Final report DUO2-Trailer

Project within Transport Efficiency:
Project Duo Trailer 2010-02849 &
Project DUO2- Energy Efficient Vehicle Combinations 2010-01342

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, Reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

Road freight transport accounts for a growing share[1] of greenhouse gas CO2. Sweden has committed[2] to reducing CO2 emissions. The aim of the project is to reduce carbon emissions in relative terms by reducing the number of vehicles and to increase the volume of goods per vehicle. In the project a combination of vehicles with a tractor pulling two semi-trailers, instead of only one semi-trailer, has been developed and tested during a period of almost 18 months. This has been possible due to a special regulation and an exemption issued by the authorities.

The project has demonstrated a reduction of 27% in both CO2 and fuel per amount of goods carried without any negative impact on road safety, vehicle or infrastructure. Since it is a modular system of components, it is very flexible. Each component could be used together or separately in the logistics system.

The project will continue with another phase where the existing combination is updated and a new type of vehicle combination is also tested in the logistic production system. The vision is that the combination of vehicles of type DUO2 and other high capacity transport (HCT) are allowed in the public service and thus achieve the goal of greatly reducing greenhouse gas emissions from road transport. NVF report 1/2013[3] concludes that instead of small-scale experiments with the approval of each vehicle combination, so should the recipe urgently scaled up in size, since a larger number High Capacity Vehicles can be of great benefit to society.

The main conclusions are that Duo - trailer:
- Can provide significant reductions in emissions of CO2 in relative terms
- Works well practice as it builds on the current modules
- Has not shown any adverse effects on road safety
- Takes up less road surface, less congestion, for the same amount of cargo carried

[1] Capacity Investigation of the transport http://www.trafikverket.se/kapacitet
[2] Analysis of a Swedish road map for Sweden without greenhouse gas emissions in 2050 http://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6487-7.pdf
[3] NVF Report 1/2013 High Capacity Vehicles (Högkapacitetsfordon), Infrastructure and Transport Safety

2. Background

Sweden has pledged to greatly reduce CO2 emissions. Road transport accounts for approximately 30% of Sweden's energy consumption and CO2 emissions. This share is increasing and if we are to achieve our emissions targets we need to change this trend. Most of the fuel used today is from fossil sources.

In most of the countries in the EU combined vehicles of 40 tonnes up to a maximum 18.75m is allowed. In Sweden and Finland, the vehicles up to 60 tonnes and a maximum of 25.25 m are allowed. Although Holland and Denmark have 60 tons and a maximum of 25.25 m, but on a limited road network. It is a well established fact that vehicle combinations that allow more cargo in less fuel consumption per transported unit. Australia is the country that has gone furthest, and combinations of vehicles in excess of 50 m and a weight exceeding 100 tons.

Finland has recently (2013-10-01) increased the maximum weight to 76 ton within 25.25 m. Sweden is currently looking on a similar change but restricted to 74 ton within 25.25 m.

In this project we investigate combinations of vehicles of up to 32 m and up to 80 tons. The hypothesis is that HCT-vehicles will further reduce fuel consumption.

Within the DUO2 - project (Dr. No 2010-01342) two Volvo rigs has been developed to go in field trials at DB Schenker (Kallebäck Transport). The tests has run for about 1,5 years on the route Gothenburg-Malmö. Initial Vehicle Modules has also been used for regional distribution hubs around (Gothenburg and Malmö). DUO - Trailer project aimed to build the component semitrailers illustrated to the left in Figure 1 below.

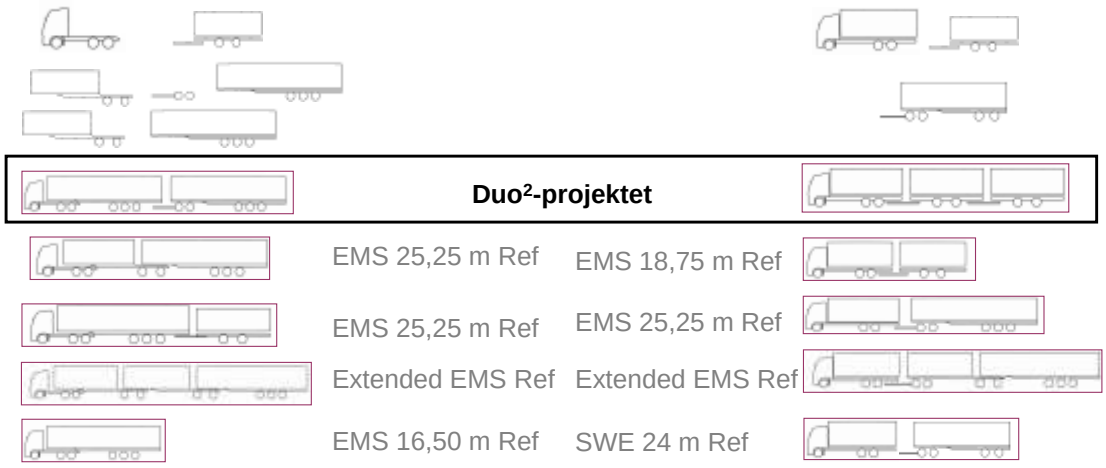


Figure 1. Project vehicles including reference vehicle

3. Objective

The main objective is reducing CO2 emissions from road freight transport in relative terms.

4. Project realization

Develop and test vehicle combinations with higher load capacity.

In the production has a set of aspects into consideration so that
- Vehicle Stability (special research task from Transport Agency)
- Fuel
- Accessibility (roundabout, lane changing, cornering)
- Shoulder and Total Weight

Regulatory sought[4] from Transport Agency through a special process. Further considerations also exemptions[5] for speed because this vehicle combination has three joints. The exemption was a really big challenge when the authority had high demands on the stability of the combination before they admitted state.

Vehicle Stability has first been calculated using a computer model. After the combination of vehicles built and linked stability has been verified on a test track. In the third step runs the combination on the road with monitoring sensors that measure lateral movements on car and all three trailers. Quarterly data are combined and sent to the VU on the transport board.

Annually, a review of the entire sequence where all the hardware manufacturers are included is performed. The car and the trailers are inspected every month of workshops.

During the project, further follow-up has been added:
- Tire wear
- Tire Pressure
- Brake wear

[4] Transport Agency's regulations on the process of long and heavy trains between Malmo and Gothenburg, TSFS 2012:3

5 Exemptions from traffic regulations SFS 1998:1276, TSV 2011-4273

5. Results and deliverables

5.1 Delivery to FFI-goals

The project:
• is fully in enhancing transport efficiency while reducing greenhouse gas emissions
• is in the forefront of knowledge creation for HCT, based on the Swedish view on the highest security.
• contribute to a continued competitive automotive industry in Sweden
• lead to industrial technology and skills
• may help to secure jobs and growth. The solutions can be implemented in Sweden, but there are also international demand.
• contribute to concrete production improvements made at participating
• has helped to make relevant research issues and allocation of responsibilities to manage and coordinate these have been made by the group around CLOSER and HCT
• supported research and innovation environments
• ensuring that new knowledge to be developed and implemented, and that the existing knowledge is implemented in industrial applications
• contribute to effective utilization of R & D results to concrete production improvements made at participating businesses
• strengthen the collaboration between the automotive industry and government agencies, universities and research institutes
• ensuring that the national human resource and regulating the R & D with international competitiveness is established

Contribution to objectives (taken from the program description at the time of application)
We contribute primarily to the following objectives for the area of transport efficiency (for reference year 2000)
• Increased traffic volumes with minimal environmental impact
  - In: The project provides the opportunity for increased transport volumes with positive environmental effects
  - Out: The project has shown that we can increase transport volumes, while reducing environmental impact
• Percentage of vehicles in the fleet that are "connected" increased to 50 % by 2020.
  - In: The project test vehicles are " connected " via the command system
  - Out: Our project vehicle with all the trailer is connected for remote reading .
• New business opportunities created
  - In. New products and services for all partners
  - Out. New products and services have been created.
• New business models created
  - In. Creates new transport

- Out. We have shown that the long distance part of the transport system could be more efficient using existing modules in a new combination. Collection and distribution are handled according to normal procedures.

• Reduction of CO2 for freight transport by 50 % by 2020 (based on the volume of traffic in 2000)
- In. This is the core objective of the project. We have a target of 15 % until 2012.
- Out. We have shown that we can reduce CO2 emissions by 27% compared with transport by one semitrailer instead of two. Continued reduction is possible.

• Increased traffic capacity in existing structures with 10% of the existing transport infrastructure by 2020
- In. Reducing the number of vehicles with a third for a given transport task
- Out. To replace two single trailers with a duotrailer reduces the need for road surface by 40% for the same load.

• Fewer accidents and actively contributing to the Transport Administration's zero tolerance
- In. Fewer vehicles for a given transport task reduces accidents
- Out. We have certainly not been able to show that the vehicle itself is dangerous. This weighted with fewer vehicles are required should increase road safety.

• Enhanced image, attractiveness and status of transportation
- In. The project highlights the transport industry efforts to reduce environmental impact
- Out. The question has clearly lit and there has been a huge media interest.

• Increased collaboration with other national research
- In. KNEG , Green Corridor , we are open to further collaborations
- Out. Established collaboration with CLOSER and HCT roadmap.

• Increased systemic (megacities, metropolitan, rural and sparsely populated areas)
- In. The system work great in everything from rural areas to the distribution in urban area
- Out. With reference to the above, you can line haulage, distribution and retrieval function with this logistical system.

• Increased expertise in the field
- In. By working on new technologies and applications raises the competence of all the partners.
- Out. We have built new knowledge.

We have met all the goals in the table above. The key objectives we have also surpassed. An industrial, Fredrik Börjesson, has been linked to the project for its duration. Furthermore, we have had a number of students who have had the combination as the basis for Aerodynamics, Vehicle stability and backing of vehicle combinations with three joints.

The field test has been delayed due to the additional requirements from the authorities. Tests on the road came off on 2 February 2012. Samples have since gone night writing in Schenker flow between Gothenburg and Malmö. More than 500 one-way trips have been carried out (250 T / R) without any incidents. A special tractor, a dolly and four semi-

trailers have been built or upgraded for this field trial. The vehicles have been prepared for aerodynamic tests and we have in addition to theoretical studies also tested air flows. In conclusion we can say that the savings potential is greater for a long vehicle because reconnection of air flow .

The drivers have received special training for the combination. Furthermore, Anna Anund researcher at VTI had in-depth training and follow-up of this long-distance referred to the night driving 19-06.

The stretch Terminal Schenker Gothenburg , Transportgatan 9-11 via E6 to Schenker Malmo, Kantyxegatan 22 has been largely trouble-free with the exception of a roundabout from Malmö. The roundabout is simple by Gothenburg where you only turn 90 degrees but more difficult at 270 ° from Malmö. Solutions for this can be the redevelopment of this roundabout is located in an industrial area or that we get a permission to drive another road connection to E6 . E6 at Örgryte in Gothenburg may not be used since this bridge is not designed for more than 60 tonnes. We drive today a detour through south road. Here one can consider allowing the carriage to pass Örgryte when we weigh less than 60 tonnes.

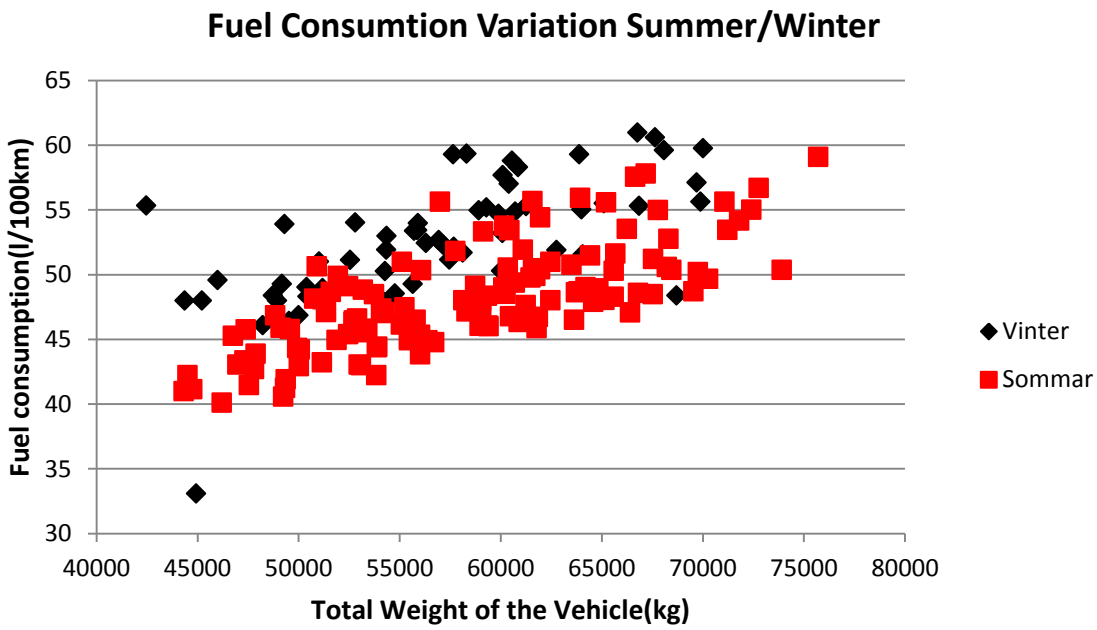
This logistical arrangement can contribute to the goal of reducing CO2 emissions by 50% by 2020. It does not have the potential to resolve the issue but can greatly help to achieve the goal.

Evaluation of different module combinations have not been done during the project, among other things due to the second combination Duo – trailer ‘Duo-kärra’ has not yet been allowed to run. This Duo - trailer construction ‘Duo-kärra’ has been delayed accordingly.

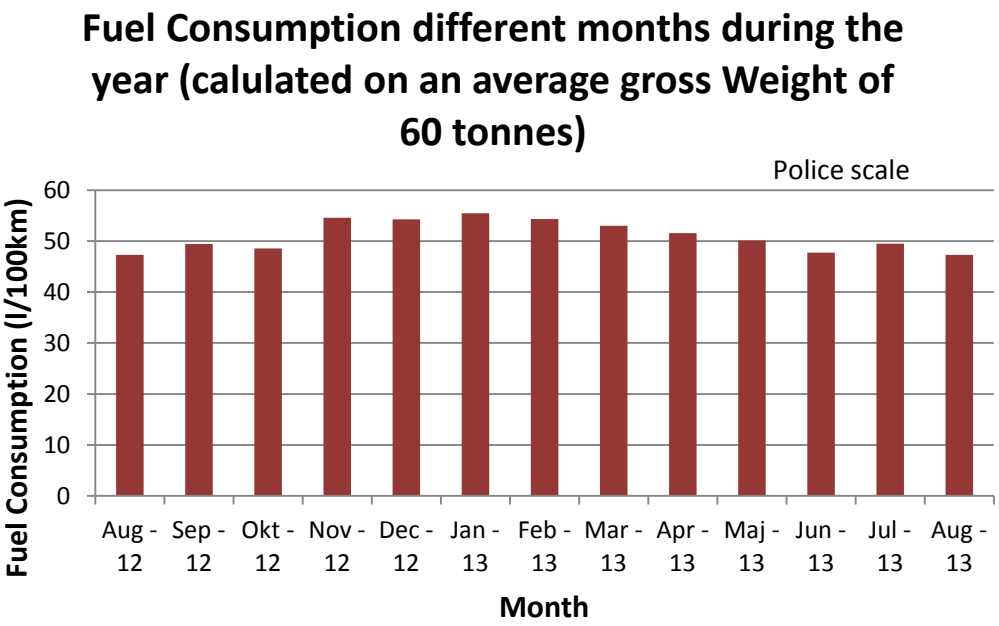
Patents have been applied for various ideas developed in the project. It turned out that one of the ideas was already protected by patents by one major axle manufacturer. The project then invited them to cooperate in order to test and develop this idea together. Furthermore claimed in aerodynamics, but it has not been possible to protect. However, three different types of louvers for reduced air resistance has been developed and tested.

5.2 Fuel Consumption

In order to follow up the fuel consumption of the vehicle the driver should complete a trip report (see Annex 5.2) each journey. About 300 of the 500 completed singled trips have been reported. In the graph below the trips could easily be compared and there is a variation in fuel consumption depending on season and the total weight. Highly deviating values may be due to extreme weather conditions as well as human or technical errors.



On closer examination we see that the fuel consumption variation follows a relatively smooth curve throughout the year.



5.3 Weight Monitoring

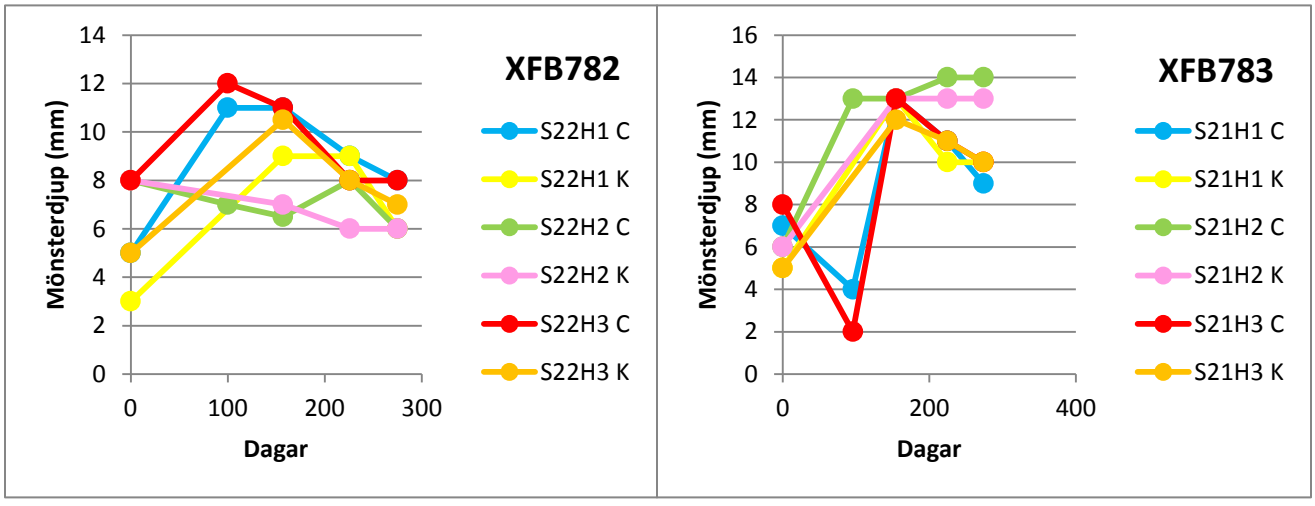
The travel report also contains a weight tracking when the weight on each axle of the vehicle entering a table. It then compares the weight that the police scale shows with the weight that the vehicle computer displays. The differences between these may not be too large; maximum limit is set at 200 kg per axle. Any overrun of the restrictions, values in red, will be discussed at upcoming meetings where actions are planned.

Fram	Boggie	Trailer 1	Dolly	Trailer 2
-1	-210	240	-80	-559
61	-175	1001	-100	-78
-8	-109	-139	-100	-379
29	-200	-119	40	-380

Investigating all the trips that provided reports for themselves and who have recorded weights from both the vehicles computer and police scale it seems that it is usually Trailer 1 that exceeds the tolerances. This applies regardless of the set up of trailer pairs. Why that this is so is unclear: it may be that the weighing principle to measure each vehicle individually, does not give a fair picture of the vehicle moves and stands in different positions all the time, which means that the torque varies during the weighing.

5.4 Tire Wear

Each month the fleet operator submits a report on tire wear. Tread depth must not be less than 5mm for winter use. If that is the case then the tires are replaced. For summer use tread depth must be at least 1.6 mm. Figure below, tire wear on the semi-trailer 2, right side. Middle pairs are labeled in green and pink.



5.5 Incident Reporting

In the project safety and deviations has been in focus. All the drivers have had a special education where among others VTI, Volvo, Schenker and Wabco have been involved. All problems that have occurred have been handled and corrected directly if possible. To be able to catch unforeseen problems a system for deviations and incident reporting has been set up.

In addition, a crisis team established in the event of a serious accident.

In the more than five hundred trips that have been conducted one single incident occurred. On January 21, 2013 the DUO trailer unexpectedly stopped when the fan belt broke. This led to the following problems that forced the driver to stop at Glumslövs hills outside Landskrona. Police and tow truck was called. The vehicle was connected apart. The truck was taken to a service center. The Trailers continued to travel to Gothenburg towed by two other standard trucks.

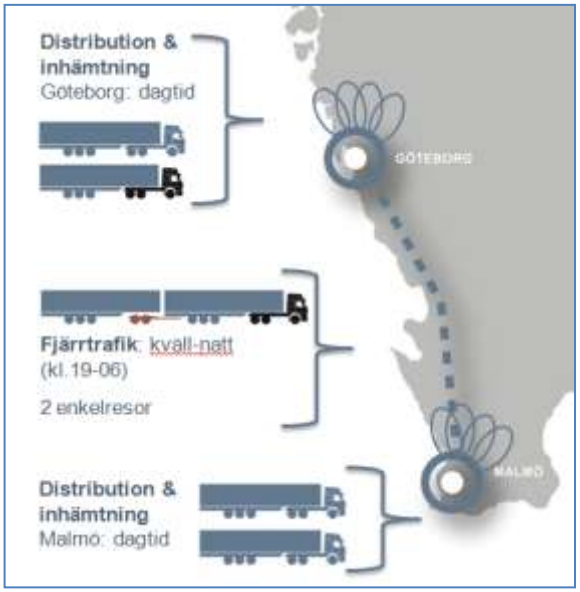
5.6 Vehicle Stability

In accordance with the requirements of the exemption to drive the combination of up to 80 km/h has all lateral movement for the 500 trips been recorded. This information is compiled quarterly and sent to the VU at the Transport Board. At no time has the lateral acceleration exceeded the threshold of 3 m/s2.

Drivers perceive the combination as very stable. We also had people who attended in more than 20 occasions. All agree that the rig is very stable. The explanation lies in the position of axles and access points interact.

5.7 Logistics Setup

The combination DUO2 vehicles have been tested in Schenker's ordinary domestic network of Kallebäck fleet, starting in February 2012 and continue with daily (nightly) traffic. Distributing and Collecting goods in each city with single trailers and double trailer on the long haulage



The good structure has been very varied for DUO2-rig just like Schenker network in general. What mainly transported by DUO2 on this route today are, illustrated in the figure below:

- Terminal handled Domestic goods and packages
- Direct parties
- Import goods and packages

The vehicles are loaded with many different products together, for example food, tires, axles, parcel cages, empty pallets, packaging materials, adhesive and seam cement, silicone, se figure below.

Development Opportunities
The logistics as a whole has worked very well during the test period. There are some areas of improvement that would make DUO2-vehicle even better so that it could be used more efficiently and it is mainly these:
• Ability to run throughout the day
• Multi-approved roads and alternate routes during disturbances in the road network

The time window admits only one round trip in the current situation. If the time window would be extended to DUO2-rig will run throughout the day, the vehicle could be used more efficiently.

Another problem experienced is that at work or traffic accidents, it is sensitive to disturbance since it does not have alternative driveways. For example, when "Gnistängstunneln" in Gothenburg is closed, it means that DUO2-vehicle cannot be used for long haul that night. If more roads were approved for DUO2-vehicle, it would open up opportunities to streamline multi-flows such as between different terminals in a transportation network or large flows with large customers.

Improving possibilities for intermodality is also a very interesting area in order to get full effect of HCT vehicle combinations. In the figure below a DUO2 on the terminal area and transshipment road-rail.

Figure 6.

6. Dissemination and publications

6.1 Knowledge and results dissemination

The project results are as base the discussion of HCT in Sweden[6]

[6] http://transportinnovation.se/sites/default/files/dokument/fardplan_for_hct_vag.pdf

6.2 Publications

Dissemination of project results has been achieved through a number of seminars and lectures and articles a selection from this are:
• Seminar, Freight Distribution and localization, NVF (Nordic vägforum) 27/10 2011
• Seminar, Logistics and Transport Fair, 5/22 2012
• Seminar, Elmia Truck 23/8 2012
• China Ministry of Transportation, visit Volvo Arendal 25/10 2012
• Seminar, Transport Efficiency Days 28/8 2013
• Newspaper in Finnish newspaper: Auto teknikka-ja-kuljetus-nr3-2012
• Deutsche Logistik Zeitung No. 79, 3/7 2012
• Article in the Goods, Transport Administration No.2 2012
• Interview P4, PL Lena Larsson, 29/5, 2012
• Report Feature 2/4 2012
• Article Southern Sweden 11/27 2012

7. Conclusions and future research

The main conclusions are that Duotrailer:
• can provide significant reductions in emissions of CO2 in relative terms
• function well in the production system and it builds on the current modules
• has not revealed any adverse effects on road safety
• take up less road surface, less congestion, for the same amount of cargo carried
Volvo and Schenker's going on with the next step in the research project "DUO2 –step 2". Field tests will be continued with a new vehicle combination – 'Duo kärra'. This combination gives the experience of another vehicle combination.

We will replace the first Duo-trailer combination to bring new technology and more tailored solutions are required. The first was a compromise in some respects. The new one will include getting appropriate wheelbase and adapted to new emission regulations

Transport Control Sens instructions on how to apply for permits are in are described on their website[7]

[7] http://www.transportstyrelsen.se/sv/Vag/Yrkestrafik/Gods-och-buss/Matt-och-vikt/Forsok-med-langa-ocheller-tunga-transporter/

8. Participating parties and contact person

The following parties are involved in the project: CLOSER, Kallebäck Transportation, Schmitz, Schenker, SKAB, SSAB, the Swedish Road Haulage Companies, Transport Administration, WABCO, VBG, Volvo,

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