THE LONGER AND HEAVIER VEHICLE DEBATE: A REVIEW OF EMPIRICAL EVIDENCE FROM GERMANY

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HIGHLIGHTS

- Evaluation of LHVs from a supply chain perspective.
- An extensive range of trials in one country, Germany.
- According to the findings, the vast majority of the research participants are interested in the adoption of LHVs regardless of the size of their companies.
- The feasibility of LHVs is evaluated from eco-efficiency perspective.

ABSTRACT

This paper aims to evaluate the likely effects of the adoption of Longer Heavier Vehicles (LHVs) from the perspective of logistics service providers (LSPs). The research consists of six case studies and a survey of companies which were involved LHV trials in Germany. Wider introduction of LHVs is being increasingly demanded so that road freight transport can better serve and support modern supply chains whilst achieving the desired eco-efficiency advancements. Available literature on LHVs puts a particular emphasis on five factors that need to be included in the assessment of their impact: energy efficiency, CO2 emissions, costs, safety and infrastructure. The research provides an original and innovative empirical study refining and validating the current conceptual framework for assessing LHVs demonstrating it is a valuable tool and providing evidence that the vast majority of companies participating in our study, regardless of their size, were interested in the adoption of LHVs. However, it should be noted that a key limitation of the research is that by focusing on a single country case, the nature and scale of the findings may not reflect practice in other countries and sectors. There is also a need to examine the long-term sustainability of the improvements made.

Keywords

Longer Heavier Vehicles (LHVs), megatrucks, gigaliners, road freight transport, freight consolidation, CO_2 *emissions, environmental impact, supply chain management*

INTRODUCTION

The ability to distribute goods safely, quickly and cost-efficiently is paramount for international and domestic trades and economic development (European Commission, 2013a). Over recent years, climate change mitigation has also gained increasing significance at policy and sectoral levels worldwide. Organisations are under increased pressure to become more eco-efficient (Rossi et al. 2013), and to reduce the environmental impacts of their logistics operations (McKinnon and Piecyk, 2009 and Piecyk and McKinnon, 2010a). Freight transport is a significant source of emissions of greenhouse gases, mostly CO_2 (Abbasi and Nilsson, 2012). Therefore, it is crucial to find solutions to reduce the carbon footprint of road freight transport operations within supply chains.

Piecyk and McKinnon (2010a), Tacken et al. (2011) and McKinnon (2012) have developed frameworks to guide CO_2 reductions in the logistics sector. One of the most discussed initiatives to reduce CO_2 emissions from road freight transport is to increase the dimension of vehicles. The issue has attracted a lively debate, with contradictory positions being taken relating to the benefits and shortcomings of a potential adoption of longer heavier vehicles (LHVs) (European Shippers Council, 2007; German Environment Ministry - Umwelt Bundesamt, 2007). McKinnon (2011) developed a conceptual framework to link the benefits and offsetting factors of the adoption of LHVs. However, this framework needs to be validated empirically as there is need for more evidence to provide better understanding and evaluation of the benefits, risks and enablers of LHVs. Thus, the main objective of this paper is to evaluate the effects of the adoption of LHVs from the logistics providers' perspective. The paper also aims to explore future actions and measures required for achieving a successful implementation of LHVs. This is conducted in the context of the German freight transport sector, which, as will be discussed, has been the setting for LHV trials.

The issue of LHV deployment is becoming increasingly relevant for a number of reasons. Two factors can be identified here. First, road freight is established and accepted as the mode of choice for many shippers, representing a market share of inland freight moved in regions such as the EU-27 of 75.5% in 2011 (EuroStat, 2013). This raises the question as to what measures can be considered to improve its eco-efficiency – as noted above, the adoption of LHVs is recognised as one option to consider in contributing to this objective. The second category of drivers, which is increasing the debate around LHV consideration, stems from the modern supply chain systems which road freight transport serves today. Increasingly, shippers are planning and managing their supply chains from regional perspectives, such as across Europe, rather than being confined by national boundaries. In this endeavour, a range of economic practices now characterise modern supply chain systems such as the concentration of production onto fewer sites to reap economies of scale, and freight consolidation. All of these characteristics of modern supply chain systems contribute to a growing demand for more efficient road transport through LHV use, over and above the ongoing traditional desire for LHVs from sectors focussed on bulkier freight movements, such as forestry.

The paper is structured as follows. Previous research on LHVs is summarised in the literature review, before the research questions are explained. Subsequently, the method adopted to undertake the research is introduced and the findings from the two stages of research discussed. Finally, the paper concludes with a discussion on the contributions of the paper for academia and practice, which brings together the contextual understanding of the issue with the findings of the research. An outline of future research opportunities is then presented. It is also worth noting that in this paper the term LHV refers solely to road freight transport, and we do not consider increasing dimensions of vehicles used by other modes of transport.

LONGER HEAVIER VEHICLES IN EUROPE

In Europe, the demand for LHVs has been clearly evident as a natural and logical need for sectors that feature bulk goods transport such as timber, stone, gravel and other aggregates, paper, steel, petro-chemicals and so on. Indeed, in countries such as Sweden, where certain forms of LHVs have been authorised for many years, these are the types of goods where LHVs are deployed. However, the factor that has fuelled the demand for larger road freight vehicles in the area of general cargo is the re-organisation of the way pan-European operations are managed today by the leading multi-nationals which trade across the region. The liberalization of borders in 1993 following the European Act of 1986, the adoption of the Common European Currency (1999) and the so-called “fall of the iron curtain” in 1989 have all led in the ensuing years to companies in many sectors organizing themselves on a pan-European basis rather than nationally, as had been more the case up to the end of the 1980’s. One consequence of this is, for instance, the development of “focused factories” where manufacturing production is then consolidated on one site to fully exploit economies of scale. This clearly has direct implications for the demand for larger freight vehicles as large volumes of goods produced at these sites need to be moved over long distances to distribution hub points to serve markets right across Europe (Gligor and Holcomb, 2012). Also, road transport is often preferred to service modern supply chains as it is the most flexible of the modes, and able to operate on a door-to-door basis. At the same time, mounting economic and environmental pressures faced by the road freight industry, call for new transport policies aimed at making the sector more sustainable. According to McKinnon (2011), consolidation of loads in LHVs is one of most effective ways of reducing vehicle kilometres and road freight transport’s impact on the environment. Thus, several governments have considered relaxing truck size and weight restrictions as a measure to support the sector in becoming more environmentally efficient.

In 1996, an EU Directive (96/53/EC) was put in place to grant all EU member states the right to operate longer vehicles, as long as they conformed to the standard modular dimensions defined in the Directive. According to the Directive, vehicle units can be coupled together in combinations of short modules of 7.82m and long modules of 13.6m. In most European countries the maximum vehicle length limit of 18.75m is permitted. However, there are a number of countries which have adopted lorries up to 25.25m as a practice or run trials to test the feasibility of them (Bergqvist and Behrends, 2011). The extension of length is often accompanied by an increase in the maximum gross vehicle weight beyond the current maximum of 40 tonnes set in most of Europe.

In the EU, Sweden has the longest tradition of long and heavy vehicle combinations. Until 1968, when the Swedish Government implemented a 24m limit, there had been no legal restrictions on the length of trucks. The maximum gross vehicle weight in Sweden was successively increased from 37t (1968) to 51.4t (1974), 56t (1990) and 60t (1993) (Vierth et al. 2008). LHVs are also operated in Finland (25.25m, 76t GVW) and the Netherlands (25.25m, 60t GVW). A trial of 25.25m/60t GVW LHVs is currently underway in Denmark (until 2017) and Belgium is considering one (Leach & Savage, 2012). In the UK, a major desk-based feasibility study of LHVs was commissioned in 2007 (Knight et al. 2008). In January 2012, the UK Department for Transport started a trial of 1,800 extended length semi-trailers. The trial consists of 900 semi-trailers of 14.6m in length and 900 semi-trailers of 15.65m in length and will run for a maximum of 10 years in order to establish the environmental and safety impacts of each length (Department for Transport, 2012). In Germany, some federal states allowed limited trials of LGVs in 2006. In October 2007, at the Conference of Transport Ministers a decision was made not to license LHVs on the country's roads. Despite this announcement, the support for LHVs in a number of German states was strong enough for some trials to continue, and a small number of regional trials started in 2008 and 2009. The recent national trial commenced in January 2012, with seven federal states allowing the use of longer vehicles (25.25m, 40t) for up to five years (Leach & Savage, 2012). Outside the EU, a number of countries permit LHV operation, for example Australia, Brazil, Canada, Norway and the USA (Nagl, 2007).

At the international level, the European Commission has recently funded a number studies to investigate the possible effects of changing the 96/53/EC Directive to allow for longer and/or heavier vehicles in cross-border transport. A study published by the European Commission (2008) focusses on technical characteristics of LHVs and models their impact on the EU freight transport market. All three scenarios considered in the study give an overall positive effect on society and the environment, when compared to the business-as-usual case. Christidis and Leduc (2009) review a number of previous studies and model different combinations of assumptions to conclude that "the introduction of LHVs would be beneficial for the EU economy, and – under certain conditions – environment and society as a whole" (p.24). Leduc (2009) considers technical aspects of LHVs that could further reinforce the positive effects of LHVs introduction, with particular attention given to energy efficiency, impact on infrastructure and safety issues. Knight et al. (2010) provide an assessment of the likely effects of potential changes in the vehicle weights and dimensions at the European level, reviewing available vehicle options and a range of policy measures relating to any future implementation of those. Steer et al. (2013) provide the most recent analysis of current evidence on LHVs and the likely consequences of permitting the use of them throughout Europe. The Joint Transport Research Centre of the OECD and International Transport Forum also published the results of a global review of opportunities to 'move freight in better trucks', which is largely concerned with productivity benefits of increases in vehicle carrying capacity (OECD / ITF, 2010). As a result of all these studies, supported by a wide consultation on the subject and the inclusion of changes in truck size and weight regulations in the EU's Logistics Action Plan (European Commission, 2007), a proposal for a Directive amending the 96/53 Directive in order to increase the maximum legal size and weight of trucks making international journeys across the continent, was published in April 2013 (European Commission, 2013b).

COST-BENEFIT ANALYSIS OF LHVs

A number of academic studies and research reports discuss the potential positive and negative impacts of increasing the maximum weight and size of trucks. Key stakeholders in the LHV debate often represent radically polarised views on the matter, making the issue one of the most controversial and politically sensitive debates in the history of logistics and supply chain research. According to European Transport Safety Council (ETSC), some 212 organisations from 24 countries oppose LHVs, usually on environmental grounds (ETSC, 2011). This section presents a summary of key arguments related to the LHVs impact on the environment, freight modal split, infrastructure, and transport safety.

Based on the UK example, McKinnon (2005) demonstrates, even within the same size limit, "increasing the legal maximum weight of trucks enables companies to consolidate loads and thus reduce the amount of vehicle movement required to distribute a given quantity of freight" (p.77). This can result in significant fuel savings and reduced environmental impact of the road freight sector. Most studies, even those generally opposing LHVs (e.g. Fraunhofer ISI et al., 2009), do not dispute their positive impacts on the environmental performance of road freight transport. For instance, Tunnel and Brewster (2005) investigate the energy and tailpipe emission impacts from operating trucks at weights equal or greater than exiting federal limits in the US and prove the environmental benefits of so doing (savings of 4-27% in fuel consumption and emission per ton-mile, depending on the configuration tested). Ortega et al.

(2014) estimated that if LHVs were to be introduced in Spain, even in the least favourable scenario of changes to vehicle demand and costs, CO_2 emissions would still be reduced by 2 million tonnes over 15 years. The Dutch LHV trial showed substantial reductions in fuel consumptions, GHG emissions and air pollution in practice (Aarts and Feddes, 2010).

The payload of LHVs seems to be the key factor determining their environmental performance. According to Leduc (2009), "it can be estimated that the payload of LHVs should be roughly above 65-70% of its maximum carrying capacity to be more energy efficient than a fully-loaded conventional HGV" (p.17). Many countries do not collect data on average utilization of vehicle capacity (Piecyk and McKinnon, 2010b). Therefore the analysis of the impact of LHVs is inherently difficult. According to the European Environment Agency (EEA) (2010), heavy vehicle load factors vary enormously amongst countries, with just over 30% in Portugal to as much as over 80% in Spain. The optimum cargo density to achieve complete utilization of a vehicle in terms of mass and volume for a 25.25m/60t GVW LHV is $0.3t/m^3$ (Glaeser and Ritzinger, 2012). Based on cargo densities presented by Glaeser (2010), empty beer bottles in boxes have just the density of $0.3t/m^3$. In Finland LHVs have a share of 73% in the road freight market (measured in tonne-mm), and are predominantly used to move food and agricultural products, textiles, coke and refined petroleum products. In the Netherlands LHVs were taken up mainly by companies operating in retail, floriculture, and container transport sectors (Steer et al., 2013). This suggests that LHVs tend to prove popular in sectors characterized by relatively low density products, which may be reflected in lower weight-based utilization rates. The average load carried by LHVs in the Netherlands is over 19t (Ministry of Infrastructure and the Environment, 2011a). This is much higher than the average for the Dutch road freight transport of around 9t, reported by Eurostat (Piecyk and McKinnon, 2010b). This may suggest that LHVs have been taken up mainly by companies that would use them most efficiently, but based on the Dutch experience, LHVs seem to have a positive effect on vehicle utilization (Ministry of Transport, Public Works and Water Management, 2010).

It is important to also consider the potential impact of LHVs on empty running. It may be more difficult to find a suitable backload, or to fully utilize loading capacity of a LHV on a return journey. However, the study carried out by the Dutch Ministry of Infrastructure and the Environment (2011a), shows that in all sectors operating LHVs, apart from waste, back loading took place. Even though the average recorded load on the return leg was on average 34% lower that on the onward journey, this pattern was consistent with that of regular vehicles operated in the Netherlands.

Some research reports, particularly those prepared or funded by pro-railway groups, argue that, due to a transfer of freight traffic from rail to road, the introduction of LHVs will cause a significant increase in GHG emission from the freight transport sector as a whole. Fraunhofer ISI et al. (2009) based on a review of German and UK studies conclude that the highest affected freight market would be container shipments, "where losses of rail demand up to 50% are predicted", but they admit that, "this, however, depends highly on assumptions of operational and service related responses of the carriers due to declining demand" (p.105) and, in the long term, efficiency gains in the road sector might compensate for the additional CO_2 emissions due to modal shift. In the UK, Knight et al. (2008) predicted a fall of 8-18% in rail tonne-km as a result of possible introduction of LHVs. Meers et al. (2014) estimated that, as a result of the introduction of LHVs in Flanders, the number of municipalities served by cheaper by intermodal barge transport would reduce by 15% for a 5% price decrease of road transport, by 63% for a 15% price decrease, and by 91% for a 25% price decrease. However, Finland where LHVs up to 76GVW are permitted, has one of the largest rail shares in Europe. In Sweden, where LHVs carry 90% of road tonne-Km, no modal shift to rail would happen, even if LHVs were to be removed, due to the lack of spare capacity for extra rail freight (Steer et al., 2013). In the Netherlands, the Ministry of Infrastructure and the Environment (2011b) conducted a monitoring study of the potential modal shift to road as a result of permitting LHV adoption. The study concluded that, despite reduced road freight transport costs, no modal shift to road had occurred, and it is not expected to occur in the future. This was explained by the unsuitability of LHVs for transporting bulk goods, necessary investment not possible to justify for use on short distances, and limited possibilities to create combinations of 40ft and 20ft containers (20ft containers make up only 20% of containers, and are often heavily loaded). This suggests that the nature of freight flows in a country, and the level of existing mode capacity utilisation greatly affects the potential for changes to the modal split.

There are also some studies that suggest that LHVs can supplement, rather than compete with, other freight transport modes. Bergqvist and Behrends (2011) assess the possibility of incorporating LHVs into pre- and post-haulage in road-rail intermodal transport in Sweden, by flexing the regulatory framework to permit vehicles using two long modules (13.6m), i.e. capable of carrying two 40-foot ISO containers. They estimate that this setup would "have the potential to decrease the total cost for intermodal transport services for a typical large-scale shipper by about 5-10% when the haulage accounts for about 20% of the total cost of the transport chain", and conclude that "this change might not seem that impressive, but this can be enough to achieve a substantial modal shift as the break-even point is moved and intermodal road-rail transport becomes competitive and attractive in new market segments" (p.600).

It is generally expected that modular combinations would cause less pavement damage than the existing trucks. This is because even though overall vehicle weight increases, it is spread across a higher number of axles. However, there is an agreement in most studies that additional investment will be required to adapt bridges, roundabouts, road crossings and intersections, parking and service stations to accommodate LHVs (Christidis and Leduc, 2009).

Regarding the impact on safety, Klingender et al. (2009) estimate savings in accident costs of up to 1,491 million €, if LHVs were introduced on European roads. Despite that, ETSC (2011) expresses "serious concerns" about the impacts of LHVs on road transport safety. They call for a comprehensive list of road safety aspects to be assessed and addressed before LHVs are allowed to circulate across national borders in Europe. Examples include strength of roadside and lane separation barriers, fire safety in tunnels, probability of secondary crashes if a LHV is involved in a road traffic accident, clearing time required at crossroads and railway level crossings, visibility restrictions LHVs create for other road users or the impact of carriage of liquid goods on the dynamic stability of LHVs. The European Federation for Transport and the Environment (2007) states that the introduction of LHVs "is not acceptable under current haulage market conditions" and "any change of the rules must be accompanied by stricter and more frequent enforcement to ensure that LHVs do not use inappropriate roads, are not overloaded, loads are correctly secured, and road haulage regulations are strictly adhered to" (p.2).

McKinnon (2011) maps the inter-dependencies between the above-mentioned issues and develops a comprehensive analytical framework to clarify the relationships in the cost-benefit analysis of LHVs (Figure 1). On the positive side, consolidation of loads in LHVs results in reduced operating costs and lower traffic levels. Fewer vehicles on the roads translate into reduced congestion, lower fuel consumption and associated GHG emissions and air pollution. A reduction in the other external impacts is also likely. For example, as the number of accidents is strongly correlated with the distance travelled, fewer accidents are expected. Nevertheless, although the overall number of accidents is likely to fall, the severity of accidents may increase due to the greater size and weight of LHVs.

Lower vehicle operating costs will certainly provide an added benefit to carriers and /or shippers. Reduction in freight costs may, however, lead to a change in logistical cost trade-offs. As a result, more transport-intensive sourcing and distribution strategies may be prioritised and the demand of road freight transport could increase. Also, if road freight transport sector gains a cost advantage, opportunities to shift freight traffic to less carbon intensive modes could be lost. Adopting LHVs could generate a need for additional investment and expenditure on road infrastructure. This spend would need to be covered by extra sources of income, possibly from new taxation imposed on road users (McKinnon, 2011).

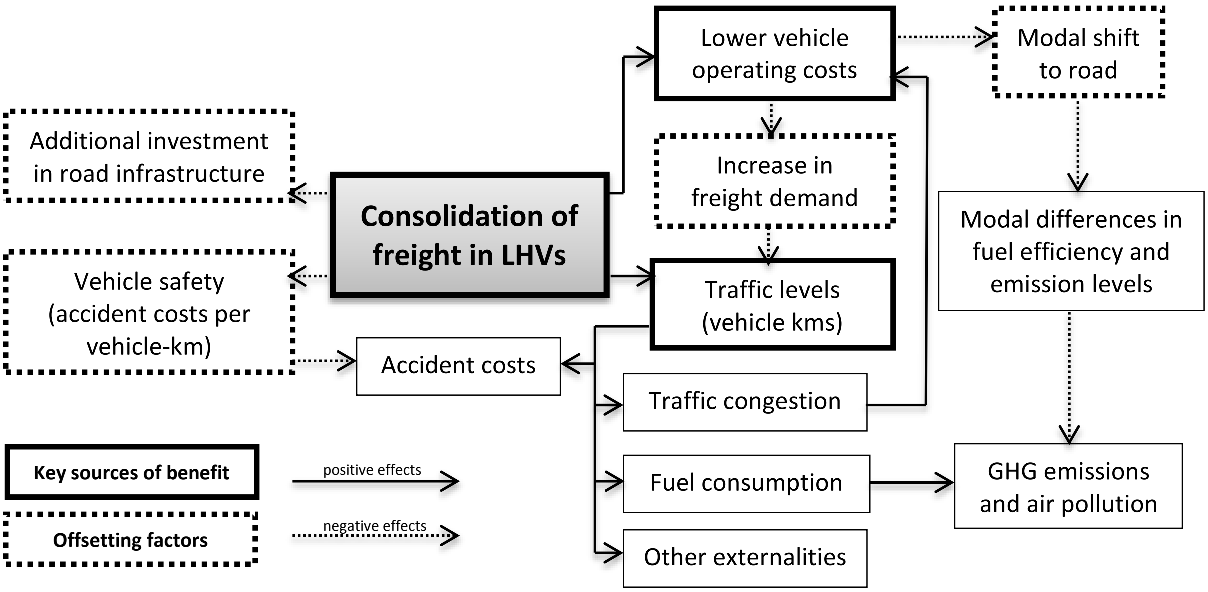

Figure 1 - Inter-relationships in the cost-benefit analysis of LHVs
Source: Adapted from McKinnon (2011)

METHOD

This study sought to better understand the specific ramifications from the adoption of LHVs in practice, by focusing on feedback derived from the trials undertaken in Germany over recent years. The main goal was to identify real issues, challenges and dilemmas German road freight operators face with regard to the possible adoption of LHVs in the country. The research was undertaken in two phases. Firstly, six case studies were conducted to gather in-depth insight into the results of the German LHVs trial. Interviews with management staff at the case study companies and data gathered from internal reports were used as the two main information sources at this stage. Semi-structured interviews are particularly suitable for exploratory research, thus this approach was selected to gather insights regarding the adoption of LHVs in Germany (Cooper & Schindler, 2008). The case study companies can be considered exemplar case studies, since they took part in the field trials run in Germany. Table 1 summarises their participation in the trails of the case study companies. The type of vehicles used in the field trials were 6.5 longer than the conventional vehicles. The questions used in the interviews (see Appendix 1) were developed based on a comprehensive literature review. The aim was to examine the views and experiences of the companies participating in the trials. The interview questionnaire comprised of questions related to background information and two main sections on LHVs.

Table 1 - Details of the field trials run be the case study companies

Company	Interviewee' position	Trial period	Route	Trips/Km/Tonnes	Commodity
A	Marketing Manager	2007 - 2008	Nettetal to Porta-Westfalica	N/A	Various
B	Assistant to the Board	2006 - 2007	Meppen to Duisburg	280/110,000/3,400	Various
C	Head of Fleet Management	2006 - 2008	Duisburg to Nurnberg	344/271,000	Intermodal transport containers
D	General Manager	2006 - 2007	Osnabruck to Lehrte	257/65,040/5,076	Various
E	Operations Director	2006 - 2007	Wolfburg to Emden	186/120,900/3,833	Automobile parts
F	General Manager	2008 - 2010	Parchim to Gallin	652/127,140	Various

Following the series of semi-structured interviews, an online questionnaire-based survey was developed. The questionnaire was piloted by asking the six companies participating in the first stage of the research to fill in the questionnaire and provide feedback on its overall appropriateness and the clarity of questions (see Appendix 2). The responses collected during the pilot study were not included in the analysis of the survey data, since the purpose of this stage of the project was to verify and generalise the findings from the case studies. Table 2 presents response rates obtained throughout the survey. 220 companies listed in the Bundesvereinigung Logistik (BVL) Association (2013) were contacted via e-mail, including a cover letter and an attached word document with the questionnaire. Subsequently, 350 additional companies from the website www.speditionverzeichnis.de were contacted by e-mail. Finally, a sample of 32 companies from the VVWL (Association of Transport and Logistics, North Rhine, Westphalia; www.vvwl.de) were contacted via telephone.

Table 2 - Response rate obtained throughout the survey

Stage	Distribution	Sample	Number of responses	Response rate (%)
1	E-mail	220	4	1.82
2	E-mail	350	18	5.14
3	Telephone	32	16	53.33
Overall		700	38	5.42

Table 3 shows the composition of the respondents in terms of the logistics services offered and the ports used by the survey participants.

Table 3 – Number of surveyed companies in terms of logistics services offered and ports used

Logistics services offered	Road freight transport	38	Warehousing	20
	Other freight transport modes	10	Value-adding services	8
Ports used	Antewerp	25	Rotterdam	19
	Hamburg	25	Bremen	19

The sample included a wide variety of logistics service providers, with a significant number of companies offering services beyond solely road haulage. Most companies offered also warehousing, value-adding services, or the use of alternative transport modes.

Table 4 presents number of responses in all three stages of the survey by the size of a company. The vast majority (36 out of 38) of the responding companies had between 1 and 499 employees. The number of respondents in this group was evenly distributed within three ranges, i.e. 1 to 49, 50 – 149 and 150 – 499 employees respectively. Only two respondents represented companies with more than 500 employees. Although this can be considered a drawback in the research process, the fact that most of respondents were from companies with less than 500 employees is not a significant research limitation, since the logistics market is dominated by small and medium-sized enterprises (SMEs) (Bundesamt für Güterverkehr, 2010). - In order to provide insight into the scale of respondents' operations, the questionnaire included a question on the weekly volume handled. Only 11 respondents disclosed their throughput (all indicated values between 10-499 TEUs per week). The remaining 27 companies stated that information about their weekly volumes is commercially sensitive and cannot be disclosed.

Table 4 – Number of responses in stages 1 and 2 and stage 3 by company size

Company size (No of employees)	Stages 1 and 2	Stage 3	Total
1 - 49	7	8	15
50 - 149	7	3	10
150 - 499	4	7	11
More than 500	1	1	2

Due to a relatively low response rate, the sample was tested for non-response bias. The independent samples t-test carried out to compare the mean scores of the early and late respondents showed no statistically significant differences in 14 out of 15 clusters evaluated in the survey. This confirmed the absence of non-response bias.

FINDINGS FROM THE STUDY

Findings from the two stages of this research project indicated that companies previously participating in the trials are supportive of a potential adoption of LHVs. Table 5 summarises the likely effects of the potential adoption of LHVs. Also, Appendices 3 and 4 include more detailed summaries of the data gathered during the case studies and survey. The positive effects of LHVs, derived from the framework adopted from McKinnon (2011), were validated at both stages of this research. The vast majority of survey respondents (73%) agreed that LHVs can provide significant increases in network efficiency. 20% of respondents believed that LHVs may generate network inefficiency, due to potential underutilisation of their higher loading capacity.

This mirrors the view already expressed in the literature that LHV utilisation is a key factor determining efficiency improvements associated with their use. 7% of the survey participants expressed the view that LHVs were only useful to transport containers to and from ports or railheads. Significant reductions in fuel consumption and CO_2 emissions from transport fleets were experienced by 70% of survey respondents. The case study companies also recorded an overall reduction in fuel consumption by about 30%. Company A could not provide exact values, but indicated significant benefits from an increase in loading capacity even when the experienced fuel penalty (2 litres/100kms) was taken into account.

Table 5 - Effects of a potential adoption of LHVs in Germany

		Interview responses	**Survey responses**
Positive Effects	**Impact on network efficiency**	All the participating companies saw significant increases in network efficiency.	73% - More efficient, but only with fixed contracts 20% - Potential underutilised vehicles
	Impact on fuel consumption and CO_2 emissions	Companies B, C, E and F believed that during the trials their operations achieved a reduction in fuel consumption of about 30%.	70% - Significant decreases of overall fuel consumption and CO_2 emissions
	Reduced costs	Companies A, C and D – 33% reduction in driver costs and fuel consumption	A high proportion of respondents expected significant reduction in the following cost elements: • Fuel/lubricants - 89% • Driver - 71% • Maintenance - 50% • Vehicle insurance - 48% • Tyres - 38%
	Impact on traffic volumes	Company E and F – 33% reduction in the overall freight transport cost	50% - Decreases in traffic volumes 25% - No impact on traffic volumes 25% - Increases in queues in ports, multimodal terminals and distribution centres
Negative Effects	**Impact on noise levels**	Companies B, E and F estimated a 33% decrease in traffic volumes of commercial vehicles.	93% - Insignificant increases in noise
	Impact on accident levels	Companies A and D perceived the increases in noise levels to be insignificant.	58% - No risks of an increase in the number of accidents as long as vehicles are equipped with safety assistance systems and drivers are trained 5% - More serious accidents
	Impact on road infrastructure	Companies B, C and E did not measure the noise levels during the trial.	93% - No impact on the road infrastructure, since maximum weight is kept at 44 Tonnes.
	Increases in the growth of the road freight transport market and decreases in the rail sector	All participating companies did not have major accidents reported during the trials.	55% - Higher increases in growth of the road freight transport market than expected

In addition, company F reported 33% reduction in fuel consumption and CO_2 emissions, mainly as a result of being able to use two LHVs instead of three conventional vehicles. This demonstrates that in order to fully exploit the benefits of LHVs, operators need to consider whether the timing and volumes of their transport flows would allow consolidation of loads in bigger trucks. Companies B, C and E experienced similar fuel savings between 16,900 and 18,600 litres within the trial period, which led to perceived savings of between 31 and 37%. Company D experienced a 30% reduction in CO_2 and 20% in particulate emissions. As a result of taking part in the trial, companies B and C saved 79,000 and 115,000 km respectively.

All case study companies experienced cost reductions resulting from LHV trials. Companies E and F reported an overall reduction in road freight transport operating costs of 33%. Company F stated that the 33% reduction came from lower investment and maintenance costs, reduced labour costs and fuel consumption, as well as less expenditure on road charges. Companies A, C and D were able to save 33% in fuel and driver costs. This was a result of fewer journeys needed to move a given amount of freight. Company C also pointed out that even though fixed and some variable costs were higher per LHV, the reduction in the number of trucks required makes the investment economical. The survey respondents also recorded significant reductions in all elements of road freight transport operating costs. For example, 89% of respondents indicated that LHVs generated significant lubricant/fuel cost reductions and 71% experienced reductions in their drivers' labour costs. Only a few participants (6%) reported no change, or a slight increase in the total operating cost. However, there were some respondents who anticipated a significant increase in costs of tyres (32%) and vehicle maintenance (21%).

The positive effects of LHVs envisaged by the participants were not only related to direct economic benefits to road freight transport operators. Interviewees from companies B, E and F estimated that during the trial they experienced a 33% reduction in commercial vehicle traffic. Companies A, E, and F agreed that road traffic is likely to decrease, since the same amount of goods could be transported with two vehicles instead of three. In the survey, 50% of respondents thought that the adoption of LHVs would reduce traffic volumes on German roads. Some participants, however, stated that the overall impact on traffic is uncertain due to the larger size of LHVs and the space they require to safely operate on roads and around terminals. The negative effect found in the survey was that 25% of survey respondents experienced increases in queues at ports, multimodal terminals and distribution centres during the trials.

Questions about the risks or negative effects proposed in the McKinnon (2011) framework were also included in the interviews and the survey. The findings indicate that the main risk of LHV introduction is related to their potential negative effect on modal split. 55% of the survey respondents expected higher than currently expected growth of the road freight transport market as a result of the adoption of LHVs. However, 77% of the respondents did not foresee a shift of the existing freight traffic from rail to road. The interviewee from company C expressed a similar opinion. Company A suggested that rail had already reached the limit of its capacity utilisation in Germany. Company B and F added that rail cannot compete in the door-to-door freight transport market. Also, company B stated that many regions in Germany have no railway terminals within a radius of 100 kilometres. Therefore, LHVs might have a positive effect on the German rail freight sector, by improving the efficiency of hinterland movements to support the growth of intermodal transport.

The other risks proposed by McKinnon (2011) were increases in noise and accident levels and damage to road infrastructure. Although logistics providers' perceptions of noise and accident levels generated by an increase in vehicle size is likely to have a degree of bias, these risks were rejected by the survey respondents and interviewees. In the survey, 93% of respondents perceived the increases in noise levels to be insignificant. The vast majority of case study companies did not report any significant changes to noise and vibration levels. Furthermore, 58% of survey respondents stated that LHVs should not have a negative impact on the frequency and severity of accidents as long as vehicles are equipped with safety assistance systems and drivers are trained. Only 5% of the survey respondents thought that a number of serious accidents could increase as a result of LHVs implementation. None of the six case study companies recorded any major accidents during the trials. Company F added that the number of accidents could decrease since fewer vehicles will be on the road. Company B expressed the view that other road users does not seem to be affected or to react to the presence of LHVs, and there were no problems with shunting, overtaking on reversing. Company C suggested that LHVs can be integrated into the existing traffic without any major issues, since there are only marginal differences in operation between LHVs and conventional trucks. 93% of the survey respondents stated that they did not think that LHVs used during the trial run in Germany had a negative impact on the road infrastructure, since the maximum gross vehicle weight was limited to 44 tonnes.

In terms of the timescale for the LHVs implementation, 54% of the survey respondents thought their companies could adopt LHVs in the short- or medium-term. Of the participants, 46% perceived that longer-term, strategic changes are required to ensure a successful transition of their business to LHVs. All six case study companies stated that they could implement LHVs in the short-term, because of only marginal investment required to do so. A summary of the findings regarding the actions/measures required for successful future implementations of LHVs is provided in Table 6.

Table 6 - Future actions and measures required

Action/Measure	Survey responses	Interview responses
Timescale of the implementation	54% - Short-term or medium-term 46% - Long-term	All companies said that can implement LHVs in a short-term time horizon due to a marginal investment cost required.
Measures on traffic safety	50% - Lorry bans on pre-defined routes 20% - General bans on specific roads 15% - Speed limits for LHVs 15% -Lorry bans at pre-defined times	Companies A, D and E said that LHVs could be operated only at night. Companies A, B and D gave additional training to their drivers. Company E said that LHVs should have a ‘Longer vehicle’ sign at the back. Companies B, C and F recommended additional technical equipment to enhance vehicle safety, e.g. mirrors, distance regulators and lane assistance.

The research participants identified a number of measures that could help to address the safety concerns associated with LHV operations. Companies A, D and E suggested that the use of LHVs could be limited to night time. Companies A and B indicated that LHVs should be routed through main motorways and the distance driven on other roads should be minimised. Companies C and D advocated extra training for LHV drivers, and possibly even an introduction of a special category of HGV driving licenses. Company E insisted on warning signs at the back of trailers. These suggestions were mirrored by the survey results. 70% of respondents stated that there should be lorry bans on specific routes or certain road categories. Some participants thought LHVs should be banned from operating at certain times, e.g. morning or evening peaks, and lower speed limits could be put in place (15% of respondents supporting each option).

DISCUSSION OF THE FINDINGS

Figure 2 maps empirical findings from this research onto the conceptual framework. The research has reviewed an extensive range of trials in one country, Germany, and demonstrated the feasibility of the adoption of LHVs. According to the findings, the vast majority of the research participants are interested in the adoption of LHVs regardless of the size of their companies. The findings show that two thirds of the participating companies and six of 16 German Federal States want to take part in a further field trial. The participating companies stated that the additional fleet capacity required due to the rapid growth of the German freight transport market is one of the main opportunities. The research also identifies significant decreases in fuel consumption, as well as in CO_2 emissions. The companies which measured their fuel consumption within the field trials reported significant savings in fuel and reductions in CO_2 emissions. According to the participating companies, risks such as noise or vibrations, induced by an increase in vehicle size, do not handicap the adoption of LHVs. Nevertheless, an increase of noise or vibrations is mentioned in the literature and can thus be considered to have a theoretical impact on the environment which may need to be reviewed further.

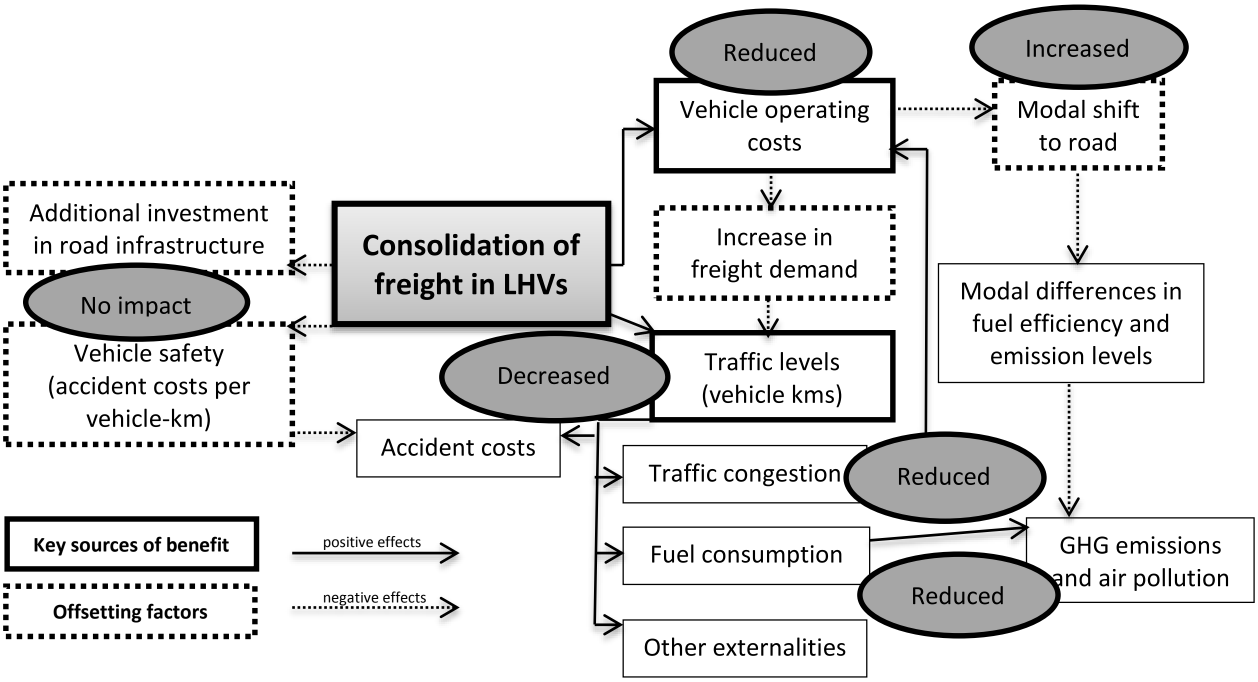

Figure 2 – Empirical findings

Regarding future actions and measures required, the participating companies, in line with the findings of the need of small investments stated in the literature review, confirm that a reconfiguration of their truck fleet will be a short-term action executed at operational level. However, for a successful implementation of LHVs, the transport and logistic sector has to persuade those organisations opposing LHVs. The participants did not foresee increases in risks to other vehicles, nor for roads or bridges, but the only way to ensure a wide acceptance of LHVs is to improve the level of safety in the operation of LHVs. To ensure improvements in safety, or at least an improvement in the perceived safety of LHVs, the participating companies stated that a range of measures can be applied such as restrictions for pre-defined sections of roads, specific speed limits for LHVs, driver training and the adoption of vehicle safety equipment.

The findings gathered from the case studies and survey provided sufficient evidence to argue that the German logistics sector providers are prepared for the adoption of LHVs. The vast majority of the participating companies see tangible economic, environmental and social benefits in the potential adoption of LHVs. Nevertheless, it is important to reflect on other wider issues which could impact upon the potential success of an LHV implementation. This section aims to discuss these issues.

One of the main issues that are discussed by several authors is that an increase in the dimension of vehicles potentially conflicts with the need to more frequent and less than full shipments. For example, McKinnon (2010) stated that the replenishment of supplies in smaller quantities within shorter lead times, just-in-time has tended to depress vehicle load factors. Efficient utilization of transport capacity can be sacrificed to achieve lower inventory and more flexible production. Nevertheless, modern supply chain systems, which today's logistics operations support, have developed and matured so that through practices such as freight consolidation as well as the concentration of production onto fewer sites to reap economies of scale, which tend to characterise modern supply chain systems, the demand for LHVs is becoming more and more apparent, thus challenging McKinnon's (2010) perspective. In particular, the adoption of vertical and horizontal forms of collaboration in logistics among logistics providing competitors, and/or between customers suppliers of products that use logistics services can be an important enabler of better vehicle utilization and economies of scale in transportation (Mason et al. 2007, Matson & Matson, 2007), thus further justifying the call for LHV.

The UK grocery sector provides a good illustration of this trend which is seen across Europe in many sectors today. In recent years, UK grocery retailers - which represent about 11% of the GDP of the country (Rhodes, 2013) - have made tangible actions to increase the capacity utilization of their vehicles. Collaboration between actors across the sector is becoming increasingly evident and whilst such strategies, which invariably can lead to enhanced freight consolidation, can be coped with through tactics such as the greater use of double-decker vehicles or the utilization of more freight trains, there is an increasing desire to use LHVs in the range of solutions available to save costs and reduce emissions.

The other significant issue that has been highlighted in this research surrounds the question of how much of an impact a greater use of LHVs would have on other transport modes, notably the use of rail. This is a complex issue, but clearly there is some evidence from this research that there is a view that legislation to support LHVs would lead to an upsurge in investment in the road freight movement sector, possibly at the expense of rail. The possible negative impact of the use of rail is an argument put forward by rail lobbyists. As a legislative body, the EU has to decide ultimately what decision best suits its objectives of supporting the movement of goods safely, quickly and cost-efficiently, whilst managing and controlling externalities arising from this movement, such as the rate of emissions (European Commission, 2013a). It has been argued in this paper that modern supply chain systems have developed in many sectors in Europe that now depend on the use of road freight movement. For instance, Logistics Parks linked to main arterial road networks such as motorways or autobahns are now an established characteristic of today's logistics scene and although an on-going strategy to deflect some freight movement to rail should be on-going, there should also be an acceptance that road is invariably the preferred means of freight movement. Therefore, as much should be done as possible to support road freight transport's efficient and environmentally friendly use through policy and legislative decisions.

This research has looked predominantly at a geographical segment. In order for LHVs to be implemented at a Pan-European level, the existent legal restrictions around the increases in the dimension of road freight vehicles will have to be relaxed. Currently, there are considerable differences among EU countries in terms of the maximum vehicle length allowed. For the adoption of LHVs to be successful, there is a need for more joined-up freight transport policy at Pan-European level, which is an area where focus is now being attended to by the current EC Directive (Kallas, 2013).

CONCLUSIONS

In recent years the LHV issue generated a large amount of research, much of it published in consultancy reports rather than journal papers. However, most publications focus on estimating the likely effects LHVs could have on a transport system, typically by modelling data published in national and European statistics. There are very few original empirical studies on this topic, and as such this study provides a vital contribution to the existing body of knowledge. The paper contributes substantially to the academic literature by developing empirical evidence which could be used as a building block for future research. The main contribution of this paper is to refine and validate McKinnon's (2011) conceptual framework of inter-relationships in the cost-benefit analysis of LHVs. Our study demonstrates that the framework is a valuable tool to frame the analysis of the impact of LHVs on a national transport system. This paper contributes a robust analysis approach that can be replicated for future studies on the benefits, risks, enablers and barriers associated with LHV use in different countries and/or at pan-European level.

From a practical perspective, the paper has explained why the debate around LHVs has become particularly topical. New trends on freight consolidation in supply chains and the greater use of focussed factories to serve wide areas of Europe are leading to LHVs being increasingly demanded by practitioners. It can therefore be argued that to support desired eco-efficiency advancements, so that road freight transport can better serve and support supply chain management practice in modern supply chains, legislation is required to develop pan-European standards with regard to the use of LHVs.

There are several limitations to this research that need to be acknowledged. First of all, the study focused on the perspective of logistics service providers who participated in the German trials, which implies they have a keen interest in using LHVs. This may result in biased responses where participants exaggerate positive outcomes, and play down any negative effects resulting from the trials. This needs to be taken into account when interpreting the results. A survey of a larger sample of companies participating in the most recent trial would be a valuable follow up to our work, and could result in a more diverse spectrum of experiences being presented. In addition, it is acknowledged that not all stakeholders were surveyed in this research. The study was focussed solely on participants in the trial with a follow-up survey of providers. Whilst we argue this has provided a valuable insight there is clearly a need for a wider study of all stakeholders before fully informed judgements can be proposed. It should also be noted that some comments were also purely opinion-based, e.g. impact of LHVs on traffic noise, road wear and tear, or statements that other road users do not even notice LHVs, as the respondents have no means to measure these. Objective evaluation of such impacts requires a different approach, which was beyond the scope of this study.

In the logistics literature, few empirical studies have been conducted to evaluate LHVs as a solution for achieving CO_2 reduction in freight transport. This paper is thus fairly novel. The study can inform future research studies that aim to explore and evaluate the feasibility of the adoption of LHVs in different European and non-European countries. For instance, the paper could be the starting point of five avenues of further research:

- A comparative study run to include more European and other non-European countries to generalise the findings;
- Research to explore the feasibility of the integration of 45-, 48- and 53-foot containers within logistics networks which have adopted LHVs;
- An exploratory project run to determine whether or not the adoption of LHVs could enable further vehicle aerodynamics improvements;
- More research to investigate how LHVs fit into international multimodal networks; and;
- A wider study to take into account views from all stakeholders involved with the LHV debate.

The European Union sets the requirements for LHVs in the directive 96/53/EG. Thereafter, contingencies are regulated to adopt these vehicles in the domestic traffic of the member states so that a very disparate legal framework has developed for LHVs across Europe. From logistics providers perspectives what is needed now is a more uniformly accepted pan-European approach which would allow for clear consistent standards to be adopted across the European region for LHV use.

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Appendix 1 – Semi-structured interview questions

Interview Part 1: General questions about the company

How many people are working for your company and how many are truck drivers?

What is the core business of your company? Which logistics services does your company offer to your customers?

Does your company handle ISO-Containers, and if yes, at which ports, how many per week, and how many are filled up with volume goods?

During which period and with how many vehicles did your company participate in the field trials?

Which goods were transported on which routes? How many tonnes-kilometres did the trial cover?

Interview Part 2: Positive and negative risks of LHVs

How efficient was the field trial with EMS for your company? How would you describe the savings of transport and logistics costs (e.g. in per cent)? Which costs could be reduced in detail?

Did you measure the reduction of fuel consumption and CO2 emissions? Could you tell me the CO2 impact you estimated during the field trial??

To what extent could the traffic volume of vehicles be affected the implementation of LHVs? What do you think about the capacity utilisation of the roads?

To what extent could LHVs cause risks to the safety of other road users? Higher noise / vibration levels than conventional vehicles? More accidents than conventional vehicles?

To what extent are there any risks regarding the infrastructure while adopting LHVs?

According to published reports, the freight market is expected to increase by 32% until 2030. To what extent could LHVs cause changes in the modal split between rail and road?

Interview Part 3: Future actions and measures required

Which time horizon does your company need for an implementation of LHVs in your truck fleet?

Which actions could be implemented to mitigate the risks of LHVs related to the safety of other road users?

Which actions or technical improvements for LHVs are necessary for further fuel savings?

Appendix 2 – Structured questionnaire (in English) used in the survey

Part 1 – Your company

1- How many employees are working in your company?

1 to 49		150 to 499	
50 to 149		More than 500	

2- What is the core business of your company? (Multiple answers possible)

Road transport		Rail	
Inland waterways		Air freight	
Sea freight		Pipeline	
Warehousing		Value-adding services	

3- Does your company import / export and/or handle ISO-containers in the day-to-day business?

Yes, continuously	
Yes, infrequently	
No	

If your answer is ‘yes’, at which sea ports do you dispose your containers (Multiple answers possible)

Hamburg		Rotterdam	
Amsterdam		Antwerp	

If your answer is ‘yes’, how many TEUs is your company handling weekly?

1 to 9		150 to 499	
10 to 49		More than 500	
50 to 149			

If your answer is ‘yes’, what is the percentage of containers handled by your company without exceeding the maximum weight of 44 Tonnes: ___________________

Part 2 – Demand of the logistics sector and requirement of the German economy

1- Participation in field trials

We have participated	
We are participating	
We have not participated due to various reasons and restrictions	

2- The German freight transport market is expected to increase by 32 per cent by 2030. Which transport mode will mostly be absorbing this increase?

Road		Airfreight	
Rail		Sea	
Inland waterways			

3- Rail lobbyists suspect that modal shift will tend to relocate freight back on the road due to the use of LHVs. What is your opinion on this concern from rail lobbyists?

A shift to LHV will take place	
No shift to LHV will take place	

Part 3 – Energy efficiency and CO_2 emissions

1- If two LHVs replace three conventional vehicle combinations, how does that change influence CO_2 emissions?

Significant decrease		Slight increase	
Slight decrease		Significant increase	
No change			

2- How do LHVs influence the fuel consumption of your fleet?

Significant decrease		Slight increase	
Slight decrease		Significant increase	
No change			

3- Which additional actions are necessary to reach a further decrease of fuel consumption for new vehicles? (Multiple answers possible)

Use lighter material in vehicle manufacturing		Technological equipment to improve driver behaviour / performance	
Improvements in vehicle aerodynamics		Technology of tyres to reduce the rolling resistance	
Use of hybrid technology and alternative fuels			

4- Will LHVs lead to a significant increase in vehicle noise and vibration?

Yes	
No	
Don't know	

Part 4 – Costs versus benefits

1- The equipping of the truck fleet with LHV can be implemented…

Only in the strategic level / long term		In the operational level / short term	
Only in the tactical level / medium term			

2- Do you think the use of LHVs would be efficient / economically beneficial for your company?

Yes, but only with fixed term contracts		No, since an increase in total vehicle capacity is not required	
Yes, for pre- and post-road carriages of containers			

3- Based on a fixed sample size (2 LHVs instead of 3 conventional vehicles), which cost items could be decreased through the use of LHVs?
(--: significantly decreased, -: slightly decreased, 0: No change, +: slightly increase, ++: significantly increased)

Cost type	Item					
Running costs	Fuel & lubricants					
	Tyres					
	Maintenance					
Driver salary costs	Additional driver labour cost					
Fixed costs	Motor vehicle tax					
	BAB-road tax disc					
	Vehicle insurance					

Cost type	Item					
Overheads	Overheads / Admin					
Other costs	Interests					
	Management wages					

Part 4 – Safety

1- Do you see any risks generated from the implementation of LHVs for other road users?

No, as long as vehicles are equipped with technical safety assistance systems and drivers have continuous training	
No, on an extension of 6.5 metres	
Yes	

2- State necessary actions required to increase the safety conditions in the operation of LHVs (Multiple answers possible)

Specified speed limits for LHVs	
LHV ban for pre-defined sections of the road	
LHV ban for pre-defined times of the day	
General ban on LHV circulation	
Reducing driving times / weekly working hours for drivers	

Appendix 3 – data gathered during the interviews

Company	A	B	C	D	E	F
Company size (employees and truck drivers)	85 employees; 38 truck drivers	400 employees, 120 truck drivers	2,300 employees, N/A truck drivers	9,228 employees, approximately 500 truck drivers	14,519 employees, approximately 400 truck drivers	90 employees, 30 truck drivers
Company core business	National and international groupage and warehouse logistics	Logistics services, national and international groupage and intermodal transports (sea, air, road, rail)	Logistics services, national and international freight forwarding and specialist in textiles logistics	National and international road freight, courier, express, parcel services, supply chain management, airfreight, sea freight, customs brokerage, direct load, rail solutions and IT solutions	Inbound logistics, transportation, module assemblies, value added services / packaging logistics and IT Solutions	National groupage and national and international freight transport
Type of freight transport services	Freight forwarding services in Germany and Benelux.	Door to door services.	Freight forwarding and distribution services.	Door-to-door services.	Door-to-door services.	Door-to-door services.
Type of freight transport services & container handling information (ports and number of containers)	Freight forwarding services in Germany and Benelux. Hamburg, Rotterdam and Antwerp. 20 Containers per week.	Door to door services. Rotterdam, Amsterdam, Antwerp. 350 containers per week.	Freight forwarding and distribution services. Bremen, Hamburg and ports in Benelux. 400 – 500 containers per week	Door-to-door services. All ports in Central Europe. More than 1000 Containers per week.	Outsourced to partner company	Outsourced to partner company
Details on participation on field trials	Governmental limitation to 1 vehicle pre-defined route between Nettetal and Porta-Westfalica from 2007 to 2008.	On vehicle between July 2006 and May 2007 in pre-defined route between Meppen and Duisburg. Night deliveries.	One vehicle between January 2007 to June 2008 in pre-defined route between Duisburg and Nurnberg.	One vehicle between June 2006 and October 2007 in pre-defined route between Osnabruck and Lehrte and some other pre-defined routes to various consignees.	One vehicle between June 2006 and July 2007 in pre-defined route between Wolfsburg and Emden.	One vehicle between September 2008 and 2010 pre-defined route between Parchim – Gallin – Valluhn – Parchim and Parchim - Rostock.

Company	A	B	C	D	E	F
Goods transported and tonnes-kilometres during the trials	Groupage, Tonne-Kms not disclosed.	Groupage (no dangerous goods), 280 run, 110,000 km and 3,400 tons in total. Capacity utilisation: Outward journey = 150 cbm = 100%, Return journey: capacity utilisation = 120-130 cbm = 85%.	Intermodal transport, 344 runs and 271,000 km	Less than truck load and FTL loadings / direct delivery, 257 runs; 65,040 km, 5,076 tons, average capacity utilisation: 74 per cent volume.	Automobile parts / spare parts, 186 runs, 120,900 km and 3,833 tons, high volume goods with an overall weight of 5.5 tones.	Groupage, 652 runs; 127,140 km.
Vehicle efficiency / cost reduction	An overall reduction of 33 per cent could be achieved, all variable cost items reduced by 33 per cent, due to the reduction of two instead of three vehicles.	High potentials of cost savings: fuel costs reduced by 55 Euro per day, driver cost reduced by 33 per cent and miscellaneous costs and investment costs estimated to be reduced by 15.88 Euro per day.	An estimated total cost reduction of 121,500 Euros per year, fix and variable costs per vehicle are higher for EMS (426,750,- EUR) compared to a conventional vehicles (325,000,- EUR) the use of two LHVs instead of three 18.75 meters long trucks leads to a significant reduction in cost.	Costs of fuel consumption could be reduced by 33.3 per cent, only in fuel there was a cost reduction of 12,400 Euro during the field trial.	A total saving in the fuel consumption of 18,800 Euro during the field trial. Also, additional cost saving in drivers and repair are expected if LHVs are implemented.	An overall cost saving of 33 per cent was calculated, due to decreased investment and maintenance costs, decreased driver costs, less fuel per year and less road charge.
Fuel consumption / CO2 emissions	An 7-metre increase in the loading metres and 2 litres of fuel per 100 Km.	A reduction of 18,600 litres, 37 per cent by a reduction of 41 per cent of the total runs, a reduction of CO2 emissions due to a reduction of the road kilometres by 79,000 km.	A reduction of 17,700 litres and a reduction of CO2 emissions of 15 per cent.	A reduction in fuel consumption of 32.9 per cent, a decrease in sooty particle from 10,000 to 8,000 PM (g) and a reduction in CO2 emissions of approximately 30 per cent.	A reduction of 16,900 litres, the LHV fuel consumption was only 1.2 litres more than the fuel consumption of a conventional truck, so the estimated reduction in fuel consumption is 30.4 per cent.	Approximately a reduction is fuel consumption and CO2 emissions of 33%.

Company	A	B	C	D	E	F
Traffic volume	Decrease of capacity utilisation since the same amount of goods can be transported with two vehicles instead of three.	The traffic could be decreased by 33% theoretically.	The company estimates an increase of 25 per cent of goods on the freight market in the next five years, 10,000 trucks more trucks per year. With LHVs they estimate that the number of motor vehicles could be unmodified.	About 10-15 per cent less freight vehicles in the road with the implementation of LHVs.	Traffic volumes will decrease, since less vehicles for commercial transport are needed.	Less commercial vehicles on the road means less traffic. That might be up to 33 per cent.
Noise /vibration	LHVs has no impact on higher noise or vibrations on themotorways.	Not measured.	Not measured.	The company suggest that noise and vibrations are not significantly higher.	Not measured.	Less noise on the motorways (no measurement about vibration).
Risk to other road users	No, throughout the whole field trial there were no problems or accidents.	No, other road users did not notice the LHV. Truck drivers of the company ranked the vehicle neutrally. No problems with shunting, overtaking of cars or turnarounds on the routes.	No problems were measured during the field trial. The LHVs could be integrated into the existing traffic without any challenges. In cooperation with the TÜV Rheinland and the GUVU the truck drivers were connected by wire with electrodes to measure the skin conductance – without any negative results. There were really marginal differences between the operation of LHVs and conventional trucks.	There were no problems along the field trial (no accidents). One driver had a critical situation on a motorway, due to carelessness of a particular car driver.	No problems were identified during the field trial. As pointed out before, the company mentioned only problems on motorway stations related to lack of parking space.	Contrary, the company foresees that that due to a decrease in the number of freight vehicles in the road, the number of accidents should also decrease.

Company	A	B	C	D	E	F
Damage to road infrastructure	No, the infrastructure (bridges and road) can be relieved due to the reduced weight per axle.	No problems with shunting, overtaking of cars or turnarounds on the routes, no extended handicap for roads or bridges, no problems due to weather conditions.	No risk for infrastructure since the total Tonne-Km per year would decrease with the implementation of LHVs.	No risk for infrastructure, as long as the maximum is not increased (maximum 44t - 48t), the parking areas are not long enough for the manoeuvres required though, but that most routes can be planned that the vehicle combinations do not have to take a rest on motorway stations.	No risks were identified; nevertheless, new motorway stations have to be reconstructed if the LHVs are implemented.	No risk for infrastructure, as long as the maximum is not increased (maximum 44t - 48t).
Potential changes in the German freight market regarding modal split	Small shift from rail to road due to rail capacity restrictions and no investments in new rail tracks. There is a very likely growth in intermodal transport.	No modal split; the road freight will increase much faster than the rail freight due to capacity utilisations	Intermodal transport will be more critically in the future, since many regions have no railway stations or terminals within a radius of 100 kilometres. According to the overall traffic distance, today the costs of equipment for intermodal transport are between 35 and 55 per cent.	Depends on investments of the rail infrastructure. If nothing changes the modal split will move more and more the road, since capacity utilisation does not allow more goods be transported by trains.	The company does not estimate modal shift from the rail to road or backwards.	Due to capacity utilisation of the rail transport infrastructure, a model split will occur from rail to road. This development is consequential, since the rail could never replace door-to-door transportation.
Timescale of the implementation	Short-term implementation, since existing vehicles are used and the company has only to invest into the motor dolly or a trailer coupling.	Short-term implementation, no investment on new vehicles, only the trailer needs to change.	Short-term implementation, within several weeks or 2 to 3 month though, due to the demand of dollies and couplings on the market.	Short-term implementation, since two different dolly axles were tested (manufactured by the company Krone) and a purchase of those dolly axles can be accomplished within several weeks.	Short-term implementation, since the acquisition of the new technical equipment required is straightforward.	Short-term implementation, due to marginal investment costs.

Company	A	B	C	D	E	F
Measures on traffic safety	The use of LHVs during the night (after 8 pm) only.	Only terminal-to-terminal runs, only truck drivers with long time experience and without any accidents are allowed to drive LHVs, lane- and braking assistance, distance regulator	Extension of driver license, additional driver trainings and improved education for employees.	The use of LHVs during the night only, additional driver trainings, only truck drivers with long time experience, without any accidents and reliable track record.	The use of LHVs during the night only, a further action is to mark the vehicles with an orange sign like "Caution! Overlength" or "Caution! Long Vehicle"	Additional technical equipment can lead to an improvement in safety conditions, e.g. additional mirrors, lane-assistance, braking-assistance, marks on the vehicles, further advanced driver training is necessary.
Other measures to reduce CO_2 emissions	Main action should be Eco-trainings due to the "MINIMAS" sponsorship program, telematics systems in the trucks offers the possibility to reduce and control the fuel consumption.	Special driver training, long experience of the dedicated truck drivers.	No other measures planned.	Use of Telematics (MAN TeleMatics) to analyse position, speed, actual and average fuel consumption, breaking points.	Further increases of the total weight up to 60 tonnes offer the possibility to decrease the fuel consumption and CO2 emissions, eco-trainings and advanced driver trainings are necessary as well.	Extended driver training, extended technical equipment for vehicles.

Appendix 4 – Summary of data gathered in the survey

Description of participating companies

		N
Logistics services offered by companies	**Road freight transport**	38
	Air freight transport	4
	Sea freight transport	4
	Rail freight transport	0
	Warehousing	20
	Value-adding services	8
Container handling activities	**Yes**	26
	Infrequently	3
	No	9
Major sea freight ports	**Hamburg**	25
	Antwerp	25
	Rotterdam	19
	Bremen	19

		N
TEU handled per week	1 to 9	15
	10 to 49	10
	50 to 499	11
	More than 500	2
Time of the participation in field trials	Currently	21
	Between 2004 and 2010	15
	Applying to participate	2

Positive effects

		Significantly decreased	Slightly decreased	No change	Slightly increased	Significantly increased
Fuel consumption		27	5	6	0	0
CO2 emissions		30	6	2	0	0
Cost reductions	**Maintenance**	19	5	3	3	8
	Tyres	15	9	0	3	11
	Fuel- and lubricants	34	2	0	0	2
	Driver	27	3	0	0	8
	Vehicle insurance	19	0	8	0	11
	Road tax disc	17	3	8	0	10
	Road vehicle tax	22	0	8	0	8
	Overheads / admin	22	0	7	0	9
	Leasing	22	3	3	1	9
	Depreciation	24	3	3	0	8
	Management wages	19	7	3	0	9
Traffic volume		19	0	10	0	9 (*1)

*1 - Increases in traffic volumes can lead to issues in service stations

Negative effects

	Significantly increased	Not significantly increased	No impact at all
Increases in noise levels	0	36	2
Increases in accident levels	2 (*1)	22 (*2)	14 (*3)
Damage to road infrastructure	0	2	36
Increases in the growth of the road freight transport market and decreases in the rail sector	21	7 (*4)	10

*1 - As long as appropriate safety equipment is installed in the vehicle

*2 - An increase in 6.5 metres in length had no a significant effect on the number of accidents

*3 - It might lead to less frequent but heavier accidents

*4 - Due to an increase in the intermodal road-rail split

Future actions and measures required

Timescale of implementation	**Short-term / operational**	15
	Short-term / tactical	6
	Long-term / strategic	17
Measures on safety	**Lorry ban for pre-defined sections of road**	19
	General ban at specific roads	8
	Pre-defined speed limits for LHVs	6
	Lorry ban for pre-defined times	6
Other CO2 reduction measures the company is more likely implement	**Eco-driving systems**	10
	Improved aerodynamics	9
	Lighter vehicles	7
	Tyre improvements	7
	Hybrid engines	6