.

The selected corridors were:

- Sweden-South to the Netherlands (1) (700 km)
- The Netherlands to Germany-North (2) (316 km)
- The Netherlands to France-North-West (3) (840 km)
FREIGHT INFORMATION PROVIDED BY DATA PROVIDER C

Available freight information from data provider C was to some extent more detailed than from company A and included only a few commodity groups.

Figure 4-3 Data provider C's three major flows of road transport marked red

The trip records contained the following basic information:

- Date
- Origin (Address)
- Destination (Address)
- Commodity
- Number of cubic meters (Euro pallets)
- Number of kilometres
- Fuel consumption (Litres)
- Costs
By use of the determined factors developed from the sample, CMRs and some other information conversions were made with the following result:

Date --> Period
Origin (Address) --> Destination area
Commodity --> Commodity group
Number of cubic meters (Euro pallets)
Number of kilometres
Fuel consumption (Litres)
Costs

In total 709 transport operations with full truckloads (FTL) recorded during the determined investigation period were provided by data provider C and used in the calculations.
5 DATA COLLECTION AND PROCESSING

NEA Transport Research Training performed data collection and processing in the Netherlands on a partnership and consultant basis.

5.1 COLLECTION OF TRIP DATA

In international road transportation the freight information of each shipment is registered and included in transport documents called CMRs (Convention on the Contract for the International Carriage of Goods by Road) which follows the transport. These documents in general only contain the most essential information about the cargo and transport. Several cells in the form are usually left empty. The amount of goods, for instance, is thus often only registered in one of the units; tonnes, cubic metres or pallets. In some instances, however, the document information includes more than one of these values. Based on a sufficient number of documents this additional information enables the calculation of standard values and the development of weight/volume conversion factors.

A CMR model form from a Dutch haulier’s handbook is shown in figure 5-1 on the next page.

In June 2001 trip records were available from all selected data providers. Company A had delivered the 300 sample CMR-records for the development of conversion factors. Company B and C completed their contribution with 709 and 37 records respectively originating from the determined time period for the investigation between 1st of February to the end of April. A large amount of additional trip records from Company A registered in the same period was soon expected to be available.

For the data conversion the 300 CMR trip records initially were completed with missing information about weight, volume, pallets or commodity by comparisons with similar records having additional information. A good deal of road transport experience also helped in this process. A more detailed description of the calculations is included in the appendix.
Figure 5-1  The CMR document
6 RESULTS AND ANALYSES

The application of the modular concept is fully beneficial when the transport demand is near, or over, full truckloads of cargo. This is usually the fact in long haul transportation of general cargo as result of internal and external organisational methods to accumulate cargo. Through co-operation between hauliers supported by forwarders cargo for the intended destination is passed over from one company to another to fill up the loading capacity. This method, which basically is normal logistics, has been successfully practised in Sweden and Finland for complete and fully loaded module vehicles in order to achieve the most benefit of the modular combination system since it was introduced in 1997. The use of the modular concept will thus have the ability to change and improve the logistic system on the European continent.

If the transport demand and cargo availability is large and extends the loading capacity of the transport module units, the use of the modular concept is limited only by the availability of required module units. For the articulated vehicle a centre axle trailer is required and for the lorry a dolly and a semi-trailer is required. Each loading unit of these types will be loaded to the maximum of its capacity either by weight or volume. The availability of cargo units to form the fully utilised modular combinations in time for departure will however sometimes require the support of co-operating haulier and forwarding organisations.

In the basic calculation of the effect of modular concept combinations the only restriction applied was the utilisation ratio of the loading module units. In practise this means that the loading units were reorganised but not the cargo.

6.1 PROJECTED SAVINGS

The following results have been calculated per route:

• changes in number of trips
• changes in fuel consumption
• changes in total (financial) transport costs (seen from the point of view of the haulier)

DRIVING DISTANCE

The driving distance is proportional to the number of trips needed for the transport. In the table on next page the difference in trips between regular and modular combinations for Company A routes are shown.
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Figure 6-1  Trips mutation in percent for Company A

In this result an average drop in the number of trips of about 33 % is shown to do the same job. The differences when comparing the reduction per route is mainly caused by different shares of the two EU-vehicle types. In routes with a more than average share of high volume, lorry and trailer combinations, the drop in kilometres is less than average.

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</tbody>
</table>

Figure 6-2  Trips mutation in percent for company B

<table>
<thead>
<tr>
<th>Company C</th>
<th>Trips</th>
<th>mutation in percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>route 1</td>
<td>-28%</td>
<td></td>
</tr>
<tr>
<td>route 3</td>
<td>-38%</td>
<td></td>
</tr>
<tr>
<td>route 5</td>
<td>-28%</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>-33%</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6-3  Trips mutation in percent for company C
For the three companies studied the number of trips on average was reduced by approximately 32 %, and with very little difference between the companies.

**FUEL CONSUMPTION**

In the tables below the mutation in fuel consumption is shown. The consequence of modular combinations is not only additional loading capacity but also reduced fuel consumption per tonne-kilometre and transported cubic metre of goods. The net effect on the fuel consumption is a consequence of the fact that the number of trips is reduced, while the fuel consumption per trip is increased. In the calculation of fuel consumption values for full load in weight have been used which is unfavourable for the mutation result.

<table>
<thead>
<tr>
<th>Company A</th>
<th>Fuel, 1000 litres</th>
<th>ordinary EU vehicles</th>
<th>modular combinations</th>
<th>mutation in percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>route 1</td>
<td>148,4</td>
<td>126,8</td>
<td>-14,6</td>
<td></td>
</tr>
<tr>
<td>route 2</td>
<td>224,9</td>
<td>191,5</td>
<td>-14,9</td>
<td></td>
</tr>
<tr>
<td>route 3</td>
<td>163,7</td>
<td>139,6</td>
<td>-14,7</td>
<td></td>
</tr>
<tr>
<td>route 4</td>
<td>164,3</td>
<td>139,2</td>
<td>-15,3</td>
<td></td>
</tr>
<tr>
<td>route 5</td>
<td>289,4</td>
<td>252,1</td>
<td>-12,9</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>990,7</td>
<td>849,1</td>
<td>-14,3</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6-5  Fuel consumption mutation in percent for company A
For the three companies studied the fuel consumption on average was reduced by approximately 15%, and with very little difference between the companies.
TRANSPORT COST

An important aspect in an evaluation of the feasibility of modular combinations is the operating cost compared with regular vehicles. For this calculation the NEA cost calculation model has been used. The model has been filled with representative cost data from the NEA haulier benchmark system (for EU 96/53 vehicles) and with additional information presented by the project team (for the modular concept vehicles). By multiplying the cost per trip with the number of trips the total cost of transporting a specific quantity of goods has been calculated.

![Company A total transport cost savings](image)

Figure 6-9  Calculated transport cost savings for Company A

![Company B total transport cost savings](image)

Figure 6-10  Calculated transport cost savings for Company B

![Company C total transport cost savings](image)

Figure 6-11  Calculated transport cost savings for Company C
Transport cost savings (%)

<table>
<thead>
<tr>
<th>Company</th>
<th>23.0%</th>
<th>23.0%</th>
<th>24.0%</th>
</tr>
</thead>
</table>

Figure 6-12  Calculated transport cost savings

The cost savings for all three companies are illustrated in figure 6-12. On an average the result means a cost saving of about 23%.

6.2 CONCLUSIONS

The introduction of modular combination vehicles (25.25 metres) will in principle imply an increase in loading capacity in volume by about 40 to 60%. This is compared with an EU road train (18.75 metres) and with an EU articulated vehicle (16.5 metres). The actual reduction in number of transports is determined by the ability to utilise this extra loading capacity.

On average a reduction in the number of trips of nearly 32% is expected. The effect of modular combinations is additional loading capacity, but it will also result in a modest rise in fuel consumption per kilometre. The total fuel consumption will drop by more than 15%. It should, however, be observed that fuel consumption values used in the calculations are for full load in weight, which is unfavourable for the mutation result.

Another factor in determining the feasibility of the modular concept is the cost of operation. The more profit the haulier will make with modular combinations the better the chances are for a broad adoption of this concept. When comparing transport costs of the present situation and the costs for modular combinations the calculations indicate that the total transport costs will drop by 23% on average.

The increase of goods transportation in the modern community and foremost in road traffic is big and continuous. The growing market trade requires more transportation and consequently additional transport work in tonne kilometres. The progress towards more refined and hi-tech products leads to an average decrease of specific weight and additional demands for loading capacity in volume. Increased product unit value requires more reliable goods protection, which leads to larger package volumes, which further reduces the specific cargo weight.
Transported volume is thus basic factor and will steadily become more important than transported weight.

The EU White Paper "European transport policy for 2010: time to decide" forecasts a rapid development in goods transport volumes. There is a need for improved efficiency in all transport modes. Larger vehicles could be one such improvement for road transports.

ENVIRONMENTAL ASPECTS

The calculations show clearly that modular combinations would contribute to the target of reduction of pollutants emitted by heavy vehicles. The actual reduction is strongly related to the ability of the haulier to use the additional loading capacity to the fullest, e.g. through developed co-operation with other hauliers.

Within the scope and limitations of this study the environmental aspects have been restricted to the emission of CO₂. Emission levels of CO₂ can be compared on the basis of fuel consumption. The lower fuel consumption also corresponds fairly well to the NOₓ emissions. Reductions of the number of trips will therefore mean reduction of the overall environmental impact. For instance the calculated fuel reduction for Company A is approximately 15 %.

CONGESTION

The amount of general and light weight cargo vehicles in long haul transport corresponding to the vehicles focused in the study is about one third of the heavy vehicles. A fair estimation is that more than one third of other heavy vehicles will be able to benefit from the modular system through the advantage of extended load capacity. A rough estimation referring to the achieved results in trip savings is that at least one third of two thirds of the heavy vehicles will disappear. That gives a reduction of almost 20 % of the heavy vehicles on the highways.

The road space occupied by heavy vehicles, which has importance in dense traffic and queuing, will be reduced by almost the same extent for the same transport (-24 % according to calculation by Volvo).

<table>
<thead>
<tr>
<th>Euro Module System</th>
<th>Comparison 25.25 m vehicles to 18.75 / 16.5 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of trucks</td>
<td>Space on road*</td>
</tr>
<tr>
<td>2</td>
<td>130 m</td>
</tr>
<tr>
<td>3</td>
<td>172 m</td>
</tr>
</tbody>
</table>

* Note: Calculated for load = 400 kg per pallet

Figure 6-13  Occupied road space and other comparisons according to Volvo
ROAD WEAR

The application of the modular system makes it possible to transport the same amount of cargo using only two motor vehicles instead of three. The cab and engine weight etc of one of three motor vehicles is not needed and consequently does not contribute to the road wear.

The modular combination of regular EU vehicles will commonly contain

1) **a three-axle lorry, a two-axle dolly and a three-axle semi-trailer** or
2) **a centre axle trailer with two axles coupled to a five- or six-axle semi-trailer unit.**

All these combinations will normally have eight or seven axles. The two axles on the dolly are replacing the two axles on the deleted motor vehicle. The gross weight needed for the same transport is lower (the excluded motor vehicle weighs more than the added dolly) and thus distributed to the same number of axles. Also other axle combinations of EU-Directive modules are possible but in most cases this will not negatively affect the road wear.

Road wear is usually calculated with a formula based on equivalent 10 ton axle loads raised to fourth power as shown below

\[ N_{10} = \sum \frac{A}{10}^{\alpha} \]

\[ A = \text{axle load in ton} \]
\[ \alpha = 4 ; (3-5) \]

Figure 6-14 Road wear according to the so-called AASHTO\(^1\) formula based on equivalent 10-ton axles and the exponent \(\alpha\)

Applied to transports of light and general cargo transported by modular combinations this formula shows that the road wear is decreased. The extent of reduction depends, however, on the type of configuration though. The semi-trailer plus centre axle trailer combination is more favourable than the lorry and semi-trailer combination due to a larger axle load variation.

The actual lightweight transport operations made by Company A in the present study shows that road wear is approximately reduced by 25 % for the lorry and semi-trailer combination and by a 15 % for the semi-trailer and centre axle trailer combination.

The average usage of capacity in tonnes in the study was 56 % for the semi-trailer and 48 % for the lorry and trailer combination. If the usage of capacity in tonnes is higher the reduction of calculated road wear is lower for the modular combination. The estimated break-even usage of loading capacity in tonnes is about 90 % for the semi-trailer and centre axle trailer-combination and about 80 % for the lorry and semi-trailer combination.

\(^1\) AASHTO = American Association of State Highway and Transportation Officials
The exponent used in both calculations was 4, which is commonly used. This factor, however, is strongly dependent on the individual road standard. The road standard of the main transport corridors is usually higher than average corresponding to a lower factor than 4. It is thus a realistic assumption that the effect of use of modular combinations on road wear will be even more favourable than calculated.

The calculated effects of road wear corresponds with the results reported in a study recently made by Scania AB named Study of the road wear of extra long vehicle combinations (Internal report c117/41B). Two main kinds of road wear that are strongly influenced by heavy vehicles are fatigue and rutting.

The break up of pavements is usually caused by fatigue, which can occur in as well flexible and rigid pavements. Fatigue or fatigue cracking is caused by many repeated loadings and the heavier the loads the fewer the number of repetitions required to reach the same condition of cracking. The majority of pavements will tend to fatigue from the base of the asphalt layer. Road wear caused by fatigue is usually calculated with the AASHTO formula earlier described.

Rutting (permanent deformation) is the result of permanent deformation in flexible pavements in each of the pavement layers. Pavement material is flowing from under the wheel path of a heavy vehicle and compacts to form a groove or rut. By comparing gross vehicle weights a fairly good overview is created about how the different combinations affect the rutting damage. Although all the combinations are less damaging than the European long distance combination when the damage is related to payload, it is hard to draw a good conclusion. The differences between combinations are so small that they are almost negligible. Therefore the conclusion will only focus on the damage related to volume capacity.

**ROAD SAFETY**

The risk of traffic accidents is usually considered very dependent on the number of vehicles in traffic. The more numerous the vehicles in movement are in a traffic network, or in fact the more numerous vehicle fronts there are, the higher the risk of accidents. The reduction of the number of heavy vehicles in traffic by one fifth, as earlier estimated, is believed to have a positive influence on road safety.

One possible negative aspect of longer vehicles has been the increased risk of accidents during overtaking. This risk was thoroughly studied by the National Road & Traffic Research Institute (VTI) when the Commission of Transport Policy proposed that the maximum permissible length should be reduced from 24 to 18 metres in Sweden in the 70-ties (VTI report 103 - 1976). A short conclusion of the results from this study is presented in the abstract as shown in the next figure.
ABSTRACT

A traffic study was performed in order to elucidate the effect of vehicle length on the accident risk when overtaking long vehicle combinations. Also the influence of a vehicle mounted sign indicating the length of the vehicle was investigated. The experiment was performed as a full scale test in a real traffic environment. Two test vehicles, 18 and 24 metres long respectively, were driven simultaneously along the test sections at a constant speed of 70 km/h and 10 km apart. Overtaking processes were recorded by means of film cameras on the roof of the test vehicles. The test vehicles covered a total mileage of 13 640 km during the test period of eight weeks. The time gap was used as a measure of accident risk, i.e. the number of seconds elapsing between the conclusion of an overtaking operation and the time when the overtaking vehicle meets or could have met an oncoming vehicle. The differences in mean values of time gaps between the two vehicle lengths were very small. There was a slight tendency for the 24 metre vehicle to induce a greater number of hazardous overtakings than the 18 metre vehicle, but this difference has not been statistically proved. The vehicle mounted signs indicating vehicle length were found to improve meeting margins.

Figure 6-15 Abstract in the VTI report 103 - 1976

Very similar results were obtained in a Finnish study, where the consequences of the modular concept of road traffic safety were calculated. The comparison was made between 22 metre and 25.25 metre long road trains (Effects on road safety of increasing the length of articulated lorries. VTT Communities & Infrastructure, Transport Research).
7 APPLICATION EXPERIENCES

7.1 BÖRJE JÖNSSON ÅKERI AB

One of several examples of a successful application of the modular concept in Sweden is Börje Jönssons Åkeri AB. This is one of the major international transport and logistics providers in Sweden with over 300 employees, about 200 heavy vehicle combinations, and a turnover 38 MEURO. The company has offices/warehouses in Stockholm, Karlstad, Helsingborg and Göteborg. The head office is situated in Helsingborg where they also offer storage facilities for refrigerated goods. Börje Jönssons Åkeri AB also has international locations in Copenhagen, Travemünde, Hamburg and Bolzano.

Börje Jönsson has organised a logistics structure to optimise the use of trailer and semi-trailer combinations, including co-operation with other hauliers. In domestic traffic they utilise modular concept combinations on three destinations carrying full loads in both directions. The transport routes are illustrated with arrows in the picture below.

Figure 7-1  Börje Jönsson AB’s transports flows used in the study marked red
As a reference to the data gathered by NEA in the Netherlands a few of Börje Jönsson's routes have been selected for comparison. These routes are marked with red and go between the Helsingborg - Malmö region and the Karlstad region. Börje Jönsson undertakes this long-term transport assignment from the international forwarder Schenker-BTL.

Schenker BTL has provided booking records for the project from their administration system for the selected transport flows. According to the BJ management it was fair to assume that the loading capacity was fully utilised in practise in all shipments during current period 1st to 31st August 2001, either by space or weight.

The analyses of the booking records indicate an average loading factor that corresponds with the results from the Dutch and Danish cases which indicates that the assumptions made in the study are practically applicable.

Fuel consumption is registered as the vehicles are refuelled. According to their experience the figure used in the project calculations (42-litre/100 km) is representative but perhaps somewhat high. This, however, can be explained by the more congested traffic situation on the continent.

Regarding the transport costs it is clear that the cost level in Sweden is higher than in the Netherlands. According to a study made in Sweden 1998 the cost difference per km between Sweden and Netherlands was +35 % (Högskolan Växjö, 1998).

### 7.2 IKEA

The IKEA Corporation has over 140 department stores in 22 countries. In addition IKEA has 20 department stores on franchise base in 13 countries/territories, about 2000 suppliers in 55 countries and 40 purchase offices in 33 countries. The IKEA industry group Swedwood has 33 factories in 10 countries. The turn over last year was 10.4 billion EURO (99.2 billion SEK). Over 200 000 m³ goods is transported via the IKEA centre in Älmhult in Sweden yearly.

One of IKEAs main road hauling contractors practising the modular concept in Sweden is Arne Johanssons Åkeri AB. Arne Johanssons Åkeri AB is a group of road hauling companies with a total turn over of about 45 MSEK and 35 employees. One of the subsidiaries, KAJ Inrikes AB operates domestically transporting volume goods mainly for IKEA. Among other vehicles they are using 34 module combinations. The other subsidiary, KAJ Utrikes AB operates mainly on a route between Sweden and Germany.

The modular concept practised by KAJ Inrikes AB is used in nearly 20 daily transports on the routes indicated in the figure on the next page. From Älmhult there are seven transports to Jönköping, three to Gothenburg and one/two to Örebro every day. From Jönköping, which is a distribution centre, goes three daily transports to Örebro, two to Malmö and two to Stockholm.

The company emphasises the advantages with combination possibilities in national and international transports. They also appreciate the extra loading capacity in volume of about nine percent to support the profitability. In general they are satisfied with the system and welcome any further developments in modular combinations.
The average fuel consumption for the modular combinations is 42-litre/100 km. This is valid for the bulk of vehicles with EURO2 specified engines. Astonishing, however, is that the acquired new motor vehicles with EURO3 engines have established a 10% higher consumption. For the EU combinations used in transports on the continent the fuel consumption is lower and slightly different for the two configurations. On average the tractor-trailer combination requires 34-litre/100 km and the semi-trailer combination 38-litre/100 km.

Figure 7-2 Transport flows with modular combination vehicles in the Swedish IKEA distribution network
REFERENCES

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(Study of the accident risk when overtaking long vehicle combinations)

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APPENDIX

In the appendix the transformation of data that was needed for information about weight, volume and pallets will be described.

DATA CONVERSION

The first sample of trip records indicated that not all required data would be available directly from the transport documents. For example information about weight, volume, pallets or commodity could be lacking. The missing data had to be calculated by use of similar records having the additional information.

For the data conversion the 300 CMR trip records initially was completed with lacking information about weight, volume, pallets or commodity by comparisons with similar records having additional information. A good deal of road transport experience also helped in this process. The completed records then were divided in two groups, one for LTL (less than truckload)-trips and one for FTL (full truckload)-trips. The desired 213 CMRs representing FTL-trips was then categorised in vehicle type O for semi-trailers and V for lorry and trailer combinations.

The FTL CMRs for O- and V-vehicles respectively then were each divided into three groups based on transport commodity and weight as described in figures below.

Description of the commodities transported with vehicles of respectively types:

- **O I**  hygienic and plastic articles, consumer goods/electronics
- **O II**  hygienic articles, parts, tyres
- **O III**  TV sets/tubes, packaged liquids, paper rolls
- **V I**  diverse
- **V II**  (lorry) parts, hygienic and plastic articles
- **V III**  tyres, (roof) windows, parts
Figure I  Commodity groups for FTL of type O vehicles

Figure II  Commodity groups for FTL of type V vehicles

By use of the CMR records in each commodity group the averages for the different measurements were calculated as shown in the figure III on the next page.
The loading capacity of the lorry and trailer combination used was not conform to the European Union legislation. In fact the loading length exceeds the dimensions prescribed by the EU with 51 cm. To assure an objective comparison with the modular concept the production of these vehicles had to be converted in the next step. 

Figure III  Characteristics of cargo transported with O and V type vehicle combinations