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Longer and/or Longer and Heavier Goods Vehicles (LHVs) – a Study of the Likely Effects if Permitted in the UK: Final Report

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LONGER AND / OR LONGER AND HEAVIER GOODS VEHICLES (LHVs) – A STUDY OF THE LIKELY EFFECTS IF PERMITTED IN THE UK: FINAL REPORT

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Executive summary

Goods vehicles that are longer and/or longer and heavier (abbreviated as LHVs in this report) than those currently permitted in the UK are in use, under trial, or being considered, in a number of countries both within the European Union (EU) and elsewhere. The European legislation that controls the maximum dimensions of vehicles, and the maximum weight that guarantees free circulation within the EU, permits trials and the use of these vehicles under certain strict conditions. The legislation is also the subject of a review by the European Commission to consider whether such vehicles should be part of the Freight Transport Logistics Action Plan to improve the efficiency of transport and logistics in the EU by 2010.

In the UK, applications from two hauliers, each wishing to trial an LHV, were refused in 2005. However, interest has grown within the road freight industry both in the UK and elsewhere in Europe. In light of this, and the work of the European Commission, the UK Department for Transport (DfT) decided to undertake research better to inform policy making. TRL, in partnership with the Logistics Research Centre at Heriot-Watt University, were appointed to undertake this research - a formal assessment of the likely combined effects on road safety, the atmospheric and built environment, and the efficiency of freight transport, including the effects on modes other than road transport, if different types of LHV in excess of the current weights and/or dimensions limits were to be permitted in the UK. This involved assessing a wide variety of factors, including but not limited to:

- potential demand for LHV operations
- economic efficiency of such operations
- effect on other freight modes and the potential impact of freight traffic generation
- effect on the frequency and distance of vehicle movements
- effect on safety and accidents
- changes to vehicle emissions and the environment
- effects on infrastructure
- effects on drivers

This enabled the effects to be estimated and compared for eight scenarios, as described below:

A business as usual (44 tonne, 16.5m articulated heavy goods vehicles (HGVs) and 44 tonne, 18.75m drawbar combinations – rigid HGVs towing single drawbar trailers)

B an increase in the length of articulated HGVs from 16.5 to 18.75m - equal to that currently permitted for drawbar combinations, with the associated increase in unladen weight reducing the available payload.

C as B but with the maximum weight increased from 44 to approximately 46 tonnes to compensate for the increase in unladen weight (i.e. a payload neutral weight increase)

D an increase in length to 25.25m, and in the number of axles from 6 to 8, with the associated increase in unladen weight reducing the available payload.

E as D but with the maximum weight increased from 44 to approximately 50 tonnes to compensate for the increase in unladen weight (i.e. a payload neutral weight increase)

F as D but with the maximum weight increased to 60 tonnes (i.e. an increase in available payload)

G an increase in length to 34m, the number of axles to 11, and the maximum weight to 63 tonnes, giving the same net payload as F

H as G but with the maximum weight increased to 82 tonnes (i.e. a larger increase in available payload)

It should be noted that the scenarios are not accumulative in that they do not include vehicles described by earlier scenarios.

The research took the form of a desk study, which included reviews of relevant scientific literature, analysis of freight data, information gathering from a wide range of stakeholders, modelling of existing road freight flows, and computer simulation of some vehicle performance characteristics. Wherever possible the results were monetised and formed inputs to a parametric model of costs and benefits. Given the breadth of scope in both the scenarios and the variables to be assessed, and the inherent limitations of a desk-based approach, it was not possible to consider every variable in depth. For example, the research attempted to quantify the likely take-up of different LHVs and to identify what route restrictions might be required if different LHVs were to be permitted. However, these questions are strongly inter-dependent and also depend on factors such as the level of taxation, which cannot be predicted at this time. An iterative exercise would be required to fully resolve these issues. Similarly, the likely mode shift would depend on the take-up in the relevant road sector, the actual cost reduction including any changes in taxation, the route restrictions applied, operational constraints in and around ports, and the viability of key rail freight routes.

These complex and inter-dependent variables, combined with a lack of data in some areas, conflicting data in others and the disparate views of stakeholders, have meant that some of the most important variables had to be estimated using relatively crude techniques involving some significant elements of subjective judgement to balance competing or conflicting evidence. In addition, the estimates of effects for “payload neutral” scenarios were based on the interpolation of the results for other scenarios. While this is expected to be reasonably representative for 50 tonne vehicle scenarios, where two boundary cases were directly investigated, estimates for 46 tonne and 63 tonne scenarios are of lower confidence. As far as possible, it was ensured that all of the estimates and approximations were balanced in order to avoid introducing any systematic bias either for or against any particular outcome. However, these limitations mean that this report should be seen as an initial quantitative assessment of the likely effects of LHVs in the UK if they were to be permitted. If the evidence presented in this report is considered sufficient to warrant further investigation of LHVs, then a focus on a smaller set of specific scenarios and types or characteristics of LHV would allow the issues identified to be analysed in greater detail.

A summary of the main findings of the research is set out below.

- There was evidence to suggest that the increase in maximum permitted weights of goods vehicles from 41 to 44 tonnes had reduced vehicle kms, freight transport costs and carbon dioxide emissions relative to what they would otherwise have been. Given that continued freight growth is expected, maintaining current regulations on weights and dimensions would, with all other things being equal, be expected to result in an increase in the number of goods vehicle movements and a relative increase in pollution, accidents and congestion arising from those movements. However, the nature of goods transported has changed and a larger proportion of loads shipped are now constrained by the available volume or deck area rather than the available payload weight.
- Currently, the standard UK heavy goods vehicle (HGV) is a 16.5m long, 44 tonne articulated vehicle. However, vehicles that offer greater volume and/or deck area are also currently used. These include the 18.75m long drawbar combination at 44 tonnes and taller, double decked, versions of the standard 16.5m, 44 tonne articulated vehicle. An increase in the appropriate use of these higher volume vehicles, particularly for double decked vehicles, would provide net monetary benefits. However, there is a risk of an adverse effect on safety, particularly if the use of standard 18.75m drawbar combinations increases substantially, especially if the trailers used are short wheelbase “full” drawbar trailers. Further specific investigation would be required if it was considered necessary to confirm and more accurately quantify the risks associated with existing high volume vehicles.
- If LHVs were to be permitted then European legislation would be very likely to substantially constrain the UKs ability to permit only those specific types of LHV with characteristics considered desirable to protect the UK infrastructure. The current European legislation would

also be likely to make it difficult to require the fitting of specific additional safety equipment that could mitigate any increased accident risks. Suitable amendments to the European legislation would be required to be certain of the outcome. The UK regulations on speed limits for multi-trailer combinations would also be likely to require amendment, even if such vehicles were to be permitted by Special Order, because their speed would otherwise be limited to 40 mile/h on motorways and 20 mile/h on all other roads.

- It was found that allowing LHVs would have a range of effects each of which was likely to vary according to the types and characteristics of the vehicles and the constraints of the road network.
- Road wear factors would increase for some of the vehicles assessed but decrease for others.
- Considerable investment would be required in new and upgraded parking facilities for LHVs significantly in excess of 18.75m in length. This could not be accurately quantified but has the potential to be in the low £billions if large numbers of new, dedicated facilities were shown to be required. The creation of such facilities could be difficult to achieve because of constraints on land availability, planning permission and the ownership of current facilities.
- A conservative analysis of bridge loading has identified some risk that 82 tonne vehicles could overload a relatively small proportion of medium span trunk road bridges and a larger proportion of such bridges away from the trunk road network.
- It is possible that vehicles exceeding 44 tonnes could represent an increased risk if they collide with bridge supports. However, further research, likely to include physical testing of the protective structures, would be required if it was considered necessary to assess and quantify this risk more accurately.
- Longer vehicles, in excess of 18.75m, would have implications for the management of the road network. For example, traffic light phasing may need to be changed to ensure safety at junctions but this would reduce capacity. In addition, if LHVs that are less manoeuvrable than current vehicles were to be allowed unlimited access to the road network, this would increase damage to infrastructure on smaller roads and junctions and increase the risk of vehicles becoming trapped by the road geometry. The problems could be minimised or prevented by using more manoeuvrable vehicles or by limiting access to only those routes that are suitable, for example, by prohibiting access to urban areas through the use of Traffic Regulation Orders. Such route restrictions can be difficult and costly to enforce but advanced technology could provide a cost-effective solution in the future. If problems associated with road closures and diversionary routes are to be avoided, it would be necessary for vehicles to be capable of meeting minimum standards of safety and manoeuvrability commensurate with use on lesser roads. However, as discussed above, this would be likely to be difficult to achieve within the current European regulatory framework.
- LHVs would be likely to be used mainly for regular flows of low density products on primary distribution in sectors such as pallet-load networks, fast-moving consumer goods, deep-sea container movements and forest products. Wide variations were found in the attitudes of road hauliers to LHVs, ranging from enthusiastic support to deep scepticism and it was thought that some types of LHV may put smaller operators at a disadvantage.
- The industry identified conflicting pressures on the utilisation of vehicle capacity. Increased weight and/or volume capacity options could increase utilisation by improving the ability to match consignment size to vehicle capacity. However, the likely difficulty in sourcing backloads of sufficient size to fill LHVs could reduce utilisation. The analysis assumed that these conflicting pressures had equal effects such that the utilisation of LHVs would be equivalent to that of standard HGVs.
- Analysis suggested that, at most, approximately one-third of articulated vehicle trips could be suitable for LHVs. The degree to which routes might be restricted, if LHVs were to be permitted, would have a large influence on the extent of use that would be likely. The

evidence provided by the information gathering exercise combined with the experience in other countries very strongly suggested that, if permitted, LHVs would be specialist vehicles working in "niche" operations and would not replace the 44 tonne articulated vehicle as the standard "workhorse" of the industry. On the basis of all this information, it was estimated that up to 5% to 10% of the tonne-kms carried by articulated vehicles could move to LHVs of 60 tonnes or more (vehicles offering an increase in both available volume and payload). This represents a migration of up to approximately 11.8 billion tonne-kms per year. Lesser migration would be expected for 50 and 46 tonne scenarios, where volume is increased but the payload is the same as for existing vehicles, and particularly for 44 tonne scenarios, where volume is increased but payload is less than that of current vehicles.

- A conservative analysis suggests that casualty rates per vehicle km would be expected to increase for most, but not all, of the options considered and there was evidence to justify restricting the use of the higher risk vehicles to safer types of road. However, in all cases the casualty rates per unit of goods moved would be expected to reduce slightly and if new safety technologies, specific vehicle configurations, and existing manoeuvrability standards could be mandated, then this would mitigate many of the risks, increase the reduction in casualties per unit of goods moved, and encourage wider use of new technologies in the standard goods vehicle fleet.

- There is a strong interaction between the types and characteristics of vehicles assessed, safety performance, effects on infrastructure and vehicle usage. In some countries outside Europe performance based standards for vehicles are being implemented. Although European legislation currently prevents such an approach in the UK, performance based standards offer the potential to authorise vehicles in a more flexible manner that allows the capacity and use of larger vehicles to be optimised while minimising safety and infrastructure risks.

- Assuming that vehicle utilisation was equivalent to that of standard articulated vehicles, permitting LHVs would have the effect of increasing the fuel consumed by between 0.06% (18.75m articulated vehicle) and 71% (34m, 82 tonne vehicle) with the associated increases in exhaust gases emitted and operational costs per vehicle km. However, the increased carrying capacity of such vehicles would reduce fuel consumption and emissions per unit of goods moved by between 8% and 28%, depending on the scenario. This would contribute to a reduction in internal operational costs per unit of goods moved of between 18% and 43%. These internal operational costs include fixed costs such as the likely vehicle purchase price and variable costs such as fuel but do not include external costs such as accidents. Based on reviews of the actual effects of the most recent changes in permitted weights, as well as the views of industry on how such vehicles would be used, it was considered that this cost reduction would, overall, generate only a very small amount of additional freight movement as a result of the price elasticity of demand.

- Permitting LHVs would be likely to induce modal shift from rail but not from waterborne transport. In particular, LHVs of 25.25 m in length or greater would be likely to present a substantial threat to rail operations in the deep sea container market. Including both the deep-sea container and bulk rail markets led to an estimate that, based on the current characteristics of these markets, a maximum of between 8% and 18% of all rail tonne kms (including the overall forecast growth) would migrate to LHVs of 60 tonnes or more maximum weight. Much reduced migration would be expected for smaller increases in capacity with the 18.75m articulated vehicle expected to have very little, if any, mode shift effect on current rail markets. However, the rail industry predicts strong future growth in the domestic intermodal rail market, representing a significant mode shift from road to rail on particular freight routes, mainly in retail markets. Permitting LHVs could limit such future growth. In addition, several risk factors, such as the potential affects of undermining the rail resource base or the capacity and congestion at ports, could not be quantified and further in-depth research would be required if it was considered necessary to quantify these risks.

- The risk of mode shift described above is that which would be expected if LHVs were to be permitted for general haulage on inter-urban freight routes. However, it may be possible to devise a means of permitting LHVs in a manner, which minimised or eliminated the risk of mode shift whilst benefiting road freight sectors not competing with rail. It is not known if, or exactly how, this could be achieved without contravening competition rules, and this has not been studied in detail in this research. However, it is possible to envisage potential methods, such as emissions trading, that could be investigated if further consideration were to be given to permitting LHVs. If such an approach could be devised it would appear to be consistent with the European Commission's notion of co-modality, which aims to improve the efficiency of each freight mode when working alone as well as when working together.
- The opinion of the general public has not been directly surveyed in this study but several stakeholders expressed concern. There was conflicting evidence from surveys undertaken for *Freight on Rail* in the UK and the Transport Ministry in the Netherlands.

It is clear that, depending on the characteristics of the vehicles considered, permitting LHVs could require much further work in terms of additional research, legislative action (particularly at the European level) and, most significantly, estimation of the capital investment required in parking facilities and network infrastructure. An analysis of the internal and external costs of freight transport has suggested that the ongoing costs could be substantially reduced. This is because of a predicted net reduction of between approximately 276 thousand and 6.96 million goods vehicle movements per year and the associated changes in operating costs, road wear, accidents and emissions. An analysis of net present value has suggested that the levels of investment that could be sustained before the costs outweighed these benefits would be between £110million and £10.4 billion depending on the scenario and the time period over which the measure was assessed (5, 15 or 60 years). However, the potential benefits, the level of investment required to achieve those benefits, and the risks introduced, vary considerably for different scenarios, each of which should be considered separately, as set out below:

- Increasing the length of current 16.5m 44 tonne articulated vehicles to 18.75m, the limit for current drawbar combinations, is likely to represent a "low risk-low reward" option. The increase in volume is relatively small and the take up by industry could be relatively low compared with the other scenarios assessed. Few, if any, additional safety risks, no additional parking problems, and no adverse effect on bridges would be expected. There is a risk of some mode shift from rail to road and, more notably, of limiting predicted future mode shift from road to rail in the domestic intermodal market where strong growth is currently expected. However, overall, the analysis predicted a saving of between approximately 276 thousand and 682 thousand goods vehicle movements per year, resulting in an annual reduction of between 45 thousand and 66 thousand tonnes of carbon dioxide, 57 million to 85 million vehicle kms, one or two fatalities, and £23 million to £37 million in net internal and external freight transport costs. The investment required would be confined to any validation exercises that might be required and the necessary regulatory amendments. The net present value of the accumulated benefits would be expected to be between £110million (low estimate, 5 years) and £386million (high estimate, 60 years) such that a benefit to cost ratio substantially in excess of one would be likely. Additional worthwhile benefits would be likely if such vehicles were both longer and slightly heavier (a payload neutral weight increase to approximately 46 tonnes), but further work would be needed to estimate the effects with a confidence similar to that for the 18.75m, 44 tonne scenario.
- 25.25m vehicles at 44 tonnes, or with a payload neutral weight increase to approximately 50 tonnes, could attract greater reductions in on-going costs. However, in addition to a likely greater effect of limiting predicted future mode shift from road to rail in domestic intermodal markets, there would be a risk of mode shift from rail to road in the deep sea container market, which would have the potential to cause adverse environmental effects. It might be possible to devise a means of limiting such a shift, particularly given the capacity constraints and predicted traffic growth at ports. If this resulted in as much port freight as efficiently possible being transported by rail and allowed what could not be carried by rail to be transported as efficiently as possible by road, such an approach would appear to be consistent

with the European Commission's notion of co-modality. Substantial investment would be required in parking facilities. This could range from alterations to marked bays at existing sites to the construction of a large number of new or expanded facilities. There is a possibility that further investment would be required to increase the collision protection around bridge supports for 50 tonne vehicles, although such vehicles would not be expected to increase vertical bridge loads because of a lower axle load at maximum weight and a lower load per metre length than current 44 tonne vehicles. Depending on the extent to which routes would be restricted, there would be additional safety and infrastructure risks, such as overtaking and junction blocking, that could not be quantified in the cost analysis. Although it is possible to minimise the risks through innovative vehicle design, the European rules that govern the weights, dimensions and construction of goods vehicles would need to be amended to allow Member States to permit only the use of vehicles with those characteristics. The UK regulations on speed limits for multi-trailer combinations would also require amendment. For these types of LHV, the model predicted a saving in vehicle movements of between approximately 217 thousand and 4.3 million per year resulting in benefits with a net present value of between £351 million (low estimate, 5 years) and £5.9 billion (high estimate, 60 years). However, the potentially large but unquantified capital investment that would be required means that it is uncertain, at this time, as to whether the benefit to cost ratio would exceed one.

- 60, 63 and 82 tonne vehicles would incur similar risks and investments to those described above for 25.25m vehicles at 44 and 50 tonnes except that there would be a much greater risk of adverse environmental effects as a result of limiting predicted future mode shift from road to rail in domestic intermodal markets and inducing mode shift from rail to road in bulk goods markets as well as the deep sea container market. Increased investment would be required to protect bridge supports, if further research confirmed the risks, and 82 tonne vehicles may require some trunk road bridges to be strengthened or such vehicles to be prohibited from using them. 63 and 82 tonne vehicles would also be likely to require a larger investment in parking facilities because of their greater size and the potential need for coupling and de-coupling points. The model predicts that 60/63 tonne vehicles would produce a saving in vehicle movements of between 541 thousand and 3.56 million per year, resulting in benefits with a net present value of between £1.02 billion (low estimate, 5 years) and £6.57 billion (high estimate, 60 years). 82 tonne vehicles could save between 1.46 million and 6.96 million vehicle movements per year, resulting in benefits with a net present value of between £1.8billion (low estimate, 5 years) and £10.4billion (high estimate, 60 years). However, given that the cost of the necessary infrastructure improvements is likely to be very high, but could not be reliably quantified, it is uncertain as to whether the benefit to cost ratio would exceed one.

A series of recommendations were made for additional work that is likely to be required if further consideration is given to permitting LHVs. It was considered that while much of this work could be included as part of trials similar to those in the Netherlands, this would not be sufficient to provide all of the required information and some of the work identified would be required before such a trial could be considered. Methodological recommendations were also presented concerning improvements to data sources that would greatly improve the quality of the type of analysis undertaken during this study.

The report concludes that recent increases in the sizes of goods vehicles have helped to reduce emissions of carbon dioxide, vehicle kms and the cost of freight transport relative to what it otherwise would have been. Further increases might, therefore, be expected to deliver additional worthwhile reductions, but the findings of the study show that if goods vehicles significantly larger than 18.75m and 44 tonnes were to be allowed they would be likely to have serious adverse effects unless:

- investment was made in improved parking facilities to provide for statutory rest periods, which could be substantial if a new nationwide network of dedicated facilities are deemed to be necessary;

- investment was made in network infrastructure to establish suitable routes and procedures to manage diversions and enforce restrictions, and/or vehicles conformed with certain weight limits and manoeuvrability characteristics that reduce risk to the infrastructure. However, for such vehicles it does not currently appear to be possible to mandate standard manoeuvrability requirements on account of European trade rules.
- the speed limits for combinations with more than one trailer were increased (currently these are 40 mile/h on motorways and 20 mile/h on other roads).

A blanket decision to permit 60 tonne vehicles with more than one trailer for general haulage would present a substantial risk of adverse environmental effects mainly because of likely mode shift from rail to road, especially in the deep sea container market. If such multi-trailer vehicles were restricted to around 50 tonnes, or less, the likely magnitude of mode shift would be much reduced and largely confined to the deep sea container market. The risk of adverse environmental affects would, therefore, be much lower.

Vehicles significantly larger than 18.75m and 44 tonnes would be likely to increase safety risks per vehicle km, but decrease safety risks per unit of goods moved. If such vehicles were to be allowed, it would be advantageous for certain safety features to be fitted in order to minimise the risks and maximise the casualty reduction potential. However, once again, requiring this does not appear to be possible within the current European regulatory framework.

Although an analysis of the internal and external costs of freight transport suggests that such vehicles offer substantial ongoing benefits, the potentially large but unknown capital investment cost means that it is not certain as to whether the benefit cost ratio would exceed one. Further work would therefore be needed to determine whether addressing the above issues would deliver worthwhile net benefits.

However, in the case of 18.75m 44 tonne articulated goods vehicles with semi trailers longer than those currently permitted, few of the problems or additional risks identified above would apply. The reductions such vehicles would offer in terms of the internal and external costs are likely to be smaller than those offered by vehicles with significantly higher capacity but the minimal investments required mean that a benefit cost ratio substantially in excess of one would be likely, with the model predicting annual savings of around:

- 45 thousand to 66 thousand tonnes of carbon dioxide,
- 57 million to 85 million vehicle kms,
- 276 thousand to 682 thousand goods vehicle movements,
- one or two fatalities, and
- £23 million to £37 million in net internal and external freight transport costs.

If the net present value of the benefits for 18.75m 44 tonne articulated goods vehicles with longer semi-trailers are evaluated over 5 years, they would be expected to be between approximately £110 million and £176 million. If the evaluation period was extended to 15 years the net present value of the benefits would be expected to be between £224 million and £359 million and over 60 years would be approximately £241 million to £386 million. Additional worthwhile benefits would be likely if the weight of such vehicles were to be increased to approximately 46 tonnes to compensate for the increase in unladen weight (a payload neutral weight increase).

If further consideration is given to permitting these longer articulated vehicles then more detailed study may be necessary in order to:

- validate the costs and benefits with respect to uptake by the industry, the effects of small (payload neutral) weight increases, legal issues, safety, manoeuvrability, and the effects on current and future rail markets; and

- assess whether additional worthwhile benefits could be achieved, relative to existing vehicles, by variations to the length, height and configuration of the longer semi-trailer.

1 Introduction

The maximum lengths of goods vehicles in the UK are set by Council Directive 96/53/EC and are limited to 16.5m for articulated combinations and 18.75m for drawbar combinations. The Directive does not set absolute height or weight limits but specifies limits which guarantee free circulation within the EU. These include a height limit of 4 metres and a weight limit of 40 tonnes on 5 axles. In the UK there is no height limit and the maximum weight is 44 tonnes on 6 axles.

The Directive also states that *"Member States may allow vehicles or vehicle combinations used for goods transport which carry out certain national transport operations that do not significantly affect international competition in the transport sector to circulate in their territory with dimensions deviating from those laid down in Annex I"*.

Operations are considered not significantly to affect international competition if either: a) specialised vehicles or vehicle combinations are used in circumstances not normally carried out by vehicles from other Member States; or b) the Member State also permits vehicles, trailers and semi-trailers which comply with the Directive to be used in combinations to achieve at least the same loading length. The assembling of such combinations is sometimes referred to as the European Modular System (EMS). For example, Finland and Sweden permit such combinations up to 60 tonnes and 25.25m long.

Goods vehicles that are longer and/or longer and heavier (abbreviated as LHVs in this report) than those currently permitted in the UK are in use, or being considered for use, in a number of countries both within the EU and elsewhere. In the UK, applications from two hauliers, each wishing to trial an LHV, were refused in 2005. However, interest continued to grow within both the UK road freight industry and elsewhere in Europe. In light of this and the work of the European Commission on a Freight Transport Logistics Action Plan to improve the efficiency of transport and logistics by 2010, the UK Department for Transport (DfT) decided it was necessary to undertake research to better inform policy making. TRL, in partnership with the Logistics Research Centre at Heriot-Watt University, were appointed to carry out a formal assessment of the likely overall effects if vehicles in excess of the current weights and / or dimensions were to be permitted in the UK.

The research involved assessing a wide variety of factors, including but not limited to:

- the potential demand for LHV operations
- the economic efficiency of such operations
- the effect on other freight modes and the wider logistics impacts, including potential freight traffic generation
- the effect on the frequency and distance of vehicle movements
- the effect on safety and accidents
- changes to emissions and the environment
- the effects on infrastructure
- the effects on drivers

The project included:

- Reviewing relevant literature – including the findings of comparable studies in Belgium, Germany and the Netherlands
- Analysing freight industry performance and other relevant information – a major source was the Department for Transport's Continuing Survey of Road Goods Transport (CSRGT)
- Modelling goods vehicle movements – a Logistics Model was used to examine the impacts of different types of LHV and access constraints
- Collecting and analysing information from a wide range of interested parties. Information was collected using an on-line questionnaire and focus groups. In addition, many individuals and organisations submitted information, and an event hosted by SOE IRTE was attended.

- Cost-benefit analysis – a parametric model was developed to assess the net effects of those factors that could be quantified in moentary terms.

This report summarises the project's findings in its main body and provides more detailed supporting evidence in Appendices.

2 Limitations of the study

The subject of the permitted weights and dimensions of goods vehicles is very complex and one which incorporates an extremely wide range of inter-dependant variables. The brief for this project was, therefore, appropriately wide ranging but the work was confined to a desk-top study collecting and analysing the information and views already in existence. The report is, therefore, very comprehensive in terms of its consideration of all of the variables which may affect, or be affected by, any decision to permit LHVs. However, for some of the variables considered there was insufficient information available to make definitive assessments of the effects. For example, a large range of possible vehicle types were considered, which meant that the freight industry was unable to provide detailed quantitative data on their likely use of each option. It was not possible to carry out comprehensive and detailed surveys of the suitability of specific roads or parking facilities and it was not possible to carry out physical testing and experimentation to more accurately quantify safety effects, such as collisions with bridges or the effect of specific technological safety measures such as collision mitigation braking systems.

Many of the questions asked of this research are inter-related such that iterative analyses would be required. For example, the freight industry was asked to identify what proportion of goods would be likely to be moved by LHVs if they were permitted but they were also asked to identify what type of vehicles they would like to use and how they would like to use them in order to assess whether any particular route restrictions and/or safety requirements might be required. However, the types of vehicles and the extent of any route or safety restrictions imposed, as well as issues such as the level of taxation applied, would all be likely to have a substantial influence on the level of take-up by the industry. Similarly, the assessment of likely mode shift was confined to a predominantly econometric analysis based on simple price elasticities. However, the effect that the level of mode shift predicted might have on the viability of key rail freight routes, the effect that congestion in and around ports and the availability of suitable LHV routes may have on the validity of the price elasticities could not be assessed. Thus, there is a risk that the mode shift predicted could be either an under or over estimate. There may, therefore, be a need to re-assess the research if, at some future time, a smaller, more detailed, set of scenarios were to be developed.

This report should, therefore, be seen as an initial quantification of the likely effects of LHVs if they were to be permitted. If the evidence presented in this report is considered to warrant further, more detailed, exploration of the possibilities then there would be a need to create a much smaller set of scenarios. Any specific issues identified in this report that were relevant to the new scenarios could then be assessed in much greater depth.

3 Trends in UK Freight

The analysis of freight data is intended to provide all of the reference information needed to form the basis of estimates of the effects that LHVs might be expected to have, if permitted. It also provides understanding of how the freight industry has responded to previous changes in the economic and regulatory environment that can help to inform judgements of how it might respond to the scenarios being assessed in this project, if they were to be implemented.

The main modes of UK domestic freight transport are road, rail, water and pipeline. The amount of goods moved between 1995 and 2005 in tonne-km (this measure takes into account both the weight of goods and how far they travel) by each of these modes is shown in Table 1.

Table 1: UK Domestic Freight Transport by Mode (billion tonne-kms)

Year	Mode of Goods Transport				
	Road	**Rail**	**Water**	**Pipeline**	**All Modes**
1995	150	13	53	11	227
2000	159	18	67	11	256
2005	163	22	61	11	257
% Increase 1995-2005	+9%	+66%	+15%	-3%	+13%
% Increase 2000-2005	+3%	+22%	-10%	-5%	0%

Source: Transport Statistics Great Britain (2006)

Notes: basis of road statistics changed between 2004 and 2005, and of rail statistics between 1998 and 1999. The figures for Road include light goods vehicles (up to 3.5 tonnes gross vehicle weight – these are excluded from the detailed analysis in Section 3.1) but exclude the activity of foreign-registered vehicles, which is incorporated by use of traffic census data in later analyses.

UK domestic freight grew by 13% between 1995 and 2005. However, almost all of this increase was between 1995 and 2000, overall goods movement being relatively constant between 2000 and 2005. Whilst road is the dominant mode (63% share in 2005), rail's share grew from approximately 6% in 1995 to approximately 9% in 2005. More information on freight movement by road, rail and water is presented below in Sections 3.1 to 3.3.

3.1 Road Freight

Council Directive 96/53/EC sets the weight and dimension limits for goods vehicles used between Member States. Most of the limits currently prescribed by Directive 96/53 actually came into force in the United Kingdom on 1 January 1993, following the earlier Council Directive 85/3/EEC. However, the United Kingdom and Ireland had derogations from some of the regulations until 1 January 1999. At the end of the derogation, the maximum weight limit for vehicle combinations (articulated and drawbar) with at least 5 axles increased from 38 to 40 tonnes. At the same time, the United Kingdom increased the weight limit for 6-axle combinations to 41 tonnes. This was to encourage the use of more road-friendly vehicle combinations equipped with air suspension systems.

From 1 February 2001, the UK maximum weight limit for 6-axle combinations was further increased to 44 tonnes, although combinations used for combined road / rail operations had been permitted to operate at up to 44 tonnes on 6 axles since March 1994. Assessing the effect that these weight increases have actually had provides important contextual information for the assessment of the effects that LHVs would likely have, if they were to be permitted.

Data from the Department for Transport's Continuing Survey of Road Goods Transport (CSRGT) have been used to examine trends in goods vehicle use between 1995 and 2005 (note that changes were made in the sampling methodology between 2003 and 2004 which means that the data for 2004 and 2005 are not fully comparable with those for previous years).

Overall, goods moved by HGVs (>3.5 tonnes GVW) rose by 6% between 1995 and 2005 (from 144 to 153 billion tonne-km). Most of this increase occurred between 1995 and 1997 – between 1997 and 2005 it was fairly constant (between 149 and 153 billion tonne-km a year) despite the changes in weight limits. Traditionally the trend in the quantity of goods moved has closely followed the trend in Gross Domestic Product (GDP) on the basis that increased economic activity leads to a greater quantity of goods to be moved. Between 1992 and 1997 there was strong growth in both GDP and road freight. However, around 1997 the growth in the quantity of freight moved by road slowed considerably and in 1999 began to diverge substantially from the growth in GDP, as shown in Figure 1, below.

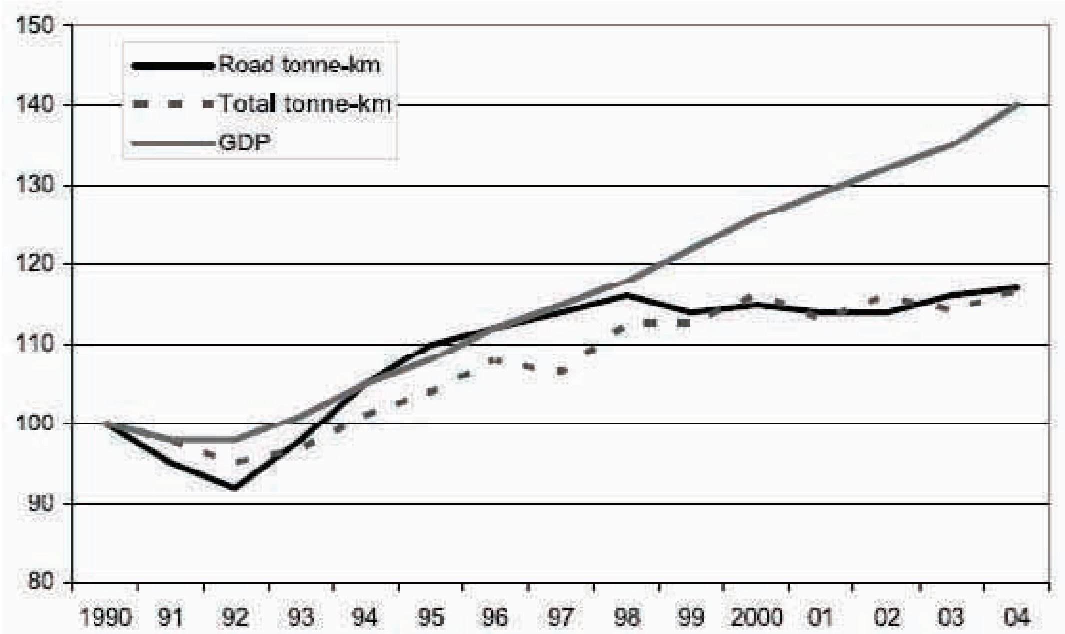

Figure 1. Indexed trends (1990 = 100) freight and GDP, 1990 to 2004

McKinnon (2007) concluded that approximately two-thirds of this decoupling can be attributed to three main factors; the increased penetration of the British haulage market by foreign operators, the decline in road freights share of the market, and real increases in haulage rates. A number of other factors, such as the relative growth of the service sector of the economy, the movement of manufacturing off-shore and the diminishing rate of centralisation of distribution networks, were also thought to have had a significant effect but this could not be quantified on the basis of available statistics.

Over the period between 1995 and 2005, the type of vehicles used to move goods has changed substantially. Goods movement using articulated vehicles rose by 9% and movement using rigid vehicles fell by 8% (see Figure 2). However, road freight statistics (DfT, 2007a) show that in terms of the number of vehicles registered the split between rigid and articulated vehicles has remained constant during the same time period, with rigid vehicles representing approximately 73% of all goods vehicles >3.5 tonnes GVW. The use of drawbar combinations (rigid goods vehicle with a trailer, which together offer more volume capacity than articulated vehicles) rose by 169%, but still only accounted for about 2% of goods moved in 2005 (the use of drawbars has been accelerating - over half of the increase in their use occurred between 2002 and 2005).

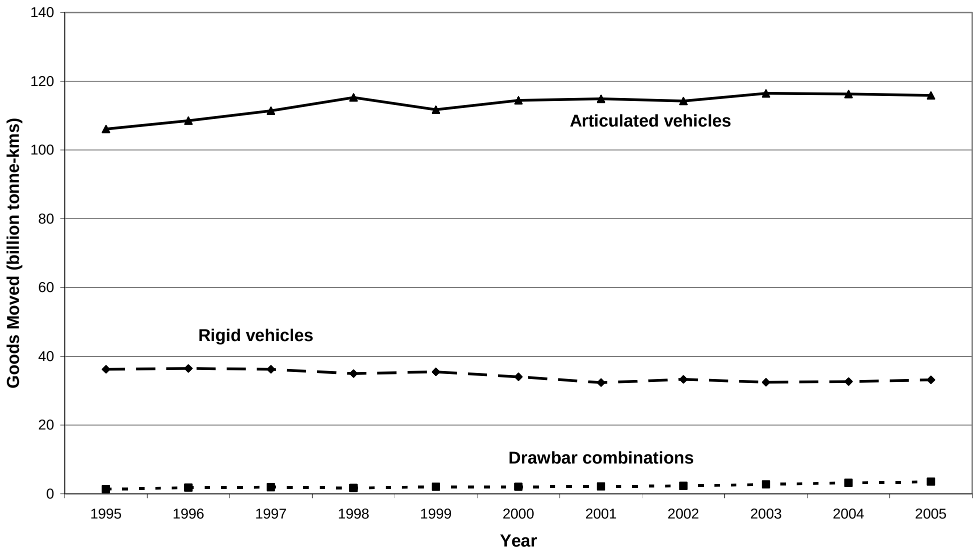

Figure 2: Trends in Goods Moved by Vehicle Type (1995-2005)

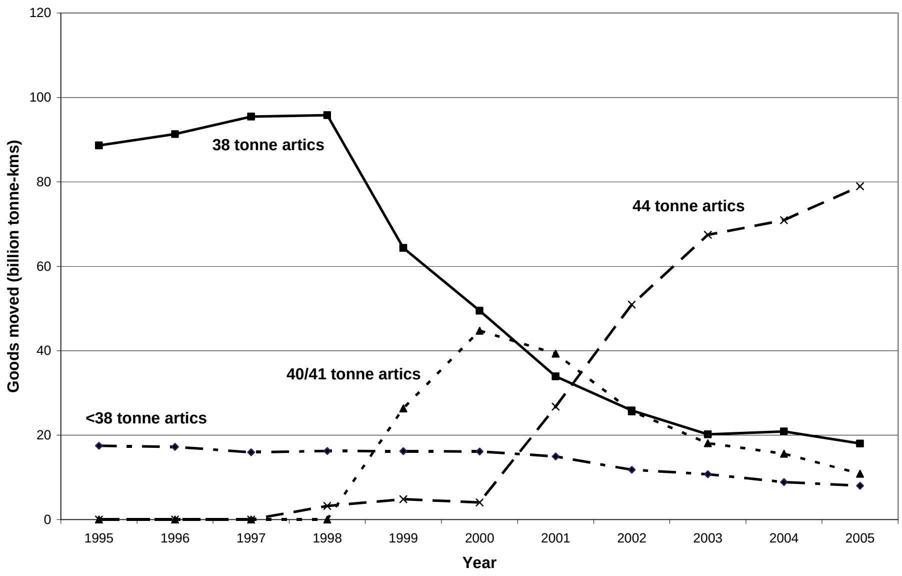

Figure 3: Trends in Goods Moved by Type of Articulated Vehicle (1995-2005)

During this period there were major changes within the articulated vehicle fleet (see Figure 3). Until 1998, 38 tonne GVW articulated vehicles were dominant (in 1998 they accounted for 86% of goods moved using articulated vehicles). From 1999, they were replaced by 40/41 tonne vehicles and, from 2001, by 44 tonne vehicles. By 2005, 38 tonne vehicles accounted for only 16% of goods moved using articulated vehicles whilst 44 tonne vehicles accounted for 68% (many vehicles were simply re-plated to operate at the higher weight limit.).

Table 2 shows the utilisation of five different types of vehicle. Overall, the heaviest articulated vehicles (over 41 tonnes GVW, almost all of which were at 44 tonnes) accounted for 52% of goods moved, had the longest average length of haul and had the highest average loads.

Table 2: Utilisation of Different Types of Vehicle (2005)

Vehicle Type	Goods Moved (billion tonne-kms)	Vehicle Travel (billion kms)	Average Length of Haul (kms)	Empty Running (%)	Average Load incl. empty running (tonnes)	Average Load when Laden (tonnes)
Rigid	33.1 (22%)	10.9 (49%)	42.3	28.6%	3.0	4.3
Drawbar	3.5 (2%)	0.5 (2%)	123.5	24.6%	7.3	9.6
Articulated:						
≤ 38t	26.1 (17%)	3.6 (16%)	119.6	23.8%	7.2	9.5
>38t ≤41t	10.9 (7%)	1.1 (5%)	120.3	27.5%	10.3	14.3
>41t	79.0 (52%)	6.2 (28%)	126.2	27.8%	12.7	17.6
All	**152.6 (100%)**	**22.2 (100%)**	**87.4**	**27.4%**	**6.9**	**9.5**

Source: CSRGT, DfT

Several of these parameters have varied notably over time. Figure 4 shows the trend in empty running and Figure 5 shows the variation in average load when laden.

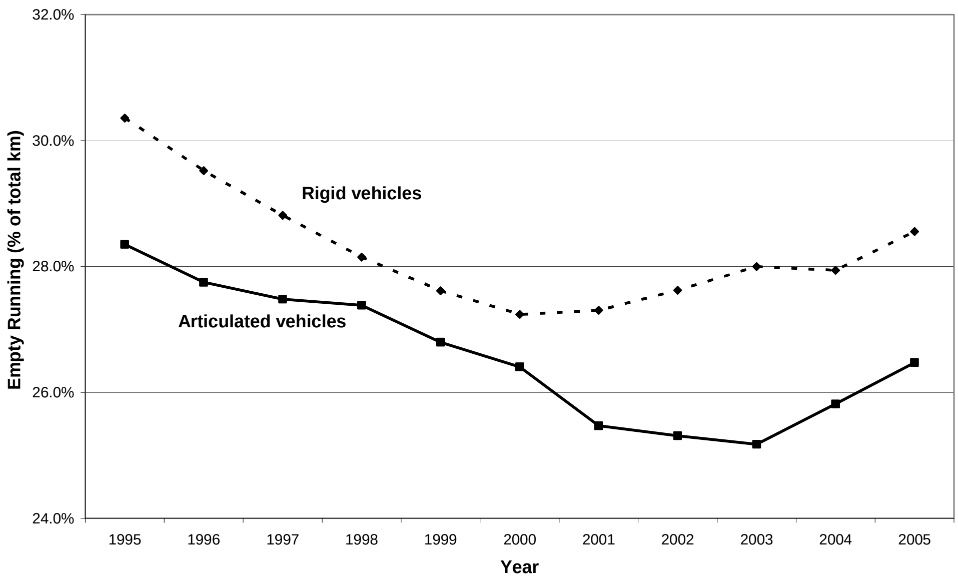

Figure 4. Empty running

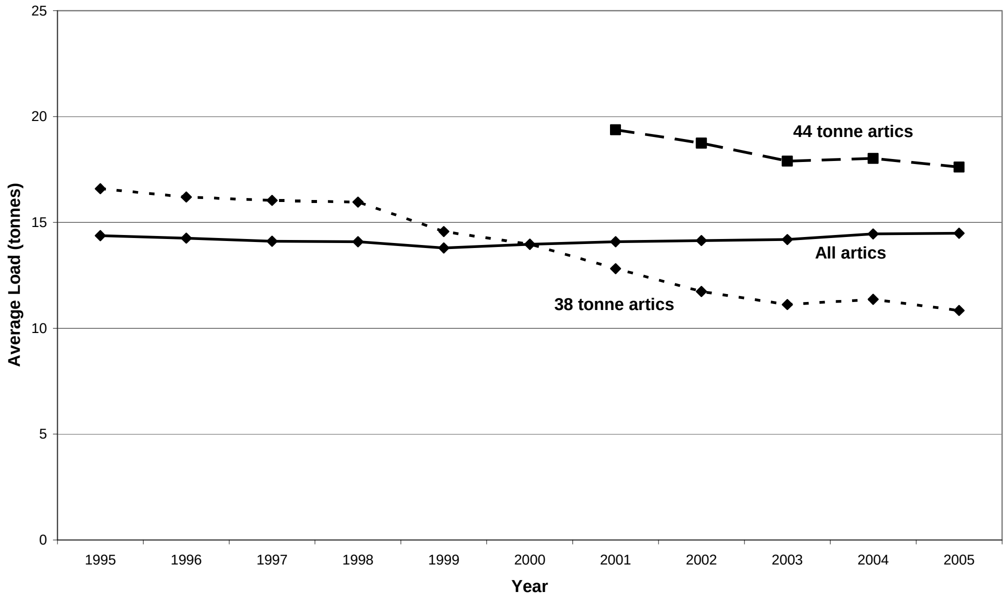

Figure 5. Average load when laden

It can be seen that over the time period assessed, vehicle utilisation has improved. Empty running has declined overall but has, since 2003, begun to increase. The reduction in average load when laden for 38 tonne vehicles reflects the fact that the heaviest loads carried by such vehicles will have migrated to the 40, 41 and 44 tonne vehicles when they became available and only those loads that were constrained by volume or were unconstrained were left. Similarly the decline in the average load on 44 tonne vehicles represents the fact that only the heaviest loads transferred immediately but, over time, more operators upgraded to the heavier vehicle and used it to carry lighter loads that did not require all of the additional capacity. The net effect of this move was, however, that the average load on all articulated vehicles increased slightly from 1999, reversing a previous slight decline. These effects, combined with the previously mentioned shift from smaller rigid vehicles to larger articulated vehicles can be seen in the trend for the average load carried by all goods vehicles (>3.5tonnes) as shown in Figure 6, below.

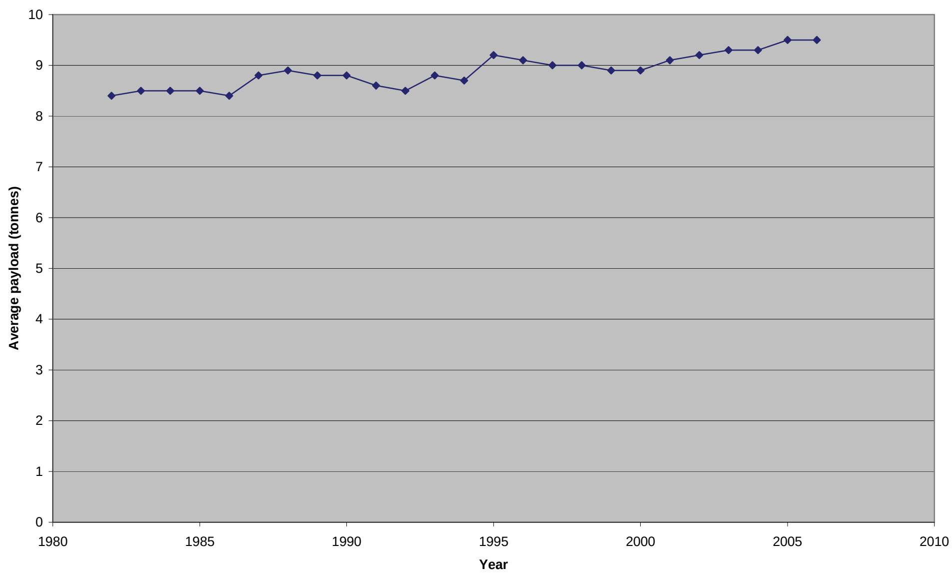

Figure 6. Average Payload on all HGVs (>3.5 tonnes GVW) Source: DfT, 2007b

It can be seen that in total, the average load on goods vehicles has increased significantly over time. This shows that the number of journeys required to move a certain quantity of goods is significantly less in 2006 than it was in 1982. DfT (2007b) also notes that this increase has occurred despite a fall in the amount of transport of the most dense and heavy bulk goods, as shown in Figure 7, below.

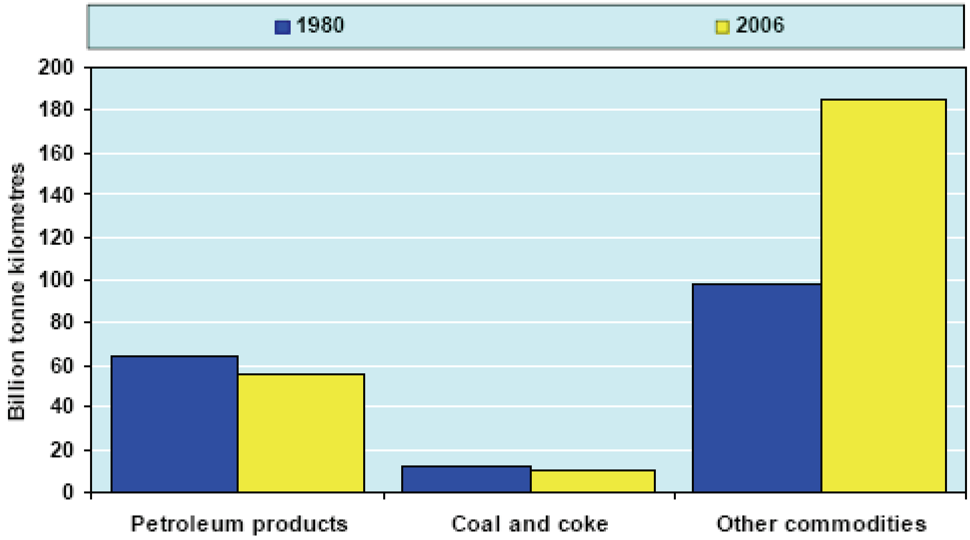

Figure 7. Change in commodities carried by goods vehicles (DfT, 2007b)

Table 3 shows the proportion of laden travel that was recorded as weight and/or volume limited. Overall, weight was shown as being a limiting factor for 17% of laden travel and volume was shown as being a limiting factor for 38%. For most vehicle types, volume was more limiting than weight (the exception was drawbar vehicles where the proportions were similar).

Table 3: Proportion of Laden Travel that is Weight/Volume Limited by Vehicle Type (2005)

Vehicle Type	Laden Travel (billion kms)	Proportion of Laden Travel				
		Limited by Weight (A)	Limited by Volume (B)	Limited by Both (C)	Weight a Factor (A + C)	Volume a Factor (B + C)
Rigid	7.8	3%	12%	8%	11%	20%
Drawbar	0.4	15%	13%	34%	49%	47%
Articulated:						
≤38t	2.8	1%	39%	8%	9%	46%
>38t	5.2	5%	38%	23%	28%	60%
All	**16.1**	**4%**	**25%**	**13%**	**17%**	**38%**

Source: CSRGT, DfT

The constraints that loads are subjected to have changed substantially over the time period assessed. For example, McKinnon (2005) shows that in 1999 weight was a constraint for approximately 55% of laden travel by 40 tonne articulated vehicles, compared with just 28% for articulated vehicles >38 tonnes in 2005 (Table 3, above). Conversely volume has increased as a constraint from approximately 22% of laden travel to 60%. Thus the influence of volume constraints has increased by more than the influence of weight constraints has decreased. However, overall the proportion of laden travel by artics >38 tonnes that is subject to a load constraint (i.e. full either by volume, weight or both) has fallen from 70% in 1999 to 66% in 2005. The changes are likely to have been predominantly because of the change in maximum permitted weights. However, it is also considered that a long term decline in the average density of goods moved is also likely to have been a significant influence. Such a decline is consistent with the changes in commodities carried, shown in Figure 7 above, and is also seen in other freight modes with the rail industry reporting a fall in the average weight of loaded maritime containers and an increase in the use of “hi-cube” containers.

McKinnon (2005) undertook an overall review of the effects of the changes to the maximum permitted weights in 2001. This analysis was based on identifying the number of tonne kms transported by 44 tonne vehicles that were fully loaded by weight and calculating the additional vehicle kms that would have been required to transport the same goods on a 41 tonne vehicle. This was an objective analysis based on CSRGT data. The results showed that after three years the annual savings were:

- 134 million vehicle kms, instead of the 100 million predicted before the move;
- £110 million in road haulage costs (at 2004 prices), instead of £60-80million (at 2000 prices), and;
- 136,000 tonnes of carbon dioxide, instead of 80,000-100,000 tonnes.

Analysis of the CSRGT statistics (McKinnon, 2005) also suggested that by the time the haulage industry have fully adjusted to the new weight limits, expected to be around 2006-7, the annual savings would be approximately 27% higher.

Similar analytical techniques were used to assess the effects in Sweden (Vierth *et al*, 2008) if they were to change from permitting vehicles of 25.25m length and 60 tonnes maximum weight to the EU standard of 16.5m and 40 tonnes. It was predicted that such a move could increase all heavy vehicle traffic (vehicle kms for all vehicles >3.5 tonnes GVW) by between 14% and 24% at an annual cost of up to SEK 7.5billion.

There is, however, a contrary view. Research by MTRU (2007, updated 2008) for *Freight on Rail* also reviewed the effects of previous changes to goods vehicles weights and dimensions but concluded that there was no direct evidence that larger or heavier goods vehicles led to reductions in HGV traffic, citing that:

- Average payload (including empty running) on articulated HGVs (>33 tonnes) has fallen between 1982 and 2005
- Articulated vehicle traffic has risen between 1986 and 2006
- The number of articulated vehicles has increased since 1983

Whilst the data presented in the MTRU report are factually correct, the interpretation of that data does not take into account many important factors, the most significant of which are discussed below:

- Almost all of the reduction in average payload for artics > 33 tonnes occurred between 1982 and 1993. Vehicles in excess of 33 tonnes were not permitted until 1983 and a comprehensive analysis of the effects on average load must also consider the vehicles of less than 33 tonnes that were replaced. Such an assessment, based on more recent data, was shown in Figure 5, where the average load on 44 tonne vehicles fell quickly from an initial high point but when all articulated vehicles were considered the average load gradually increased. It was also shown that the average payload considering all HGVs has also increased, as shown in Figure 6.
- The possibility that volume constraints could be a factor influencing average payload weight were largely rejected without accounting for the following:
    - The CSRGT data showing a large increase in the proportion of volume constrained loads
    - The statistics in Figure 2 showing that the tonne-kms carried by drawbars has increased by 169% (half of it between 2002 and 2005)

- o The relatively recent introduction of double decks, which now carry approximately 3% of all goods moved by articulated vehicles
- o The falls in average container weight and increased use of “Hi-Cube” containers reported by the rail industry.
- o The changes in the UK Economy since 1982 (i.e. a shift from heavy industry and domestic manufacturing to growth in consumer goods and the service sector), as indicated, at least to some extent, by the change in commodities carried shown in Figure 7.

- The move from 41 tonnes to 44 tonnes had no environmental disbenefit because the vehicles used did not change; the increased capacity arose from a simple administrative exercise in re-plating. This also helps to explain why hauliers might have chosen to speculatively upgrade to the higher weight limit – there was no significant cost assosciated with doing so. However, this would unlikely be the case if permitting LHVs, which would be physically different and more costly.
- The UK economy, as measured by GDP, has grown substantially since 1999. Increased economic activity tends to increase goods vehicle traffic.
- Growth in HGV traffic has slowed considerably since 1999, the time of the first of the recent changes in permitted weight, reducing traffic by more than 2 billion vehicle kms in 2005 compared to what would have been expected in 1999 based on a continuation of the historical trend (see Figure 8). McKinnon (2005) suggested that the move from 41 to 44 tonnes gave a relative reduction in vehicle traffic of 134 million vehicle kms, less than 7% of the difference between actual traffic growth and the continuation of the historical trend. There are many other factors that will also have contributed to the change, including a growth in rail market share from 6% in 1995 to 9% in 2005. These other factors were examined by McKinnon (2007) and summarised earlier in this section (see Figure 1 and the accompanying text).

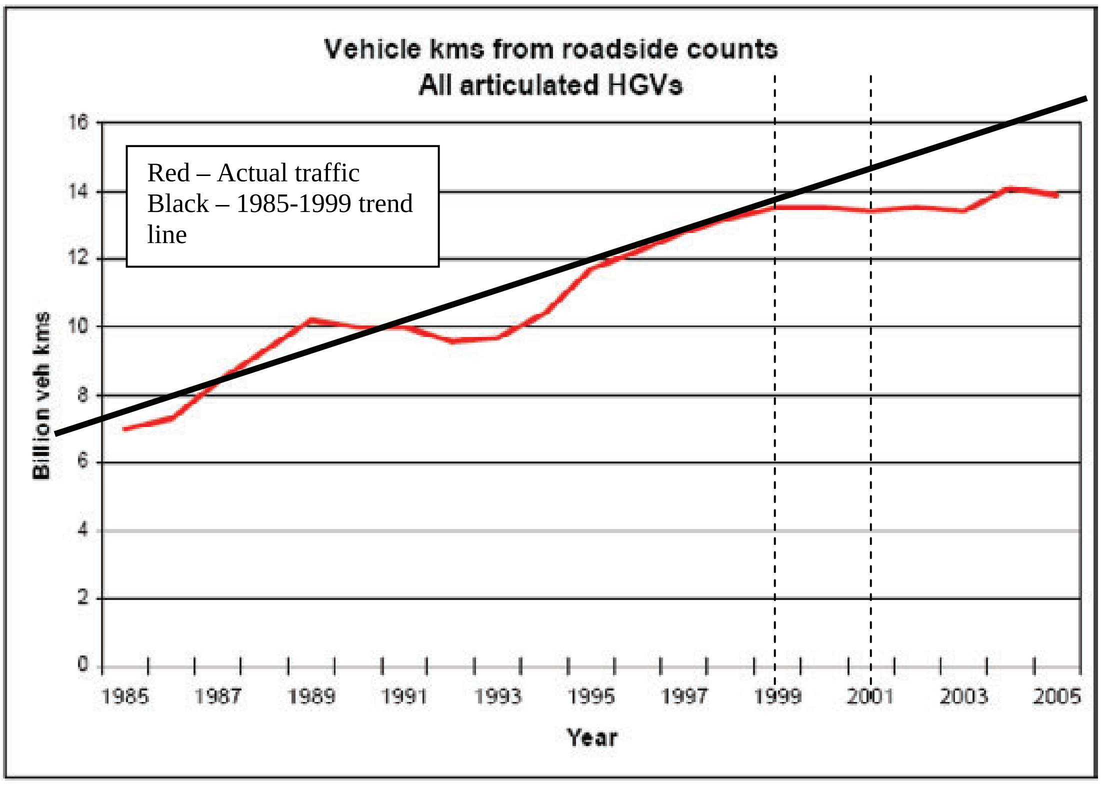

Figure 8. Articulated vehicle traffic (Transport Statistics Great Britain, 2006)

It can be seen that rigorous analysis of the effects of previous weight changes is extremely complex and it can be very difficult to isolate the effects, especially considering the many other changes to freight and logistics practice and the wider economy. However, based on the research and freight data reviewed, it is considered that, although the exact effects are difficult to enumerate precisely, the previous increase in HGV capacity has had a beneficial effect in terms of limiting road freight traffic growth or, in other words, it has resulted in a relative reduction in road freight traffic.

If permitted, LHVs would be of greatest value to goods vehicle operations which are currently weight or volume constrained. This project has therefore focussed on weight-constrained 44 tonne vehicles and volume-constrained articulated vehicles. The analysis has also examined the impacts of drawbar combinations and of double-deck semi-trailers.

Drawbar Combinations are longer than articulated vehicles (maximum length 18.75m compared with 16.50m for articulated vehicles) and have a longer loading length (maximum combined deck length behind the cab of 15.65m, compared with about 13.60m for articulated vehicles). However, their higher unladen weight and two separate loading areas (rigid and trailer) have tended to limit their use - in 2005 about half of all goods moved using drawbars was “Other building materials” (typically bricks and building blocks) and “Machinery, etc” (mainly cars).

Double-deck semi-trailers provide operators with increased deck area and are increasingly used to move low-density goods. In 2005 they moved about 3.5 billion tonne-kms of goods (similar to the use of drawbars and about 3% of all goods moved by articulated vehicles). Their average load when laden was 12.4 tonnes (14.5 tonnes for all articulated vehicles). Less than 1% of their travel was limited by weight compared with 38% limited by volume and 12% limited by weight and volume. The proportion of double-deck travel that was limited by volume was similar to that for all articulated vehicles >38 tonnes, despite the available deck area increasing by a factor of up to 2. This suggests that only the lowest density goods have transferred to double decked vehicles.

3.2 Rail Freight

The impact that LHVs could have on rail freight is a significant consideration of this study, and for this reason it was important to examine relevant industry statistics as part of this review. Table 4 shows current rail freight movement by commodity and estimates of how the quantity of each rail freight commodity might change in the future. In 2005, the main commodities were coal (largely for electricity generation), maritime containers (major flows were of deep-sea containers from Felixstowe and Southampton) and other minerals (such as aggregates from quarries in the South West, East Midlands and Peak District). The rail industry forecasts a 20% increase in rail freight between 2005 and 2014, including significant growth in those commodities, such as maritime containers and domestic intermodal / wagonload, where there is most direct competition with road freight.

Table 4: Forecast Rail Freight Movement by Commodity

	Actual and Estimated Goods moved (million tonne-kms/% of total) (Top down approach)						Percentage change	
Commodity	**2005**		**2014**		**2030**		**2005-2014**	**2014-2030**
Coal	7,753	34.8%	5,603	21.0%	4,115	13.5%	-28%	-27%
Maritime Containers	4,782	21.4%	6,797	25.4%	11,342	37.1%	42%	67%
Other Minerals	3,478	15.6%	4,466	16.7%	4,260	14.0%	28%	-5%
Metals	2,037	9.1%	2,068	7.7%	1,896	6.2%	2%	-8%
Own Haul (Network Rail)	1,482	6.6%	1,463	5.5%	1,422	4.7%	-1%	-3%
Petroleum & Chemicals	1,388	6.2%	1,456	5.4%	1,456	4.8%	5%	0%
Channel Tunnel	543	2.4%	2,095	7.8%	3,091	10.1%	286%	48%
Ore	256	1.1%	242	0.9%	213	0.7%	-5%	-12%
Domestic Intermodal / Wagonload	251	1.1%	2,124	7.9%	2,347	7.7%	746%	10%
Waste	225	1.0%	229	0.9%	203	0.7%	2%	-11%
Automotive	109	0.5%	175	0.7%	186	0.6%	61%	6%
Total	**22,304**	**100.0%**	**26,718**	**100.0%**	**30,531**	**100.0%**	**20%**	**14%**

Source: Network Rail (2007)

The source of these data is the Freight Route Utilisation Strategy (FRUS) published by Network rail. The study that led to this strategy document used two separate approaches to predict future growth. These were called a "top-down" approach, which was based on the results of the GB Freight Model produced and used by MDS Transmodal, and the "bottom-up" approach, which was based on the market intelligence and forecasting of the rail freight operating companies. The figures shown in Table 4, above, are based on actual data for 2005 and the top-down approach (GB Freight Model) for 2014 and 2030. It can be seen that this approach predicts strong overall growth to 2014 with continued, slightly slower, growth through to 2030. Network Rail (2007) does not provide directly comparable data for the "bottom up" approach based on the forecasts of the train operating companies but provides the data shown below (Table 5) comparing growth in terms of tonnes lifted (instead of tonne-kms in Table 4 above).

Table 5. Top down and bottom up forecasts of rail freight growth by commodity (goods lifted)

	Estimated goods lifted 2014/15 (million tonnes/% of total)				Percentage change over 2004/5 baseline		Difference between approaches (multiplication factor lower to upper)
Commodity	**Bottom up approach**		**Top down approach**		**Lower**	**Upper**	
Coal	50.5	38.0%	43.1	32.1%	-8%	9%	-1.1
Maritime Containers	20.3	15.3%	18.8	14.0%	42%	83%	2.0
Construction	23.6	17.8%	31.5	23.5%	20%	45%	2.3
Metals	14.6	11.0%	11.8	8.8%	12%	39%	3.3
Petroleum & Chemicals	7.1	5.3%	7.0	5.2%	4%	5%	1.3
Channel Tunnel	6.0	4.5%	6.5	4.8%	200%	266%	1.3
Ore	5.9	4.4%	6.0	4.5%	-5%	-3%	0.6
Domestic Intermodal / Wagonload	2.5	1.9%	6.5	4.8%	177%	838%	4.7
Waste	1.8	1.4%	2.3	1.7%	-9%	14%	-1.6
Automotive	0.5	0.4%	0.6	0.4%	25%	76%	3.0
Total	**133**	**100.0%**	**134**	**100.0%**			

For the later analysis of costs and benefits it was considered useful to be able to express all of the different estimates in terms of tonne-kms. This data was not directly available, so an estimate of what is implied by the available data has been made by calculating the average length of haul in 2014, based on the tonne-km and tonnes lifted data from the top down approach. It was then assumed that the same average length of haul would apply to the bottom up prediction, allowing a tonne-kms estimate to be derived from the published tonnes lifted value. The results of this are shown in Table 6, below.

Table 6. Comparison of top down and bottom up estimates of goods moved (million tonne-kms)

Commodity	Av length of haul (2014) based on top down figures (km)	Million tonne kms predicted for 2014 bottom up approach based on top down average length of haul	Percentage change in tonne kms 2005 to predicted 2014 (bottom up)	Percentage change in tonne kms 2005 to predicted 2014 (Top down)	Difference between approaches (multiplication bottom up to top down)
Coal	130	6,565	-15%	-28%	1.8
Maritime Containers	362	7,339	53%	42%	0.8
Metals	175	2,559	26%	2%	0.1
Petroleum & Chemicals	208	1,477	6%	5%	0.8
Channel Tunnel	322	1,934	256%	286%	1.1
Ore	40	238	-7%	-5%	0.8
Domestic Intermodal / Wagonload	327	817	225%	746%	3.3
Waste	100	179	-20%	2%	-0.1
Automotive	292	146	34%	61%	1.8

Note that the commodities listed by Network Rail (2007) in the different tables do not match exactly. Table 6, therefore, only shows commodities where the description was consistent in both data sets.

The data above shows that coal and maritime containers are currently the most important rail freight markets by quite a large margin. Coal traffic is expected to decline substantially (-15% to -28%) while maritime container traffic is expected to grow substantially (+42% to +53%), which represents the largest expected growth in rail freight tonne kms. Substantial proportional growth is expected in channel tunnel traffic. The largest proportional growth is expected to be in domestic intermodal traffic, which could potentially grow rapidly to as much as 817 million to 2,124 million tonne kms by 2014, depending on the forecasting methods used. The wide range predicted is likely due, at least in part, to a relatively low volume of baseline (2004/5) traffic.

3.3 Water Freight

The overall figure for goods moved by water (60.9 billion tonne-kms in 2005) included traffic which did not directly compete with road or rail freight (see Table 7). Excluding foreign trade on inland waters and one-port traffic reduced the total by 35% to 39.5 billion tonne-kms. Of this, 39.4 billion tonne-kms was coastwise trade and 0.17 billion tonne-kms non-seagoing (mainly in the Thames and Humber areas).

Table 7: UK Waterborne Freight Movement in 2005

Type of Traffic	Goods moved (billion tonne-kms)	Notes
Inland waters non-seagoing	0.17 (0.3%)	Includes tidal rivers and estuaries
Internal waters portion of foreign	1.05 (1.7%)	Foreign traffic in estuaries, etc
Coastwise between UK ports	39.35 (64.6%)	Traffic between ports in GB, Northern Ireland, Channel Islands & Isle of Man
One-port traffic of UK ports	20.30 (33.3%)	Traffic to / from offshore oil and gas installations and dredged sand and gravel
Total	**60.87 (100.0%)**	

Source: Waterborne Freight in the United Kingdom 2005

Of the coastwise traffic, 4.9 billion tonne-kms was with Northern Ireland, the Channel Islands and the Isle of Man, leaving 34.4 billion tonne-kms between ports in Great Britain. The average length of haul for this traffic was much longer (744 km) than that for either rail (213 km) or road (87 km) (see Table 8). This is consistent with the primary use of coastwise shipping for long-distance bulk transport. Of the coastwise traffic between GB ports, 28.6 billion tonne-kms was bulk liquids, leaving 5.8 billion tonne-kms of other commodities.

Table 8: Average Lengths of Haul for Different Modes (2005)

Mode	Goods lifted (million tonnes)	Goods moved (billion tonne-kms)	Average length of haul (km)
Water (coastwise between GB ports)	46	34	744
Rail	104	22	213
Road (HGVs>3.5tonnes)	1,746	153	87
Total	**1,896**	**209**	**110**

3.4 Forecast Growth in UK and European Freight

One of the arguments used by supporters of LHVs is the need to offset forecast growth in European road freight. The European Commission has forecast growth in freight transport activity by mode for each Member State (see Table 9).

Table 9: Forecast Growth in Freight Movement (2005 - 2020)

	Forecast growth in Freight Movement (tonne-kms) between 2005 and 2020 by Mode		
	Road	**Rail**	**Water**
United Kingdom	+14%	+18%	+2%
EU15	+33%	+9%	+13%
EU27	+42%	+9%	+15%

Source: European Energy and Transport Trends to 2030 – update 2005

This table shows that UK road freight is forecast to grow at only one-third of the rate for the whole of the EU whilst UK rail freight is forecast to grow at twice the rate for the whole of the EU.

The forecast growth in freight movement is very important for the subsequent analysis carried out for this report because it forms the basis of the business as usual case against which the potential effects of various types of LHVs are compared. The analysis of different predictions for road freight transport is shown in Figure 9, below.

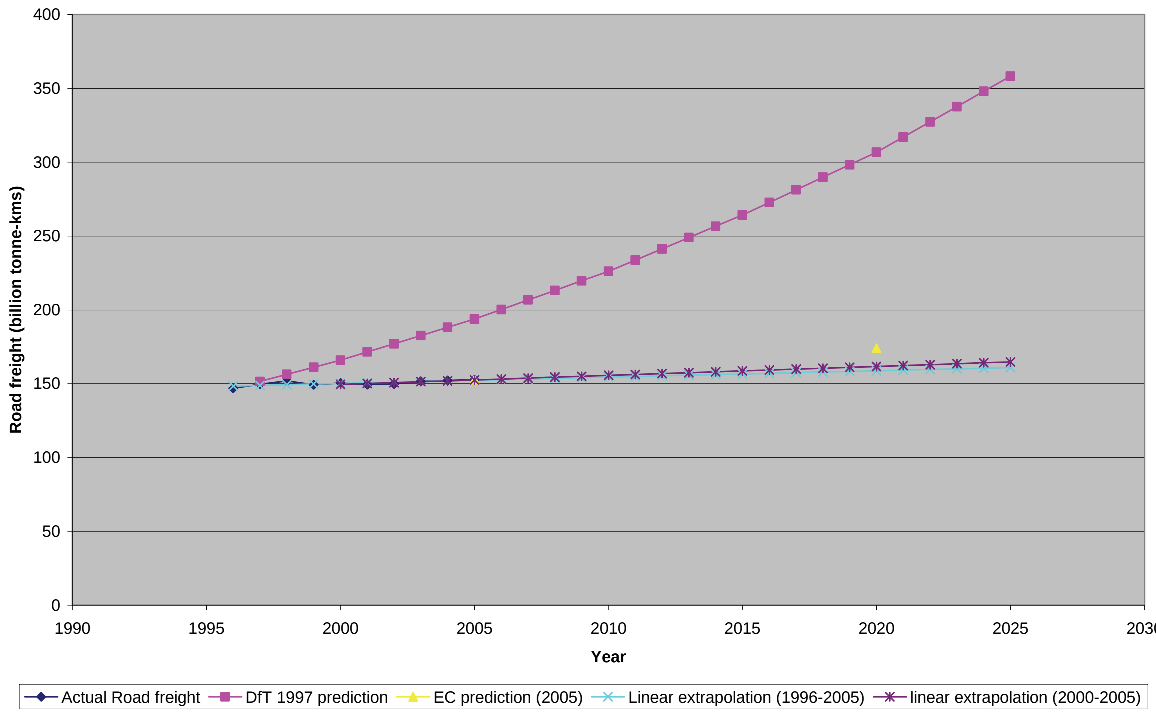

Figure 9. Different predictions of growth in road freight

It can be seen that the last official UK prediction (DfT, 1997) has since been shown to greatly over-estimate the growth actually seen. Linear extrapolations of the actual data predict a much more modest growth, slightly lower than predicted by the EC. The linear extrapolation is based on CSRGT data and thus excludes the activity of non-UK registered vehicles. Equivalent predictions for rail freight are shown in Figure 10 below.

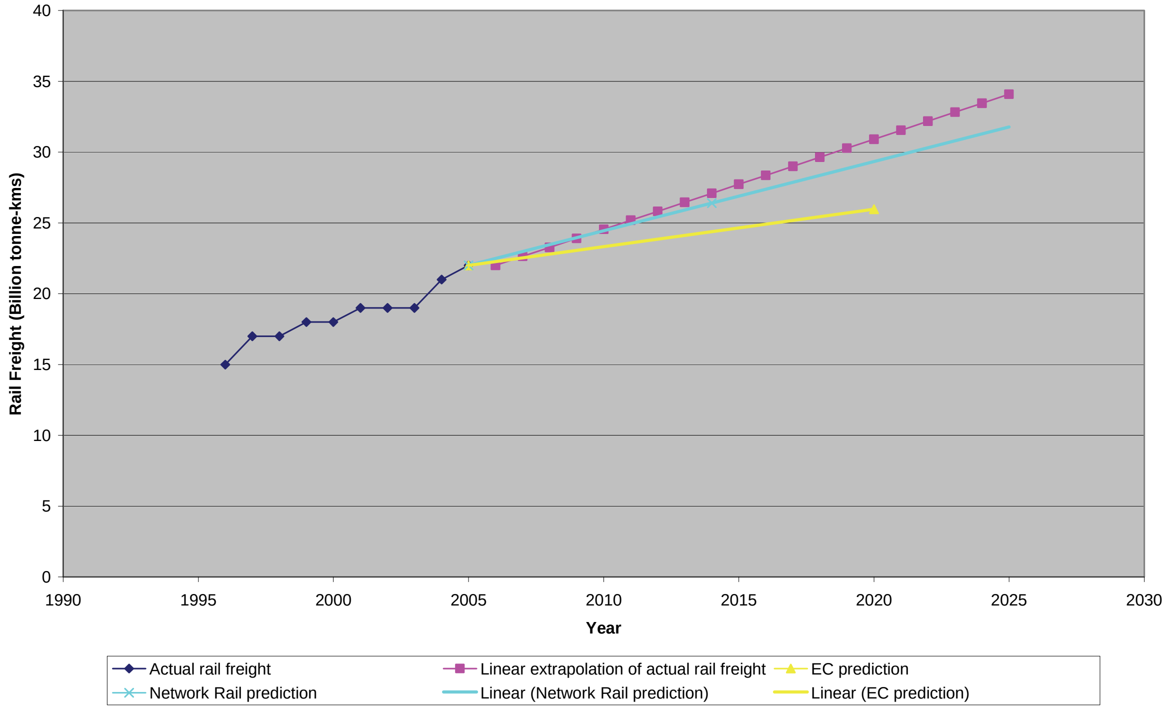

Figure 10. Different predictions of growth in rail freight

Again, it can be seen that predictions vary. The EC and, to a lesser extent, Network Rail predict less growth in future than was actually experienced in the preceding ten year period.

For the purpose of the later analysis of costs and benefits, the predicted growth in road and rail freight was based on the linear extrapolation of the actual data. While providing a consistent set of assumptions for the comparative analysis, this may mean that the analysis is cautious because this represents the lowest growth in road freight and the highest growth in rail freight. If the ECs prediction was later proved to be correct then the subsequent analysis in this report would slightly under-estimate the potential benefits of consolidating existing road freight loads on LHVs and substantially over-estimate the effects of modal shift from rail.

4 LHV Scenarios

The analysis of potential impacts of LHVs was undertaken in two stages. Firstly, potential LHV designs were examined and 6 LHV types were identified for detailed analysis on the basis of specific designs of vehicle. This initial selection process is described in detail in Appendix A. Secondly, 8 scenarios representing different potential regulatory approaches were identified, for illustrative purposes, to consider the affects of LHVs in a way less specific to vehicle design. The concept of "payload neutral" options was included in these scenarios and was defined as a situation where the gross weight limit was increased by an amount equivalent to the increase in unladen weight of the vehicle combination, such that the payload carried was the same as for a standard 44 tonne HGV.

4.1 Vehicle types

The following definitions are used in this report:

- Rigid vehicle – motor vehicle constructed to carry goods;
- Tractor – motor vehicle constructed to form an articulated vehicle when coupled to a semi-trailer;

- Semi-trailer – a trailer constructed to form part of an articulated vehicle and designed to be connected, via a fifth wheel coupling, to a tractor unit, a rigid vehicle via a converter dolly or another trailer so that a substantial part of it's weight rests on the tractor unit / dolly / trailer and part rests on its own wheels;
- Articulated vehicle – tractor coupled to a semi-trailer;
- Trailer – a trailer constructed such that all, or almost all, of its weight rests solely on its own wheels (i.e. not a semi-trailer) and towed via a drawbar connection. Trailers can either be full trailers (i.e. freestanding with a steered axle at the front and fixed axle(s) at the rear) or a centre-axle(s) trailer (with a fixed link to the towing vehicle at the front and a group of axles in the centre of the trailer);
- Drawbar combination – a rigid vehicle towing a trailer;
- Interlink semi-trailer – a semi-trailer designed so that a second semi-trailer can be connected to it via a fifth wheel coupling at the rear;
- Multi-articulated vehicle – a vehicle combination that has more than one articulation point. This will typically be a vehicle with more than one trailer or a combination where a semi-trailer is towed by a dolly. However, it can also be a single trailer combination if it is a "full" trailer with a steered front axle coupled via an "A" frame.
- Multi-trailer vehicle – a vehicle combination that has more than one trailer. Within this definition a single trailer towed by a separate, detachable, converter dolly would be considered to be a multi-trailer vehicle.
- Dolly – a dolly temporarily attached to the front of a semi-trailer to convert it into a full trailer. These can be A-frame dollies, where the front of the dolly is connected to the towing vehicle with a single hitch, or C-frame dollies where the front is connected rigidly via two drawbars (this eliminates one of the points of articulation and at least one of the axles on the dolly must be steered to reduce tyre wear). It should be noted that in some regulations a semi-trailer towed by a dolly is considered to be one trailer but in other regulations a dolly may be considered as a separate trailer in its own right.

A wide range of different LHVs have either been proposed in the UK, are permitted or are the subject of trials within Europe, or are used in other countries (such as the USA, Australia and Canada).

To ensure that the analysis was manageable, a sub-set of 2 baseline vehicles and 6 LHV types was selected for detailed analysis (see Table 10). Vehicle types were selected that initially appeared to have least potential for adverse safety effects, fitted best with the existing UK vehicle fleet, and represented the major variables such as the type of vehicles in the combination, the type of dolly used and whether the combination was likely to meet current manoeuvrability criteria. The elimination from the detailed analysis of any particular type of LHV at this stage in the research should not necessarily be taken as an indication that it would not be suitable for use on UK roads.

Table 10: Vehicle types selected for detailed analysis

Vehicle Type	Description	Maximum Length (metres)	Maximum Weight (tonnes)
1	Base case – single-deck articulated vehicle	16.50	44
2	Base case - double-deck articulated vehicle	16.50	44
3	Articulated vehicle with longer (up to 16m) steered semi-trailer	18.75	44
4	Tractive-unit, steered interlink semi-trailer, semi-trailer (B-double)	25.25	44
5	Rigid vehicle, converter dolly (A), semi-trailer	25.25	44
6	Tractive-unit, steered interlink semi-trailer, semi-trailer (B-double)	25.25	60
7	Rigid vehicle, converter dolly (A), semi-trailer	25.25	60
8	Tractive-unit, semi-trailer, converter dolly (C), semi-trailer	34.00	82

Note: all the LHVs were assumed to be single-deck, and all axle and bogie weights were assumed to comply with existing regulations.

The selected vehicles include the three main types of LHV being promoted in the UK: the longer semi-trailer (Type 3); the “B double” (Types 4 and 6); and the use of two standard length semi-trailers (Type 8). In Type 8, a “C” converter dolly was selected because it was expected to improve the dynamic stability and the A-dolly was to be assessed in types 5 and 7. The selected vehicles also included one of the main types of LHV used in Scandinavia (rigid vehicle, converter dolly, semi-trailer - types 5 and 7). Drawbar combinations involving two trailers and articulated vehicles towing a drawbar trailer were excluded because the literature indicated that the dynamic stability of these combinations would be lower than that of the other vehicles selected and the initial freight analysis showed that use of drawbar trailers is relatively low in the UK. It should be noted that the extent to which the UK could place limits on the type of vehicles that could be operated has been examined as part of work looking at regulatory issues, as described in detail in Appendix E and summarised in section 5.8.

4.2 Scenarios

For illustrative purposes, the following 8 scenarios, representing different potential regulatory approaches were defined and are described in Table 11, below.

Table 11: LHV Scenarios

Scenario	Maximum Length (metres)	Maximum Weight (tonnes)	Axles	Scenario Characteristic and Vehicle Type
A	16.50	44.0	6	Business as usual (vehicle types 1 and 2)
B	18.75	44.0	6	Longer semi-trailer (Volume only, vehicle type 3)
C	18.75	45.8	6	Longer semi-trailer (as B but payload neutral)
D	25.25	44.0	8	Volume only increase (Vehicle type 4 & 5)
E	25.25	49.5	8	As D but Payload neutral
F	25.25	60.0	8	Volume and weight (Vehicles type 6 & 7)
G	34.00	63.2	11	Volume and weight (payload equivalent to 25.25m combination at 60 tonnes GVW)
H	34.00	82.0	11	Volume and weight (Vehicle type 8)

It should be noted that 'Payload neutral' was defined as a situation where gross vehicle weight limits would be increased, but only to offset the loss in payload as a result of extra unladen 'tare' weight (i.e. the weight of the additional trailer components that would not otherwise be required). In effect, this would allow LHVs to carry the same net payload as that currently allowed for existing vehicle combinations. No direct vehicle cases were analysed in payload neutral conditions so these scenarios were extrapolated or interpolated from the results of other vehicle cases. While interpolation would be expected to be reasonably reliable for the 25.25m c.50 tonne vehicle, because 44 tonne and 60 tonne versions were directly evaluated to provide boundary conditions, the 18.75m and 34m payload neutral scenarios would be expected to be less reliable given the absence of a second boundary case.

5 Impacts of LHVs

During the project, the expected impacts of LHVs were compared with those for the main baseline vehicle, a 44 tonne 6-axle articulated vehicle.

5.1 Safety

The analysis of the effects of LHVs on safety is described in detail in Appendix B and is summarised below. A number of safety issues have been investigated. These include:

- Manoeuvrability, including the swept path of the vehicle
- Field of view
- Braking
- Stability
- Collision severity

A review of past research and performance based standards was carried out and, where appropriate, the findings were extended using theoretical and analytical methods to ensure that they were applicable to the vehicle types selected for detailed analysis.

The safety of heavy vehicles has been improved considerably in the past with the development of new safety features and technologies. In recent years sophisticated electronic control systems have been developed that appear likely to deliver substantial additional casualty saving benefits. While many of these are not yet standard on all vehicles, this is quite likely to change in coming years, and a number of systems such as stability control and other advanced braking systems may well become mandatory on all new vehicles. For this reason, it was considered that these could not be ignored as part of the safety assessment. It is important to note however, that the question of whether such features could be required on all vehicle modules used as part of an LHV at the present time (and in particular LHV combinations operated by companies based outside of the UK), has been considered as part of the assessment of legal issues (section 5.8). A similar situation exists for safety measures that are mandatory on new vehicles but where older vehicles without the measure could potentially be used in an LHV combination. It is likely that specific provisions in the regulations would be required to prevent this problem.

5.1.1 Manoeuvrability

Additional length will tend to reduce the manoeuvrability of a vehicle, cause inconvenience to other road users and potentially present an increased risk of accidents and injuries. The factors to take into consideration include:

- Low speed off-tracking. When a vehicle combination turns at low speed, the trailer(s) may take a path several metres inside the path of the tractive-unit, increasing the amount of road space required when turning. The trailer(s) could encroach into an adjacent lane and collide with another vehicle or object, or could endanger a pedestrian or cyclist. Low speed off-tracking is related to the trailer wheelbase (e.g. the distance from the fifth-wheel coupling / kingpin to the centre of the rear axle) and increases significantly as the wheelbase increases. Increasing the number of articulation points and the use of steered axles decreases low speed off-tracking. Swept path is a measure of low speed off-tracking. EU Regulation 96/53/EC specifies that vehicle combinations must be able to turn within a swept circle having an outer radius of 12.5m and an inner radius of 5.3m (i.e. a swept path of 7.2m). Sweden operate LHVs up to 25.25 metres long and permit outer and inner radii of 12.5m and 2.0m respectively when the vehicle is driven in a 360-degree turn (i.e. a swept path of 10.5m).
- Out-swing or tail swing - the lateral distance that a point on a vehicle moves outwards, perpendicular to its initial orientation, when the vehicle commences a small-radius turn at low speed. Out-swing is influenced by the amount of rear overhang on the vehicle and the wheelbase. The position of trailer couplings has a lesser effect on out-swing, whilst the use of steerable trailer axles reduces the effective wheelbase producing higher values of out-swing.

Existing test data were used to evaluate the manoeuvrability of the 8 vehicle types specified in Table 10. Where such test data was not available computer simulation (using the AutoTrack swept path analysis package) was used to predict the likely behaviour. In addition to this, some assessments were made of the longer semi-trailer and B-double without steered axles in order to understand the magnitude of the effect of requiring such technology. The results are shown in Table 12.

Table 12: Off-tracking and out-swing performance

Vehicle types	Descriptions	Swept path width (limit: ≤ 7.2m)	Out-swing performance (limit: ≤ 0.8m)
1 and 2	Tractor / semi-trailer (6 axles) – max length 16.5m	✓ (6.7 – 6.8m)	✓ ≤ 0.3m
3	Tractor / 16m semi trailer (6 axles) – max length 18.75m (steered bogies near rear)	✓ (4.8 – 5.9m)	✓ (< 0.1m)
N/A	Tractor / 16m semi trailer (6 axles) – max length 18.75m (fixed bogie as far forward as possible)	✓ (7.2m)	x (0.8 – 1.2m)
4 and 6	Tractor / interlink semi trailer (steered bogie) / semi trailer (8 axles) – max length 25.25m	✓ (5.2 – 6.9m)	✓
N/A	Tractor / interlink semi trailer (fixed bogie) / semi trailer (8 axles) – max length 25.25m	x (> 7.4m)	✓ (< 0.1m)
5 and 7	Rigid truck / converter dolly (A-train) / semi-trailer (8 axles) – max length 25.25m	x (≤ 10.5m)	✓ (< 0.1m)
8	Tractor / semi trailer / converter dolly (C-train) / semi trailer (11 axles) – max length 34m	x (> 9.2m)	✓ (≤ 0.1m)

It can be seen that, as expected, the existing length vehicles (1 and 2) comply with the EU 7.2m wide swept path. The longer semi-trailer (type 3) and B-double (type 4 and 6) also comply when equipped with steered axles (as specified for the purposes of later analysis of costs and benefits) but would not comply if they were not fitted with trailer steering systems. The other LHV combinations do not comply with the 7.2m wide swept path but would comply with a 10.5m wide path (which has been permitted in other countries such as Sweden). The effect of steering axles was not evaluated for these other combinations. Such axles may have the potential to enable these other combinations to comply with the requirements.

Most vehicles would not have a problem complying with the 800mm out-swing limit specified in EU Directive 97/27/EC. However, the analysis showed that the longer semi-trailer (vehicle case 3) could only achieve both the swept path requirements and an out-swing limit of 800mm when it was equipped with steered axles. Research by Consano and Werner (2006) suggests that articulated vehicle combinations of 17.8m are the longest that can meet both swept path and outswing requirements without steered axles.

The characteristics shown for the main vehicle types assessed were used in all cases evaluated in the later analysis of costs and benefits.

5.1.2 Field of view

The field of view from a vehicle is defined as the areas that a driver can either see directly, through glazed areas, and indirectly, via mirrors or other field of view aids. Providing an adequate field of view for existing heavy vehicles can be difficult and a number of blind spots do remain. These blind spots can contribute to accidents, frequently with vulnerable road users but also with other cars, particularly when carrying out low speed manoeuvres or changing lanes. Directive 2003/97 introduced expanded requirements for the field of view which included new mirrors to enable the blind spot immediately in front of the vehicle to be seen as well as an expanded view from existing mirrors. These requirements are compulsory for new vehicles and there is a requirement to retro-fit close proximity mirrors that were previously optional. However, many older vehicles that do not comply with these requirements will still be in existence.

LHVs are likely to have the same or similar cabs as existing HGVs and therefore direct vision is expected to remain largely unaltered. However, the amount of the vehicle combination which can be seen through indirect vision (using mirrors or alternative optical devices) will depend on the geometry of the combination. CAD models were used to analyse these indirect fields of view. It was concluded that:

- While travelling straight ahead or changing lane LHVs' fields of view would be similar to those of the baseline vehicle and thus, problems and accidents related to field of view in these situations would be expected to stay the same.
- When cornering, most of the LHVs assessed would suffer some additional blind spots. These would be similar for the B-double (vehicles 4 and 6), rigid/A-dolly/semi (vehicles 5 and 7) and the C-train (vehicle 8) configurations. For each of these, the rigid vehicle or front trailer would prevent vision of the area in front of the rear trailer. A B-double with fixed axles on the interlink trailer may be slightly safer than the others because it does not have exposed dolly wheels that cannot be seen by the driver and which could present an increased risk to vulnerable road users. However, this may not be true for the version assessed in this research where the interlink semi-trailer has a steering bogie. The risks associated with cornering would, therefore, be slightly higher for these LHVs than for the baseline vehicle.
- The longer semi-trailer (vehicle 3) would have minimal impact on the visible ground plane area compared to existing 13.6m trailers. The rear of the semi-trailer would not be visible in the mirrors during very tight turns, but this would only occur at slightly smaller turning angles than for existing vehicles. In these positions the semi-trailer would be likely to be visible via direct vision, at least for right turns.

The assessments carried out were based on vehicles equipped with mirrors conforming to the latest requirements. Based on the findings of the analysis, it would be prudent to ensure that LHVs are fitted with mirrors compliant with Directive 2003/97 and in the later analysis of costs and benefits all the scenarios tested assumed that this would be the case if they were permitted. Although some field of view problems do still occur with existing HGVs equipped to this standard it would minimise the chances of problems being exacerbated for LHVs.

It may be possible to introduce new technology to reduce this risk further. For example, camera technology may have the potential to provide the driver with a view of the areas of concern which cannot be seen using mirrors, if they can be mounted in suitable positions. To avoid overloading the driver with information, it may be advisable to only display information on monitors when the driving manoeuvre requires the additional views. This concept was included in a package of potential countermeasures that contributed to one of the two main cases in the later analysis of costs and benefits.

5.1.3 Braking

When a vehicle is braking, it should achieve as high a level of deceleration as possible without losing stability or directional control. The stability and control of a heavy vehicle combination relies on avoiding locking any of the wheels because:

- if the front wheels of the tractor unit lock, the vehicle will not be responsive to steering
- if the rear wheels of the tractor unit lock, an articulated or drawbar combination may jack-knife
- if trailer wheels lock, a trailer swing may ensue.

All of these conditions are undesirable and each of them could lead to an accident.

Considerable research has been carried out in the USA evaluating the braking stability performance of various types of LHV. However, most of this work considered the potential for jack-knife and trailer swing instabilities as a result of under or over braked axles in the presence of different load conditions. This research appeared to be based on vehicles with much older brake technology than is typical in Europe today. It is likely that the mandatory introduction of ABS and requirements for the distribution of braking amongst the axles will have largely eliminated the problems described in the research. However, older vehicles not equipped with this technology are still used and, if LHVs were to be permitted, a requirement that all components of the vehicle comply with current braking regulations would be expected to be beneficial and to minimise risks. It has been assumed that this would be the case in all scenarios evaluated in the later analysis of costs and benefits.

A further problem was identified for LHVs operating using pneumatic braking systems. Air pressure takes a finite amount of time to travel the length of the vehicle and there is, therefore, a delay before full braking is applied. If the length of the vehicle is increased, this delay will also increase. This is reflected in Australian standards that permit longer reaction times for B-doubles and road trains - research suggested that the lower standards for these vehicles could result in stopping distance increases of up to 20%.

Many new vehicles are now equipped with Electronically-controlled Braking Systems (EBS). In these systems, the signal to brake is carried from the brake pedal to the pneumatic distribution valve electronically, which allows locally stored air to generate the high forces required to apply the brakes. This system has been found to substantially reduce reaction times on standard articulated vehicles. It would be expected that the reaction time of an LHV fitted with EBS would not be substantially different to that for a standard articulated vehicle fitted with the system (i.e. faster than purely pneumatically controlled articulated vehicles). EBS also has features that act to enhance the performance of ABS and braking distribution control to further improve stability.

Tests on prototype examples of the vehicles proposed for the UK (BTAC, 2006) were found to be consistent with the findings of this report, that is, that with proper control of the brake system using modern technology there were no adverse effects. These findings may need to be empirically confirmed if LHVs were to be considered.

At present, EBS are not designed to cope with multiple trailers and do not have units mounted on trailers for controlling a second trailer's braking. Manufacturers of such systems have suggestged that these are not currently marketed due to lack of demand but are technically available. This may require confirmation if LHVs were to be considered.

For the purposes of the analysis of costs and benefits, EBS was included in a package of countermeasures assumed to be capable of halving any increase in risk per km and which was assessed in one of the two main cases modelled.

5.1.4 Stability

Vehicle stability is one of the main concerns cited with LHVs and can involve either directional instability, where at least one part of the combination starts to follow a path different to that demanded by the driver, or roll instability where at least one part of the combination begins to rollover. Each of these modes has a strong potential to cause serious accidents, although for current HGVs roll stability is considered to be a bigger problem than directional stability. A number of measures of the stability of vehicle combinations were examined and the implications were assessed for different types of LHV:

- Static rollover threshold (SRT) - the lateral acceleration at which rollover occurs during steady state cornering. Rollover in LHV combinations is complex and depends on the type of coupling between each of the trailers. Semi-trailers which are connected via a fifth-wheel coupling will rollover as connected units whilst trailers which are connected via a dolly can rollover independently of each other. This means that if the last trailer of an LHV combination reaches its rollover threshold and overturns, the other trailers would not necessarily reach their rollover stability limit. However, overall it was found that for single decked LHVs (as assumed for all LHV types assessed in this research) the SRT was unlikely to be significantly different from a standard articulated HGV. The vehicle type likely to have the lowest static stability would be the double decked articulated vehicle, which is already permitted but is taller and can have a higher centre of gravity. If double decked LHVs were considered then there may be much greater implications in relation to the SRT.

- Rearward amplification - the degree to which the trailer(s) amplify or exaggerate the sideways motion of the tractor unit (technically defined as the ratio of the lateral acceleration of the rearmost trailer to the lateral acceleration of the tractor). It usually has a greater effect on vehicle combinations with more than one point of articulation and typically occurs when the vehicle performs a manoeuvre with unusually high frequency content, such as an avoidance manoeuvre. In extreme cases, the sideways movement of the trailer can result in a rollover. Although estimates of rearward amplification vary, the conclusions in terms of rank order are consistent. In general, current articulated vehicles are least susceptible, B-double and C-dolly combinations are the least susceptible of the LHV types and the most susceptible vehicles are “full” drawbar combinations with short wheelbases such as those that are already legal in the UK and Europe.
- Dynamic load transfer ratio - a measure of the dynamic roll stability of a vehicle, it measures the proportion of a vehicle’s total axle load that is carried on one side of the vehicle relative to the other. A perfectly balanced vehicle would have a load transfer ratio of 0, whilst a vehicle with all of its weight on one side (and the other side in the air) would have a load transfer ratio of 1.0. The dynamic load transfer ratio is linked to both the static rollover threshold and rearward amplification and is another measure of a vehicle combination’s ability to perform turning and avoidance manoeuvres safely.
- High speed off-tracking - at speed the rear trailer(s) may track to the outside of the path of the towing unit. This can be influenced by turn radius and speed. A vehicles’ tracking ability is measured by the lateral displacement between the centre of the tractor unit and the rear of any trailer. It would be important to ensure that an LHV would remain within its lane. If the vehicle crossed the centreline of the road, there is a risk of a collision with oncoming or overtaking traffic. A combination that crosses the edge of the road may cause damage to the edge of the road or instigate a rollover.
- Yaw damping ratio - this quantifies how quickly yaw oscillations (sway) of the rear of a trailer take to settle after a rapid steering manoeuvre. Trailers where the yaw oscillations take a long time to settle represent a higher safety risk. Yaw damping tends to decrease with speed, so at higher speeds the oscillations may take longer to decay, with the potential for rollovers in extreme cases. When a system is over-damped the vehicle would become extremely slow when responding to steering.

Static roll stability was not considered to vary significantly for the LHV types assessed in this research and the dynamic load transfer, high speed off-tracking and yaw damping ratio are all related to the rearward amplification, at least to some extent. Stability issues for each vehicle assessed were, therefore, characterised by the data on rearward amplification in the assessment of likely accident rates for use in the later analysis of costs and benefits.

Electronic Stability Controls (ESC) are in existence that can act to mitigate many of the stability risks described. Such systems act to identify yaw or roll instability and selectively apply the brakes at individual wheels in order to stabilise the vehicle. For the purposes of the later analysis of costs and benefits it has been assumed that ESC will form part of the suite of countermeasures assessed in one of the two main cases. However, it should be noted that yaw stability controls are, at the time of writing, not yet available for trailers.

Table 13 shows the effect that various vehicle configurations have on the static rollover threshold, rearward amplification and high speed off-tracking. This information has been synthesised from a number of studies and reports.

Table 13: Relationship between design parameters and stability/safety factors

Vehicle Configuration	Static Rollover Threshold	Rearward Amplification	High Speed Off-Tracking
Increasing gross vehicle weight	xx	xx	x
Increasing number of articulation points	-	xx	x
Increasing trailer length	-	-	xx
Longer wheelbase	-	✓✓	✓
Longer overhangs to rear hitches	-	xx	x
Increasing number of axles	✓✓	xx	x
Increasing axle spreads	-	xx	x
Type of dolly (B or C instead of A)	-	✓✓	✓

Where: xx = Significantly degrades the level of fundamental safety
x = Moderately degrades the level of fundamental safety
- = Not applicable or only a small effect
✓ = Moderately improves the level of fundamental safety
✓✓ = Significantly improves the level of fundamental safety

It should be noted that the use of steered axles can greatly improve the low speed manoeuvrability and could enable many of the assessed LHV combinations to meet both the low speed off-tracking and outswing requirements. However, these can have an adverse effect on the stability criteria such as rearward amplification and high speed off-tracking. These adverse effects can be avoided by ensuring that the steering mechanisms are locked in a straight-ahead position at higher speeds. For all cases assessed in the later analysis of costs and benefits it has been assumed that the vehicles equipped with steering axles will be fitted with speed interlocks such that no additional stability problems would occur.

5.1.5 Impact Severity

Accidents involving Heavy Goods Vehicles (HGVs) have, on average, more severe consequences than those involving only smaller vehicles. HGVs account for approximately 5.8% of all vehicle traffic (distance travelled), yet approximately 18.3% of all road accident fatalities occur in accidents involving at least one HGV. There is concern that allowing heavier goods vehicles might increase the proportion of truck accidents that result in fatalities.

The majority of fatalities in accidents involving HGVs are car occupants. For HGV to car impacts, the primary determinants of the casualty severity are the speed at which the vehicles collide, their masses and the impact configuration. The relative closing speed (essentially the sum of the two vehicles' velocities) at impact is the single largest predictor of the likelihood that a given crash will have a fatal outcome. Higher closing speeds result in higher changes in velocity for the car.

As the ratio of the masses of the vehicles increases, the change in velocity sustained by the lighter vehicle as a fraction of the closing velocity quickly rises. In HGV to car impacts where the mass ratio is sufficiently large, physics dictate that the energy dissipated in a collision becomes insensitive to the mass of the truck – at mass ratios around 10:1 the smaller of the two vehicles sustains virtually all the change of velocity resulting from the collision. Current mass ratios in car-truck collisions are sufficiently large – mass ratios of up to 50:1 are possible – that there would be no perceptible increase in impact severity for the car were heavier goods vehicles allowed. However, this only holds true where there are no obstacles in the path of the car post-collision. If the car were to suffer a secondary collision with another heavy vehicle then the severity could be increased. There is, therefore some chance that the severity of multi-vehicle accidents could increase if vehicles with increased mass were to be permitted. Such multi-vehicle accidents form a relatively small proportion of all truck accidents. The most relevant situation is likely to be accidents where the heavy vehicle collides with the rear of a stationary queue of traffic.

HGV occupants account for a much smaller proportion of the fatalities from accidents involving HGVs. Their chance of survival is dependent on the ability of the vehicle to maintain a survival space and absorb some of the energy from a crash (e.g. by crumpling). When the collision partner is another heavy vehicle or a rigid fixed object, the structure of current truck cabs is only capable of meeting these criteria at relatively low closing speeds. Increasing the mass of the truck is likely to exacerbate this existing problem and could lead to an increase in the risk of an occupant fatality.

A small number of new trucks are equipped with a system known as a Collision Mitigation Braking System (CMBS). This system uses forward looking sensors to detect other vehicles ahead and in a front to rear shunt type collision will act to warn the driver of a likely collision. If the driver fails to respond to the warning, such that a collision becomes inevitable, then the brakes are automatically applied in order to reduce the collision speed. Research by Grover *et al* (2007) has suggested that such a system could reduce fatalities in shunt accidents involving heavy vehicles by as much as 25% to 75%. Such a system has the potential to be very effective at mitigating the additional risks of LHVs described in this section, potentially to a level lower than that currently experienced with most standard HGVs (i.e. those not equipped with the system). This system has been included in a package of safety systems capable of halving any increases in risk per km and has been evaluated in one of the two main cases evaluated in the later cost-benefit analysis.

5.1.6 Junctions, Railway Crossings and Overtaking

A recent German study (Glaeser et al, 2006) of the impact of LHVs did not find that there were any increased safety risks on motorways. However, on non-motorway roads the researchers expected to find negative safety and performance impacts due to the use of LHVs at junctions, railway crossings and more generally on single carriageway rural roads. This was considered to be mainly due to the increased time that a longer vehicle would take to clear a junction, execute a manoeuvre or to be overtaken. Some evidence was found that supported the conclusion that longer vehicles would take longer to clear junctions and this was considered to cause a risk at traffic light controlled intersections where the time to clear the junction was likely to exceed typical “inter-green” times. This could present a hazard and increasing the “inter-green” time would reduce the capacity of the junction.

One of the commonly cited risks that could potentially be associated with LHVs is the longer time required to overtake them. A study was carried out in Sweden (VTI, 1976) operating 18m and 24m length vehicles in ordinary traffic on predefined test sections. In total, the vehicles covered more than 13,000 km during the tests. The amount of time between the completion of an overtaking manoeuvre and the arrival of oncoming traffic was used as an indicator of accident risk and was recorded by cameras mounted on the test vehicles. The difference in this mean time between 18m and 24m vehicles was very small. The data suggested that the longer vehicle tended to induce a greater number of overtaking manoeuvres defined as “hazardous” but this was not statistically significant. Computer simulations of this type of situation in the USA suggested a greater increase in risk than implied by the Swedish research in 1976. However, Vierth *et al* (2008) studied accident data that compared rigid trucks with longer vehicle combinations in overtaking accidents. They were unable to prove any statistically conclusive results, although the data that was available suggested that the risk of overtaking related accidents actually decreased with increasing length.

No studies were found that could definitively quantify these risks in terms of accident rates. This risk has not, therefore, been specifically considered in the analysis of costs and benefits although some of the data contributing to the estimates of accident rates for LHV was based on extrapolations of existing data and may, therefore, include the potential effects of this risk, at least to some extent.

5.1.7 Accident risk

Data on accidents involving LHVs are very scarce. There are no data from the UK because there are no vehicles and the data from trials in Europe are relatively weak because of low numbers. There is a numerically much greater body of evidence from countries such as the USA but even in these countries the numbers are such that it has been found difficult to draw statistically significant conclusions and the operating environment is substantially different to the UK. Predictions of UK accident risk have, therefore, been formed on the basis of combining data from a number of sources. The findings are summarised below:

- Extrapolation of UK data on casualty rate (number of casualties per unit of distance travelled) by number of axles (a surrogate for increasing size/weight) showed a strong increase in rates with greater number of axles. This dependency increased on roads with a higher overall casualty rate. However, there is an acknowledged weakness in this method because accident data sources count the total number of axles on a vehicle whereas the travel data is based on the number of axles on the ground meaning that 6 axle artics travelling with retractable axles lifted would be counted as 6 axle artics in the accident statistics but as 5 axle artics in the travel data. This method predicted large percentage increases in casualty rates but is highly likely to significantly over-estimate the risk because of the inconsistency in the data sources.
- Extrapolation of actual UK data on casualty rate by gross vehicle weight showed some variation in rates for different weight groups but no clear consistent trend linking increased weight to increased casualty rate and no large effects of the type seen when comparing by number of axles.
- A risk based approach suggested moderate increases in casualty rate up to approximately 10% dependant on the vehicle option and road restrictions selected. This approach involved assessing the casualty rates for the specific groups of accidents that physical testing and scientific theory had suggested may be a problem for larger vehicles.
- The literature reviewed showed that very severe accidents can and do happen with larger goods vehicles but that in general accident rates were comparable with standard goods vehicles, although this is likely to hide an increase because they travel on safer roads. Few specific figures were available but Fancher (1989) cited research that suggested that the involvement rate of double trailer combinations was 5% to 10% greater than for singles, once the different patterns of road use were controlled for.
- The Dutch trial cited no change in accident rate, although it was acknowledged that the size of the trial was too small to draw robust conclusions.

These estimates were combined using a simple weighted mean firstly assuming that no additional safety interventions were mandatory for LHVs and secondly assuming that the possible countermeasures discussed in sections 5.1.2 to 5.1.5 above halved the increase in risk for LHVs. The casualty rates predicted are shown in Table 65 and Table 67 in Appendix B and later used in combination with standard DfT casualty prevention values in the analysis of costs and benefits described in section 7 and Appendix H. After this analysis was complete, further information became available from Australian and Swedish research (Moore, 2007; Vierth *et al*, 2008). This data suggested that any effect on the casualty rate per vehicle km would be small and thus, suggests that the analysis described above could be considered conservative.

If additional safety measures, such as EBS, ESC or CMBS were required for LHVs then it is highly likely that there would be additional benefits to accidents involving HGVs of current weights and dimensions because it is likely that an increased number of vehicles would be fitted with the countermeasures discussed in order to provide operators with the flexibility to use them as part of an LHV combination if required. However, these effects would be difficult to quantify and have not been included in the overall assessment of net effects.

5.2 Environment

The environmental assessment considered exhaust emissions (including CO_2) and noise.

5.2.1 Emissions

The analysis of tailpipe emissions from vehicles is described in detail in Appendix C and summarised below. The emissions and fuel consumption of each of the 8 vehicle types selected for detailed analysis was assessed using state-of-the-art modelling. The PHEM (Passenger car and Heavy-duty Emission Model) model estimates fuel consumption (FC) and the emissions of carbon monoxide (CO), total hydrocarbons (THC), oxides of nitrogen (NO_X) and particulate matter (PM) based on the instantaneous engine power demand and engine speed during a driving cycle specified by the user.

TRL holds a database of in-service driving characteristics, measured over a range of road types and vehicle classes. One hundred and twenty typical HGV driving cycles were selected to represent a range of average speed driving conditions between 5 km/h and 90 km/h. Emission and fuel consumption estimates were derived using PHEM over each of these selected cycles, for each of the 8 vehicle types and for Euro 3, 4 and 5 emission classes (introduced into the UK fleet in 2000/01, 2005/06 and 2008/09 respectively). This included simulations of these vehicles operating part laden and fully-laden. Although carbon dioxide (CO_2) was not calculated directly, it was derived from the standard carbon balance equation, as specified in the Commission Directive 93/116/EC. Total CO_2 emissions were calculated by summing the fractional contributions of each carbon-containing exhaust pollutant.

Table 14 (Euro 4) shows the estimated emissions for each of the 8 vehicle types, expressed in terms of g/km of pollutant and per tonne km of payload transported. These emissions were estimated with an average associated vehicle speed of 86.9 km/h which is typical of existing 4-axle and 5+ axle articulated Heavy Goods Vehicles in operation on the high speed road network.

Generally, the heavier the vehicle, the greater the exhaust emissions and fuel consumption. Vehicle 8 (82 tonnes) generally produced the highest tailpipe emissions and had the greatest fuel consumption. This was followed by vehicles 6 and 7 (60 tonnes). However, when the emissions rates per tonne of payload carried were considered, these heavier vehicles produce similar or lower relative emissions than the current 44 tonne vehicles. When fully-laden, vehicle 8 produced significantly lower relative emissions than the 44 tonne vehicles together with lower fuel consumption. The analyses were also carried out with the average load when laden assumed to be the same as for current 44 tonne articulated vehicles. The emissions were lower per vehicle km but the relative performance of the different vehicle types was broadly similar and analyses suggested that the results could be linearly interpolated or extrapolated to other loading conditions with reasonable confidence.

Table 14: Emission rates for Euro 4 vehicles with maximum laden weight

Vehicle Type	Emission rates						
	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	CO_2 (g/km)	FC (g/km)	Payload (tonnes)
1	0.109	0.013	6.031	0.023	1081.297	340.989	29.1
2	0.110	0.013	6.237	0.023	1124.248	354.543	28.2
3	0.109	0.013	6.031	0.023	1081.495	341.055	28.1
4	0.111	0.013	6.325	0.024	1140.834	359.775	23.3
5	0.111	0.013	6.317	0.024	1139.771	359.443	23.7
6	0.140	0.017	8.011	0.030	1445.306	455.759	39.3
7	0.140	0.017	8.014	0.030	1445.172	455.759	39.7
8	0.174	0.018	9.752	0.034	1758.198	554.614	60.4

Vehicle Type	Emission rates per tonne of payload					
	CO (g/tkm)	HC (g/tkm)	NOx (g/tkm)	PM (g/tkm)	CO_2 (g/tkm)	FC (g/tkm)
1	0.004	0.000	0.207	0.001	37.146	11.714
2	0.004	0.000	0.221	0.001	39.842	12.564
3	0.004	0.000	0.214	0.001	38.445	12.124
4	0.005	0.001	0.271	0.001	48.860	15.409
5	0.005	0.001	0.267	0.001	48.191	15.198
6	0.004	0.000	0.204	0.001	36.730	11.582
7	0.004	0.000	0.202	0.001	36.447	11.494
8	0.003	0.000	0.162	0.001	29.119	9.185

The emissions from rail freight were also assessed, based on previous analyses for the rail industry (see Table 15).

Table 15. Rail Freight emissions (EWS, 2007)

Emission	grams per tonne-km
CO_2	18.769
Methane	0.00078
Carbon Monoxide	0.02921
Nitrous Oxide	0.00718
Nitrogen Oxides	0.10177
Sulphur Dioxide	0.01580
Non-methane VOC	0.02143
Benzene	0.00004
1,3-butadiene	0.00186
PM_{10}	0.00485

It should be noted that the literature suggested that rail locomotives emitted some harmful emissions that were not considered in the computer model for road vehicles. For example, sulphur dioxide remains an issue for rail because different grades of fuel are used. Road vehicles use ultra low sulphur fuel such that the emissions of sulphur dioxide are negligible.

The financial value of emissions has been derived based on published literature in order to enable the emissions to be combined with predictions of vehicle travel to produce a cost of emissions for each vehicle type assessed in the final model of costs and benefits.

5.2.2 Noise

A computer simulation was used to predict the noise produced by each vehicle type. Each rolling wheel acts as a noise source while the propulsion noise is not expected to vary significantly with engine size. All the engines would develop power in excess of 200 hp and, therefore, would be type approved to the same maximum noise level of 80 dB(A) under full throttle acceleration at 7.5 m (UN-ECE, 1996).

The HARMONOISE source model was used to calculate the Sound Exposure Level (SEL) at various speeds. Two point sources are used – one represents mainly the tyre sources (rolling noise) and is located close to the road surface and the other represents mainly the propulsion unit sources. 80% of the rolling noise is assumed to radiate from the lower source whereas 20% is assumed to radiate from the higher source - this allows for some “smearing” of the source which in practice rarely takes the form of a discrete point source. The effects of increasing the number of axles was based on the correction $\Delta_{WR,axle}$ which is calculated from the number of axles

$$\Delta L_{WR,axle} = 6.8\ Log\left(\frac{N}{4}\right)$$

A smooth and relatively quiet surface, Stone Mastic Asphalt (SMA), and a rough and relatively noisy surface, Hot Rolled Asphalt (HRA), were used in the modelling to span the range of typical road surface conditions.

Table 16 gives the noise predictions for the vehicles with 6, 8 and 11 axles. For noise prediction, the configuration of the axles is unimportant.

Table 16: Sound Exposure Levels (dB(A)) by number of axles and road surface type

Surface	Speed km/h	Number of axles		
		6	8	11
SMA	30	82.59	82.77	83.01
	50	83.46	83.87	84.38
	90	86.84	87.48	88.22
HRA	30	82.75	82.96	83.24
	50	83.82	84.27	84.81
	90	87.35	88.02	88.78

The increase in SEL with number of axles was relatively small. The largest effect was on the rougher surface (HRA) at the highest speed (90 km/h) (rolling noise is relatively high on a rough surface at higher speeds). In this case, the difference in level between the 6-axle and the 11-axle configuration was 1.4 dB(A).

Under urban conditions, where speeds are low, propulsion noise will dominate the overall noise level and the effects of additional axles will be relatively small.

5.3 Infrastructure

The potential impacts that LHVs could have on roads, bridges and parking / interchange points were also evaluated. The analysis is described in detail in Appendix D and summarised below.

5.3.1 Roads

The structural road wear attributable to vehicles is normally assumed to be proportional to the fourth power of the axle weight. Thus, a 10 per cent increase in axle weight is assumed to increase structural wear by 46 per cent. Structural road wear is measured in terms of “standard axles”, where one standard axle is defined as the wear associated with an 8.16 tonne axle and the wearing power of a heavier or lighter axle is calculated as:

$$\text{Road wear factor (standard axles)} = (\text{axle weight in tonnes} / 8.16)^4$$

Road wear factors were calculated for the 8 vehicle types. For each, factors were calculated using typical lading patterns from the 2005 CSRGT data.

Table 17: Relative Road Wear Factors

Vehicle Type	Gross Vehicle Weight (tonnes) and number of axles	Relative wear factor (standard axles) for a typical lading pattern	
		per vehicle	per 100 tonnes of goods
1 (base single-deck)	44 tonnes / 6 axles	1.00	1.00
2 (base double-deck)	44 tonnes / 6 axles	1.06	1.18
3 (longer semi-trailer)	44 tonnes / 6 axles	1.04	1.11
4 (B-double)	44 tonnes / 8 axles	0.55	0.68
5 (rigid + semi-trailer)	44 tonnes / 8 axles	0.61	0.75
6 (B-double)	60 tonnes / 8 axles	1.46	1.08
7 (rigid + semi-trailer)	60 tonnes / 8 axles	1.48	1.09
8 (C-train)	82 tonnes / 11 axles	1.80	0.90

Generally the wear factors per vehicle (see Table 17) increased with increasing Gross Vehicle Weight (GVW) and decreased with increasing number of axles. The lowest values were for the 8-axle 44 tonne GVW vehicles and the highest for the 82 tonne vehicle. The factors for vehicle cases 2 (double-deck semi-trailer) and 3 (longer semi-trailer) were higher than those for vehicle case 1 because their unladen weights were higher and therefore the road wear factors when unladen and at each stage of partial loading were higher.

The wear factors per 100 tonnes of goods take into account the relative carrying capacities of the vehicles and assume that the average load and empty running remain the same as for current articulated vehicles. Using this measure, three vehicles had wear factors lower than those for the base vehicle. These were the two 8 axle 44-tonne GVW vehicles and the 82 tonne GVW vehicle. The highest value was for the 44 tonne articulated vehicle with double-deck semi-trailer (which is permitted under existing regulations) where the relatively high unladen weight increased the number of vehicles required to carry 100 tonnes.

Whilst road pavement designs have been based on the assumption that structural road wear is proportional to the fourth power of the axle load, research has shown that thick well-constructed fully flexible pavements do not weaken gradually through the effects of cumulative traffic loading but maintain their strength with time. For these pavements, the deterioration is not structural but generally occurs only at the surface. Provided that non-structural deterioration is detected and remedied before it has serious impacts on structural integrity, these pavements remain structurally serviceable for indeterminate periods without the need for any structural maintenance (i.e. maintenance is limited to the replacement of the wearing course at regular intervals and the underlying layers are “permanent”). A significant proportion of the trunk road network is classified as “long life” and therefore, if most LHV travel is on the strategic or trunk road network, they would be expected to have a limited impact on the structural performance of pavements.

There are a range of defects in the surfacing which could potentially be influenced by the level of traffic loading. An investigation of the effect of traffic loading showed that an increase in wheel load would result in a proportional increase in rutting. Therefore, rutting per unit of goods moved would be lowest for vehicles with the highest ratio of payload to maximum permitted weight. This ratio would be highest for vehicle case 8 (C-train) and lowest for vehicle cases 4 and 5 (8-axle 44 tonne combinations).

Road wear costs per standard axle km were calculated for inclusion in the final analysis of costs and benefits.

5.3.2 *Bridges*

The ability of a bridge to carry LHVs would depend on the axle load and spacing. The current loading specification used for UK bridges is given in the Design Manual for Roads and Bridges standard BD 37. Two types of loading are used. Normal traffic loading (HA) represents the most severe loading that can be envisaged as a result of a span being fully loaded by vehicles complying with the current regulations. Abnormal loading (HB) consists of a notional vehicle with a Gross Vehicle Weight (GVW) of up to 180 tonnes and is used to cater for heavy vehicles and trailers used to transport very heavy abnormal indivisible loads. The loading specifications include the vertical loads due to heavy vehicles and the horizontal forces transmitted through the deck as a result of vehicle braking and centrifugal effects.

Analysis determined the maximum mid-span bending moment and the maximum shear force produced as each vehicle rolled across bridge spans of various lengths between 5 and 100m. The analysis was considered to be a cautious one because it ignored several factors of safety built in to the design standards. Thus the magnitude of loading derived in relation to the standards is, therefore, likely to be an over-estimate. This was considered to be justified because of the potentially very severe consequences of overloading a bridge.

In all cases, the bending moments produced by the LHV types assessed were less than those obtained from HA loading. For short spans (up to 10m), the loading is controlled by the single heavy axle or bogie in the vehicle configuration and the moments produced by all LHVs were very close to those from the HA loading. This suggests that LHVs would be unlikely to cause problems in terms of bending moments for bridges designed for HA loading. For spans up to about 40m, the LHV types assessed were similar to two conventional vehicles placed close together. For spans greater than 40m, the HA loading was more onerous than the LHV loading. This is because, with HA loading, the whole span is loaded while for the analysis carried out here, the LHVs were assumed to be acting alone.

Similar conclusions were drawn for the analysis of shear forces. However for spans between 27 and 51m, the shear forces for the 82 tonne vehicle were marginally greater (maximum of 5%) than those obtained from HA loading. The LHV types assessed were comfortably covered by 30 units of HB loading for both bending and shear. This shows that bridges constructed to modern Highways Agency standards would be unlikely to suffer problems if LHVs were permitted. However, LHVs may have an effect on bridges which were constructed to older, less stringent, standards. Data extracted from the Structures Management Information System (SMIS) database of bridge loading capacities are shown in Figure 11. This shows the loading criteria used to design a sample of 5,800 of the Highways Agency’s under-bridges (i.e. bridges carrying the motorway / trunk road network).

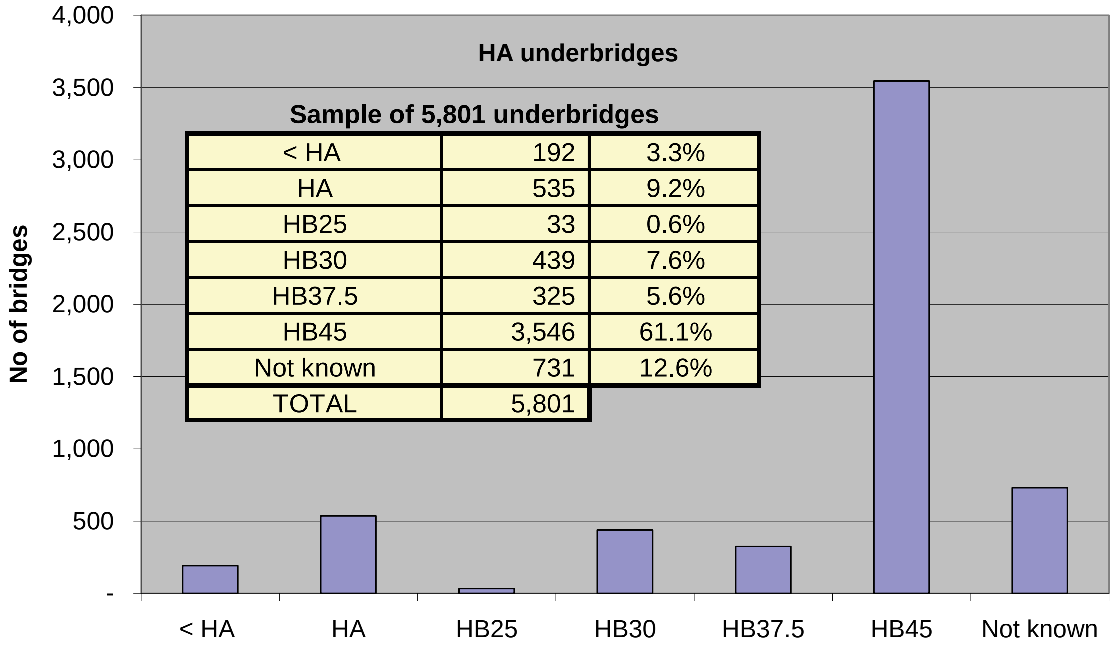

Figure 11: Loading standards for HA bridge stock

Examination of these data suggested that 75% of these bridges were designed for at least 25 units of HB and are thus likely to be adequate for all of the LHVs assessed. Nine percent of bridges were designed only to HA loading criteria, meaning that they would be expected to be adequate for all the LHVs assessed except for the 82 tonne variant when the bridge span is between 27m and 51m. Just over 3% of the bridges were constructed to standards lower than HA and thus would not be suitable for existing 44 tonne vehicles or any of the LHVs. Twelve percent of bridges were built to unknown standards.

A maximum of approximately 25% of trunk road bridges would be affected if the C-train were to be permitted. However, the span of the bridges was not taken into account, so it is not known how many of these bridges have spans in the critical 27-51m range. If 60 tonne LHV combinations were permitted only the 3.3% of bridges known to be constructed to less than the HA standard (plus whatever proportion of the 12.5% unknowns fell into this category) would be at risk. LHVs at 44 tonnes would offer no threat to bridges over and above that already in existence in relation to 44 tonne articulated vehicles. Although payload neutral options at 25.25m and 50 tonnes were not directly assessed they would be unlikely to present any additional risks in terms of bridge loading. This is because the maximum axle weight would be lower than for a 44 tonne 6 axle articulated vehicles and the additional load would be spread over a longer distance such that the total load on a longer bridge with multiple vehicles carried would not be any greater than for a chain of close following standard articulated vehicles.

No comparable information was available for local authority owned bridges. However, at a focus group meeting with infrastructure owners and enforcement agencies the stakeholders present suggested that a much greater proportion of such bridges would be at risk at each level of increased weight.

If any LHVs were to be permitted with an increased GVW then it will be necessary to survey the bridges where the load that they are designed to is currently unknown. If 82 tonne LHVs were permitted it is likely that less than 25% of trunk road bridges but a greater proportion of local authority bridges would be at risk. If the LHVs were prohibited from passing over these bridges it would be likely to substantially limit the routes that they could travel on or a substantial capital investment would be required to upgrade the bridges. If LHVs were permitted at a GVW of 60 tonnes then a similar exercise in route restriction or bridge upgrading may be required but the route limitations or capital investment would be substantially smaller in magnitude because the number of inadequate bridges would be much lower and many of those unsuitable for 60 tonne LHVs would also be unsuitable for 44 tonne HGVs and would already be appropriately signed and restricted. If LHVs were permitted at a GVW of 44 tonnes then no adverse effects on bridge loads would be expected over and above those already applied to standard 44 tonne vehicles.

In addition to vertical loads, LHVs have other structural implications:

- Bridge supports must be designed to resist the loads that may result from strikes by errant vehicles. The collision loading to be used is specified in BD 60 and represents a 40 mile/h collision with a 30 tonne rigid LHV at an angle of 20 degrees. A 56 mile/h collision with a 44 tonne articulated vehicle at 20 degrees or more would, therefore, already exceed the minimum standard. Permitting LHVs in excess of 44 tonnes would significantly increase the collision loads applied by the vehicle but unless the bridge supports and their protective structures are designed considerably in excess of their minimum standards then this would not represent any additional risk compared with a 44 tonne vehicle, that is, both a 44 tonne vehicle and a heavier vehicle would produce very severe damage. Further research, likely to involve physical testing, would be required to confirm the level of increased risk, if any. If existing bridges required strengthening, the cost would be dominated by user delay costs and previous research has estimated the total cost to be in the range of £40k to £285k per bridge column.
- Collision with bridge decks: These can and do occur with existing HGVs. However, the LHVs types selected for assessment in this project were restricted to the height of a standard European semi-trailer, which would minimise the risk of bridge strikes.
- Centrifugal forces need to be considered when vehicles travel at speed on bridges curved in plan with radius of curvatures less than 1,000m. The maximum centrifugal force generated by an LHV travelling on a curved bridge is a direct function of its gross weight. The critical case would be for the 82 tonne LHV. This would impart similar centrifugal forces as two separate articulated vehicles, although it is unlikely that two such vehicles would be travelling close together at speed over a tightly curved bridge.
- Braking forces are longitudinal forces acting on a bridge and its supporting structure imposed by a braking vehicle through friction between the tyres and the road surface. Analysis suggested that LHVs with a GVW of 82 tonnes would be at risk of exceeding the design standards for braking forces on medium span bridges. LHVs of lesser GVW would be expected to be adequately catered for by the current loading specifications.

It has not been possible to accurately monetise the effect of LHVs on bridges and so this will be considered as a risk factor in terms of the final analysis of costs and benefits.

5.3.3 Parking / interchange points

The review of issues associated with parking facilities and interchange points is discussed in detail in section D.3.5 of Appendix D and summarised here.

If LHVs were to be permitted it would be essential that they could gain access to sufficient parking facilities to enable drivers to take their mandatory rest breaks. In some areas of the country there is a shortage of Heavy Goods Vehicle parking, with “fly parking” occurring in illegal or undesirable areas such as on hard shoulders. Many stakeholders from all of the focus groups (including the road freight hauliers groups) have expressed concern that permitting LHVs would exacerbate this problem as described below.

Goods vehicle parking at Motorway Service Areas (MSAs) was designed to accommodate the maximum length vehicles in use at the time they were built. Some MSAs are more than 20 years old and were not designed to accommodate the 18.75m vehicles already in use. A significant number have back-to-back parking for two Heavy Goods Vehicles and an LHV could, therefore, use two spaces.

However, this could have an adverse effect on capacity even if the use of LHVs did lead to a reduced number of goods vehicle trips.

At many MSAs, HGV spaces are single bays and there would be no spaces available for LHVs without substantial changes to the layouts. If no changes were made this would substantially reduce the number of MSAs that LHVs could use to take their rest breaks.

Newer MSAs would have parking bays designed to accommodate 18.75m drawbar combinations and so the 18.75m articulated vehicle type of LHV, if permitted, would not be expected to create any additional parking problems over and above those already in existence and may reduce the existing problems if the measure reduced or limited the expected growth in overall goods vehicle traffic.

There may also be problems with the access and internal roads at many MSAs. These are not required to conform with HA design standards for motorways and there are some areas where existing length vehicles can only negotiate the geometries at very slow speeds. This would be a particular concern for any LHV types that were not capable of meeting current manoeuvrability requirements.

Some MSAs are designed in a way that allows them to accommodate vehicles carrying Abnormal Indivisible Loads (AIL), which can be longer than the LHVs assessed in this report and are not required to meet existing standards of manoeuvrability. This means that there will certainly be some MSAs to which LHVs could physically gain access but these MSAs are typically only designed to accommodate one or two AIL vehicles.

There are currently 92 MSAs in England if two sided facilities are counted as separate facilities. Six more are at various stages of the planning or development process and while it is possible that more new facilities will be proposed it is anticipated that there will not be many more. At this stage it is not known how many would be capable of accommodating LHVs but stakeholders have suggested that all of them would require at least some physical alteration if LHVs of more than 18.75m in length were to be permitted.

Truck stops are often better equipped for Heavy Goods Vehicles and may be better equipped for LHVs. However, they are often situated on poorer quality roads and there have been problems with closures of truckstops in recent years, although a European project (SETPOS) is aiming to help reverse this trend by investing in improved facilities at 5 truck stops across Europe, which includes a site at Ashford in Kent.

Some stakeholders in this study and some of the European studies of LHVs have suggested a potential mode of operation whereby an LHV would carry a load along the main trunk route (e.g. motorway) before stopping at a special interchange point where the vehicle would be split into two for onward distribution into urban areas. Such interchange points would not require many special facilities – the vehicles could be separated into their constituent parts at any suitable parking area provided that there is appropriate access, and space to manoeuvre and securely park trailers, dollies, etc as required. However, such sites do not currently exist in the UK and the use of existing MSAs would be problematic because of available space, health and safety constraints, and a lack of incentive for MSA operators to invest in such facilities.

Stakeholders have suggested that the improvement of current facilities would be difficult because of substantial constraints associated with land availability and planning permission and because the HA has no power to require MSA operators to undertake the necessary works. It may, therefore, be more practical to build dedicated facilities, if LHVs were to be permitted, although these would still be subject to the difficulties of land availability and planning permission. It was suggested that, based on a previous study considering the possible introduction of free-standing motorway picnic areas, that a cost of £5m to £7m plus land acquisition costs could provide access and egress slip roads, parking space for in the region of 6 LHVs (>18.75m) and a toilet facility.

Accurately predicting the demand for LHV parking spaces is likely to need a complex analysis including factors such as the:

- number of trips undertaken by LHVs,

- proportion of those trips where drivers' hours could be exceeded,
- availability of rest facilities at origins and destinations,
- time of day the trip is undertaken,
- preferences of individual drivers
- willingness to pay of drivers in different market sectors

Most of these factors could not be objectively considered within the scope of this study.

It was clear from the fact finding activities that there are existing problems in relation to parking current vehicles and that these would be exacerbated by the introduction of LHVs, even if the overall number of vehicle trips was reduced as a result. The extent to which these problems would be exacerbated, and the exact number of MSAs and Truckstops that would have difficulties in accommodating LHVs, are not currently known. The initial views of stakeholders and the simplistic analyses carried out have served to highlight the complexity of this problem and the lack of detailed current knowledge about the national use of rest stop facilities by the haulage industry. Without this important baseline data it is not possible to reliably estimate the overall effect that the introduction of LHVs longer than 18.75m would have and what investment might be required, although it is clear that it has the potential to be measured in £billions if large numbers of new, dedicated facilities were shown to be necessary. Clearly, this would need to be considered carefully if LHVs longer than 18.75m were to be permitted. However, this would not be the case if permitting longer articulated vehicles of up to 18.75m, which would not be expected to exacerbate any of the existing parking problems because they would be no longer than standard drawbar combinations already in use.

5.4 Operating costs

The operating costs of the eight vehicle cases were estimated using data from published cost tables, combined with data from the literature review and fact finding, and assumptions regarding the non-standard vehicles. A summary of the relative costs is shown in Table 18.

Table 18: Relative Costs

Vehicle Type	Gross Vehicle Weight (tonnes) and number of axles	Capital Cost	Operating cost		
			per km	per tonne-km	per pallet-km
1 (base single-deck)	44 tonnes / 6-axle	1.00	1.00	1.00	1.00
2 (base double-deck)	44 tonnes / 6-axle	1.07	1.02	1.09	0.51
3 (longer semi-trailer)	44 tonnes / 6-axle	1.10	1.01	1.05	0.82
4 (B-double)	44 tonnes / 8-axle	1.37	1.13	1.29	0.73
5 (rigid + semi-trailer)	44 tonnes / 8-axle	1.13	1.11	1.27	0.72
6 (B-double)	60 tonnes / 8-axle	1.37	1.21	0.75	0.79
7 (rigid + semi-trailer)	60 tonnes / 8-axle	1.13	1.19	0.73	0.77
8 (C-train)	82 tonnes / 11-axles	1.50	1.35	0.57	0.67

The operating cost per km was lowest for the baseline single-deck articulated vehicle. When the average load including empty running was considered, the cost per tonne-km was substantially reduced for all types involving a weight increase and increased for all the volume only types. When the average cost per pallet-km was considered (on the basis of maximum pallet capacity because no data exists on the average load in volumetric terms, see Table 46 in Appendix A for payload and pallet capacities), all types offered substantial cost reductions compared with the baseline single-deck vehicle, but substantial cost increases compared with the baseline double-deck vehicle.

The operating cost of rail freight has also been estimated as an average based on data from the Rail Environmental Purchase Scheme. As an average, this was found to be a lower cost than for a baseline articulated vehicle. This is likely to be a function of the work the different modes currently do, that is, the rail cost is based on a market predominantly carrying large quantities of goods a long distance whereas the average road costs will be based on the full range from local deliveries to long haul trunking. The costs are, therefore, not a direct comparison of costs for sectors of the market where road and rail will be competing. It is likely, that in many such circumstances rail costs will be higher than road costs.

The operating cost of different vehicle types has been directly incorporated in the final analysis of costs and benefits. However, it should be noted that the difficulties of providing comparable cost data for road and rail may mean that the analysis will slightly favour rail transport and slightly exaggerate the consequences of any modal shift from rail to road.

5.5 Congestion

Detailed descriptions of the work to analyse congestion issues is provided in Appendix D and is summarised here. The impact of LHVs, if permitted, on other traffic will vary between different parts of the road network. On flat major dual-carriageways and wider roads, where overtaking is easy, their impact would be expected to be similar to that of standard Heavy Goods Vehicles (HGVs). On single carriageway roads, especially those with many bends and steep gradients, their impact would be much greater. In urban areas their impact will be related to their manoeuvrability (see Section 5.1.1) and their impact on junctions, etc (see Section 5.1.6).

It is difficult to quantify the impact of LHVs on congestion - simulation models in current use do not reliably model overtaking on single carriageways roads. A comprehensive survey of truck size and weight issues in the USA (ORD, 2001) suggested that length was not a significant factor in congestion, but that the main factors were the power to weight ratio, the gradient of the road and the type of road. The impact of abnormal loads on congestion on UK roads has been studied. The most important factors determining the impact of a vehicle carrying an abnormal load were its speed and lane take-up, and the traffic volume. The impacts on motorways were greatest for slow-moving abnormal loads and were small for speeds greater than 50 km/hr.

The overall impact of LHVs will also depend on whether they reduce overall HGV travel and on the road space occupied. Where LHVs carry more goods than existing vehicles, their introduction should reduce overall HGV travel. However, if the introduction of LHVs leads to modal shift (LHVs carrying goods previously moved by rail – see Section 6.5) or generates additional road goods traffic (see Section 6.6), the effect on HGV travel will be less than implied by the capacity increase and the more efficient use of road space. The overall impacts are considered in Section 7.

The relative amount of road space occupied by LHVs was estimated by dividing the vehicles' capacities (maximum payload or maximum pallet capacity) by the road space occupied assuming a 50m headway (2 seconds at 90 km/hr) (see Table 19).

Table 19: Relative Use of Road Space

Vehicle Case	Gross Vehicle Weight (tonnes) and number of axles	Relative use of road space (assuming full vehicle and 50m headway)	
		By Payload (tonnes per metre of road space)	By Pallet Capacity (pallets per metre of road space)
1 (base single-deck)	44 tonnes / 6-axle	1.00	1.00
2 (base double-deck)	44 tonnes / 6-axle	0.90	2.00
3 (longer semi-trailer)	44 tonnes / 6-axle	0.91	1.19
4 (B-double)	44 tonnes / 8-axle	0.71	1.36
5 (rigid + semi-trailer)	44 tonnes / 8-axle	0.72	1.36
6 (B-double)	60 tonnes / 8-axle	1.20	1.36
7 (rigid + semi-trailer)	60 tonnes / 8-axle	1.20	1.36
8 (C-train)	82 tonnes / 11-axles	1.59	1.58

In terms of payload, the 60 and 82 tonne LHVs had higher (more efficient) use of road space than the single-deck base vehicle. In terms of pallet capacity, all the LHVs had higher use of road space than the single-deck base vehicle, but lower use than the double-deck base vehicle (the LHVs were assumed to have a single-deck).

This more efficient use of road space would normally be expected to reduce congestion and mechanisms exist for assigning financial values to the reduction in congestion. However, such mechanisms are based on the congestion caused by current vehicles and thus they may not be appropriate for assessing the congestion effect of replacing standard vehicles with a smaller number of LHVs. This is because although LHVs make more efficient use of road space in terms of the load carried, they also have the potential to create additional congestion in their immediate surroundings, particularly on gradients and at junctions and intersections. It has not been possible to quantify the effects of these localised phenomena on congestion and for this reason, the final analysis of costs and benefits does not include a calculation of the congestion costs – effectively assuming that the net effect of the more efficient use of road space and the localised congestion that could be caused is zero. It should be noted that if a calculation ignoring the localised congestion issues had been included in the analysis of costs and benefits, the total cost changes predicted would have been greater (i.e. greater reduction in total transport cost where total vehicle kms reduced or a greater increase in total cost where mode shift or induced demand suggested an increase in total vehicle kms).

5.6 Drivers

The demands on goods vehicle drivers that may cause fatigue are complex. Their daily routines are characterised by both physical and psychological demands and a wide range of factors that characterise their work have been identified as potential contributors to fatigue and crash-related outcomes. These include work overload, schedule irregularity and working at a variety of times which run counter to natural circadian rhythms.

A US study (Federal Motor Carrier Safety Administration, 1997) explicitly investigated the effects of different truck configurations on driver workload and fatigue. In the study, 25 experienced LHV drivers drove approximately 2,700 miles each in specially equipped and loaded single and triple trailer combinations under controlled experimental conditions. The tractive-units were equipped with video and digital equipment to gather data on the drivers' performance during the study. The drivers also answered questionnaires concerning their perception of stress and fatigue at five scheduled times during the driving day. Participants had at least 9 years of commercial motor vehicle driving experience and had experience with triple-trailer combinations. The results indicated that the drivers of C-dolly triple-trailer combinations would experience substantially less fatigue and a lower probability of lane exceedance than the drivers of A-dolly triple-trailer configurations. They also indicated that average triple-trailer drivers, particularly when driving the A-dolly configuration, would be expected to experience critically high workload levels during which performance could decline rapidly to below acceptable levels. These results are supported by a study that found that 79% of experienced drivers felt that double-trailer units (in comparison to single-trailer units) are more difficult to operate on slick pavement, and 78% said they are more difficult to control in emergency braking. While these vehicle types were not subject to detailed analyses in this project, the finding is important in relation to selecting the type of connection (A, B or C) to be used if any multi-articulated LHV were to be permitted.

Research has found that the accident severities of large truck drivers vary significantly between rural and urban locations. These differences are likely to be related to factors such as driver behaviour, characteristics of driver populations and driver behaviour as a function of the visual “noise” in different traffic environments. The perceptual, cognitive and response demands placed on drivers are significantly higher in urban than in rural areas.

The Dutch LHV pilot study had a number of restrictions on drivers and operations (Staatscourant, 2003). These included:

- The driver had to have at least 5 years experience driving articulated combinations.
- The driver’s license had not been suspended, withdrawn or declared invalid during the last 3 years.
- The driver had successfully completed certification for driving LHVs. Special attention was given to awareness of other road users and the mentality of the driver.
- Driving was not allowed in poor visibility (< 200m) or when the roads were slippery.
- Driving was only permitted on expressways and connecting roads, and “allowed stretches”.
- The permitted routes excluded those with rail level crossings if the trains were permitted to exceed 40 km/h.

Although most of the research identified was carried out in different countries with different road conditions and different training requirements, it is likely that many of the issues identified would also be applicable in the UK. If LHVs were to be permitted in the UK it is likely that further consideration of some of these issues may be required, in particular:

- The effect that different vehicle handling and field of view characteristics may have on driver fatigue and awareness and how drivers could be trained to cope with this. Some LHV types (A-dolly) appear to cause more fatigue than others (C-dolly).
- How the use of LHVs could be controlled to minimise the exposure of LHV drivers to environments which generate high driver workloads (such as urban areas or poor weather).
- The management of drivers working hours and driving time to ensure that any additional complexity of the driving task does not increase the risk of accidents relating to fatigue.

For the purposes of the analysis of costs and benefits, it has been assumed that driver’s costs remain constant. Although there may be additional costs for training, it is likely that fewer drivers will be required.

5.7 Public opinion

Public opinion has not been directly assessed during this research because it was considered premature to do so. At this stage, a large range of potential options were being assessed, each of which may or may not be permitted and, if permitted, could be implemented in a variety of different ways. Professionals in the freight industry found this large matrix of possibilities difficult to deal with when their views were sought in the information gathering exercise. It was considered that the general public would find this even more difficult. In any case, it was considered that this initial research needed to be completed before the respondants could be properly informed of all the issues.

However, the perception of other road users was raised as a concern by several stakeholder organisations that were involved in the information gathering exercise. In general it was suggested that the general public would be opposed to introducing larger vehicles. While it was acknowledged by the majority at the stakeholder meetings that this was likely to be true, it was pointed out that such views were not restricted to large goods vehicles. One stakeholder pointed out that their organisation received a large quantity of complaints about light commercial vehicles of less than 3.5 tonnes GVW.

Subsequent to the focus group meetings *Freight on Rail* has published the results of an NOP survey of public opinion, which found that 75% of the public was opposed to the introduction of LHVs. The survey appeared to only consider 25.25m 60 tonne vehicles and appeared to ask two simple questions:

- The Government is considering legislation that will allow 60-tonne lorries, which are more than a third longer and heavier than the present legal limit, onto our roads. Would you be likely to support this or not?
- A possible alternative to allowing 60 tonne lorries onto our roads could be for the Government, through planning policy and funding, to encourage more freight to go by rail. Would you be likely to support this as an alternative or not?

The limited data available to the project team suggests that the sample was of adequate size and was balanced in terms of age, sex, social class and region. However, it was not apparent from this data whether any supporting information had been provided to respondents and, if so, whether that supporting information was accurate and unbiased.

A survey of public opinion was also undertaken in the Netherlands, on behalf of their Transport Ministry, where the public may have had a chance to interact with an LHV on the road network. This involved a sample of approximately 1,000 respondents. The results of this survey were quite different from the NOP survey in the UK. It was found that although a large proportion of people reported feeling either unsafe or neither safe nor unsafe when interacting with current HGVs, there appeared to be no significant difference when considering interaction with an LHV. Motorists were found to have a *"reasonably positive attitude"* and were able to cite a "*sufficient number of advantages"* arising from the use of such vehicles. There appeared to be "*substantial"* support for the concept of introducing LHVs, although there were concerns over the safety of right turn manoeuvres (equivalent to left turns in the UK).

5.8 Regulatory Impacts

The impacts that LHVs would have on the existing regulatory framework are described in detail in Appendix E and summarised here. The regulatory framework in the UK and the EU is, in the main, not designed with LHVs in mind. There are, therefore, a variety of regulations that would have an effect on, or be affected by, any decision to allow such vehicles in the UK. These include:

- Regulations that would need to be amended to permit LHVs in national transport
- European Regulations constraining what can be permitted in Member States national transport
- Existing regulations that may impose constraints on LHV use, if they were permitted
- New regulation, or amendments to existing regulation, that may be required in order to enforce constraints considered desirable on LHV construction and/or use or to provide suitable facilities to allow LHV use, if they were permitted.

LHVs could be permitted in the UK by amending a number of different regulations, either individually or in combination or by the use of Vehicle Special Orders. Vehicle weights, dimensions, and technical requirements could all be controlled. However, any amendments to these regulations would have to be consistent with European legislation.

The main European regulation related to weights and dimensions is Council Directive 96/53/EC. This Directive harmonises the maximum dimensions of goods vehicles circulating in national and international traffic within the EU (16.5m length for articulated vehicles, 18.75m for drawbar combinations). It prescribes the maximum weight of vehicles (40 tonnes on 5 axles) that will guarantee free circulation in international traffic within the EU. It also prescribes the minimum standard for manoeuvrability for vehicles in traffic in the EU via the minimum turning circle requirements of being able to turn within the space between two concentric circles of 5.3 and 12.5 metre radius.

However, Directive 96/53/EC is extremely important in relation to any decision whether or not to permit LHVs because it does permit, in national transport, certain deviations from the weight and dimension requirements, as described below:

> *"Member States may allow vehicles or vehicle combinations used for transport which carry out certain national transport operations that do not significantly affect international competition in the transport sector to circulate in their territory with dimensions deviating from those laid down in points 1.1, 1.2, 1.4 to 1.8, 4.2, and 4.4 of Annex 1"*

This means that vehicles can be used in national transport, under certain conditions, that are not subject to the requirements concerning:

- Maximum length
- Maximum width
- Manoeuvrability (turning circle) requirements
- The maximum distance between the rear axle of a towing vehicle and the lead axle of a trailer
- The maximum distance between the king-pin of a semi-trailer and the front and rear of the trailer

National transport operations are deemed not to significantly affect international competition if one of the following conditions is fulfilled:

a. *"the transport operations are carried out in a Member State's territory by specialised vehicles or specialised vehicle combinations in circumstances in which they are not normally carried out by vehicles from other Member State's e.g. operations linked to logging and the forestry industry."*

b. *"the Member State which permits transport operations to be carried out in it's territory by vehicles or vehicle combinations with dimensions deviating from those laid down in Annex I also permits motor vehicles, trailers and semi-trailers which comply with the dimensions laid down in Annex I to be used in such combinations as to achieve at least the loading length authorised in that Member State"*

Additionally, in respect of trials:

> *"Member States may allow vehicles or vehicle combinations incorporating new technologies or new concepts which cannot comply with one or more requirements of this Directive to carry out certain local transport operations for a trial period. Member States shall inform the Commission thereof."*

The implications of condition (b) could be significant in that if a Member State permits vehicles, or vehicle combinations, in national traffic that do not comply with the requirements of Annex I of the Directive, then it must permit combinations of motor vehicles, trailers or semi-trailers of equivalent loading length (modular concepts) that meet the requirements individually. This suggests that if 18.75m articulated vehicles were permitted in domestic legislation then potentially the UK could be forced to permit longer vehicles made up of standard components in order to comply with European law. The same arguments also suggest that there is a risk that specific types of 25.25m LHVs (for example, a B-double) could not be permitted without permitting other types of 25.25m LHVs and that it may not be possible to require such vehicles to have specific safety features over and above what is currently mandated for standard components.

However, detailed study of the regulations and associated Commission documents, such as that clarifying the position regarding the carriage of 45 foot shipping containers, has suggested that in respect of 18.75m articulated vehicles it may be possible to formulate UK regulations in such a way as to prevent the consequences summarised above. However, any such approach would be subject to the views of the European Commission, other Member States and possibly the courts.

It therefore seems likely that if the UK wished to permit any non-modular vehicle, to restrict modular vehicles only to types with certain safety characteristics or to those fitted with certain safety features, then an amendment to 96/53/EC would be required to ensure that the UK and other Member States would not be obliged to accept modular concepts that were considered to be unsuitable.

One exception to all of the above would be the use of LHVs only in operations conforming with condition (a) described above. This would mean only permitting their use in specific types of operation where it can be demonstrated that foreign operators do not currently compete with domestic operators. The example given in the Directive is that of the forestry industry but other sectors of the UK market could, potentially, comply and it is understood that certain “low loader” trailers are already permitted under this clause. In these cases it would appear possible to permit any vehicle considered suitable and apply any suitable restrictions without the consequences described above. However, the number of operations possible under this clause, which would not affect international competition, are likely to be limited in number.

A further exception applies in respect of a trial. If the UK decided that permitting LHVs could potentially be beneficial but wished to first carry out a trial to generate real world data to better assess their affects before proceeding to more widespread use, then it should be possible to impose whatever restrictions might be deemed necessary without incurring the consequences of permitting unwanted modular concepts during the trial period.

European Directive 97/27/EC, as amended, effectively implements the mass, dimension, and manoeuvrability requirements of Directive 96/53/EC (which refers only to national and international traffic circulating in each territory) in the technical requirements for individual vehicles subject to the type approval requirements (70/156/EC). It may become necessary to amend this regulation to incorporate LHVs more specifically, particularly in relation to the technical standards for dollies or if non-modular vehicles were to be permitted.

Schedule 6 of the Road Traffic Regulation Act 1984 specifies the speed limits for vehicles of certain classes. In this table, specific consideration is given to Heavy Goods vehicles (GVW>7.5 tonnes) towing more than one trailer. Such vehicle combinations are currently subject to speed limits of 40 mile/h on motorways and 20 mile/h on all other roads. Based on this regulation, it is likely that all of the options assessed by this project, with the exception of the longer semi-trailer, would be subject to these speed limits if they were to be permitted. In some UK regulations, a semi-trailer supported by a converter dolly is considered as one trailer. However, that does not appear to be the case in the Road Traffic Regulation Act, suggesting that even a rigid vehicle towing a single semi-trailer on a dolly would still be subjected to the reduced speed limits. It should be noted that these speed limits would apply even in the case of a trial because it is not possible to use Special Orders to permit vehicles to exceed speed limits.

Other research reviewed as part of this project has suggested that speed is a very important factor when considering the congestion effects of larger vehicles. From this point of view a reduced maximum speed would be undesirable and it would also substantially reduce the economic advantages of using such vehicles. If it was considered that LHVs should be permitted and should be allowed to travel at the same road speed as other HGVs then an amendment to the Road Traffic Regulation Act would be required.

One of the options that has been discussed elsewhere in this report is that if LHVs were to be permitted they should be restricted to certain classes of road. In regulatory terms, only the motorway network is defined by its own regulations, The Motorways Traffic (England and Wales) Regulations 1982 and their Scottish equivalent. All other roads are covered by the Road Traffic Regulation Act. If LHVs were permitted only on Motorways then the Motorways Regulations could be amended to control their use. If they were to be permitted on a sub-network that was defined to include only some of the other roads in the country then much more complex amendments or regulations may be required.

The Traffic Signs Regulations and General Directions (TSRGD) 2002 define a Primary Route as one where the traffic authority has determined that it is the most suitable route for through traffic between places of traffic importance. It has been suggested that this definition could be used as a basis for a sub-network for LHV use. However, it has also been noted that not all of this network would be suitable for LHVs and, therefore, traffic authorities should have the power to exclude LHVs from certain parts of this network in a similar manner to that whereby current weight limits are applied.

The Road Traffic Regulation Act, 1984, empowers traffic authorities to restrict or prohibit, by Traffic Regulation Order, any class of traffic for a variety of safety and/or environmental reasons. It is, therefore, unlikely that any further powers would be needed to prohibit LHVs from parts of the network deemed unsuitable by the local traffic authority. However, if such restrictions were to be applied, or if any other aspect of LHV use was required to have LHV specific signing, then it would likely be necessary to either authorise non-standard signs or to amend the TSRGD 2002 in order to create standardised designs for these signs.

As discussed previously, if LHVs were to be permitted it would be essential to allow access to suitable parking areas and that various constraints at existing motorway service areas (MSAs) may mean that insufficient parking areas exist. Legal issues are likely to influence the ability of the Highways Agency to develop any infrastructure improvements that may be required.

Most MSAs are now privately owned and operated and are situated on land either owned privately or leased from the Highways Agency (HA). It should be noted that the HA has no powers to force operators to make changes to current sites. Any changes would, therefore, have to be made via agreements with the operators of each MSA individually. Given that there is no economic incentive for MSA operators to modify their sites to permit LHV entry and parking (reduced number of paying customers (i.e. truck drivers) per square metre of parking space occupied) they would be likely to demand that the government meets the cost of the work and pays compensation for loss of business during the works and potentially for ongoing loss of business as a result of the reduced number of drivers that can be accommodated in the parking area.

Many MSAs have already been developed to use all of the land available and any additional parking facilities may, therefore, need to be developed outside of their existing boundaries. The Highways Agency does have powers available under the Highways Act to use Compulsory Purchase Orders to make the land available but these could only be used in conjunction with a successful planning application.

The HA does, however, have the power to influence the design of new MSAs but can only impose requirements relating to vehicles which are currently permitted on UK roads. It would not, therefore, be possible to require special provision for LHVs unless such vehicles had already been permitted. This creates a problem because any design of new facilities would take time meaning there could be a period between any decision to permit LHVs and the provision of suitable rest areas.

5.9 Compliance and Enforcement

This section summarises issues of compliance with, and enforcement of, any regulations regarding LHVs. It is drawn from sections in the detailed appendices on infrastructure (Appendix D) and safety (Appendix B).

There has been much discussion of how any requirements that might be imposed on LHV use, if permitted, would be enforced. Many stakeholders expressed a great deal of concern about current HGVs that were found to be defective, speeding, exceeding drivers hours, overloaded, or travelling on inappropriate roads, particularly with reference to vehicles operated by companies from outside the UK.

Stakeholders involved in enforcement activities agreed that it was likely that LHVs would exacerbate some existing enforcement problems because larger, potentially less manoeuvrable, vehicles would not be able to gain access to all of the enforcement sites, weighbridges and test stations currently in use. While developments such as VOSA enforcement cameras and weigh-in-motion systems would help to mitigate these problems they may not eliminate them entirely without substantial further development. However, it was considered that the powers of the O-license system in terms of potential penalties (traffic commissioners can revoke a company's license) were adequate to provide a strong deterrent and considered more likely to be effective than the criminal charges that could be considered for many infringements.

A range of enforcement measures were discussed with stakeholders that could be adapted to LHVs, if they were to be permitted. One suggestion was to amend the O-license system to create a special category for LHV operators such that only those companies with good records could apply to operate LHVs and higher standards could be required.

Many stakeholders considered that modern technology could provide many of the solutions required to problems of enforcement of technical requirements. In particular it was considered that telematics and GPS was in use in many current heavy vehicles and could be further developed to provide warnings to the driver and evidence for later prosecution if drivers did not comply with route restrictions. It was thought that this type of system could be even more effective if other systems such as congestion charge zones and/or road pricing schemes were in place to identify vehicle movements. Difficulties with such a system included the fact that they tend to be fitted in vehicle cabs and, current systems at least, do not identify whether the vehicle is towing a trailer. Such difficulties were not considered to be insurmountable, a view supported by current research efforts in Europe aiming to develop much more effective guidance and monitoring technology. In addition to this, in London traffic authorities already have powers to enforce 7.5 tonne and 18 tonne weight restrictions using CCTV and Number Plate Recognition equipment. New legislation extending that option to the rest of England is expected to be available in 2009.

It was considered that foreign registered vehicles and operators presented a greater problem because they were not subject to the control of the UK operator licensing authorities and because stakeholders perceived that the rate of infringements found for current foreign vehicles was much higher than for domestic vehicles. It was considered that enforcement of any LHV requirements on foreign operators would have to rely on roadside patrols and stop-checks.

Any increase in the technical requirements or levels of enforcement required, if LHVs were permitted, would result in an increased cost to the enforcement authorities. It is not possible to accurately quantify this cost at this time but an estimated allowance of £1million per annum has been incorporated in the analysis of costs and benefits to represent this activity.

6 Assessing the potential use of LHVs

The reaction of the freight industry to LHVs is described in detail in Appendix F and summarised here.

Eight focus group discussions were held with the freight industry to explore, in an interactive forum, a range of issues relevant to the use of LHVs. Altogether 109 delegates from a broad spread of hauliers, logistics companies, manufacturers, retailers, rail companies and other agencies expressed their views at these forums. This was generally a self-selected sample of delegates / companies that volunteered to take part and as such may not constitute a wholly representative group.

The delegates at the focus groups were presented with background information about the scope and objectives of the project and asked to consider a range of questions, which varied according to the particular audience but generally included:

- To what extent could efficiency and vehicle utilisation be improved within existing weights and dimensions regulation?
- Should LHVs be considered and, if so;
  - Which of the vehicle options being assessed by the project did they have a preference for?
  - What would be the effects of restricting LHVs to different classes of road?
  - What role could be seen for LHVs in supply chains?
  - What benefits could delegates see in permitting LHVs?
  - What operational factors would constrain the use of LHVs?
  - What utilisation (load factors, empty running etc) of LHVs would delegates expect?
  - What effect would LHVs have on freight modal split?
  - What would the wider implications of LHVs be for logistics and supply chain management?
  - What other issues might be relevant to the consideration of whether LHVs should be permitted?

Sections 6.1 to 6.3 present the views of road freight industry representatives, while Sections 6.5 and 6.6 describe concerns and issues raised by rail freight operators. Potential impacts on water freight are also considered within these latter sections.

6.1 Factors Affecting the Replacement of Existing Heavy Goods Vehicle Movements

Delegates from the road freight industry attending six of the eight focus groups were asked to rank the eight scenarios assessed in terms of the benefit that their company could gain from using the new vehicles permitted. Each participant was asked to assign a score between 1 and 8 (where 1 represents not very useful and 8 represents very useful) indicating how beneficial they thought that each option would be for their company.

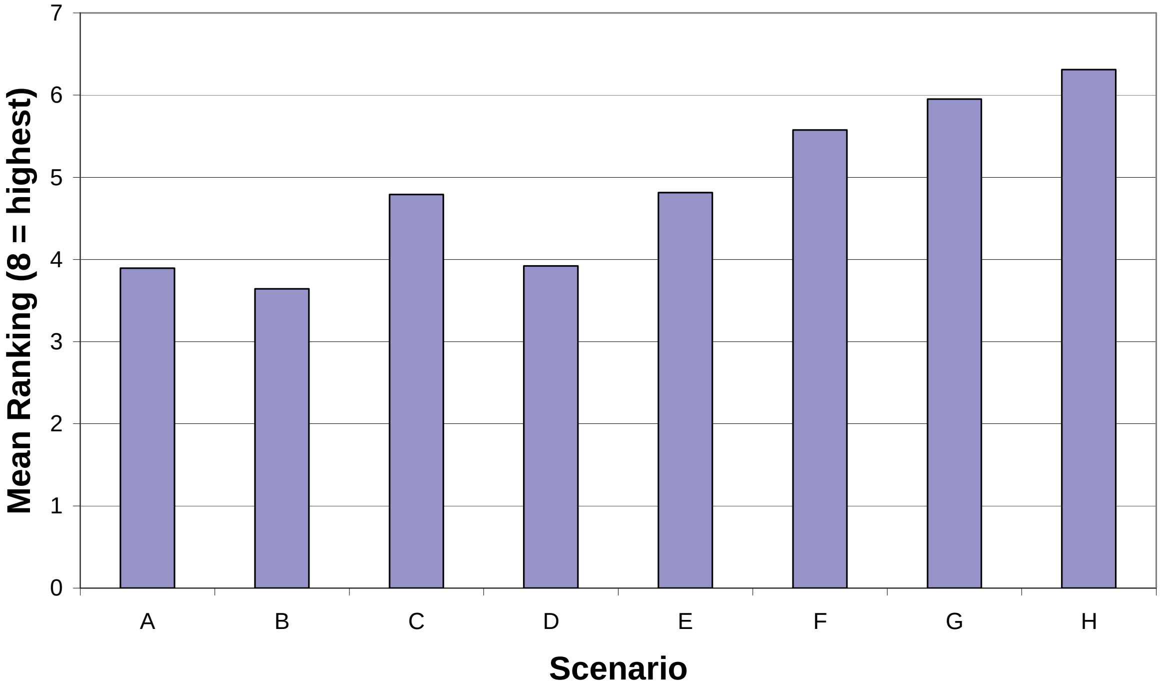

Figure 12: Average ranking of LHV Scenarios by focus group attendees

Based on an arithmetic mean of the ratings provided by the representatives of the road freight industry, the most popular option was Scenario H, permitting the coupling of two 13.6m semi-trailers at a gross weight of 82 tonnes. Delegates offered three reasons for this: maximum carrying capacity; ability to use standard equipment; and minimal additional capital cost. The next three rankings were in line with declining vehicle capacity. The payload neutral version of the longer semi-trailer (Scenario C) received a higher average ranking than a 25.25m combination restricted to 44 tonnes (Scenario D). The substantial loss of payload weight on the latter vehicle proved unpopular, even among companies distributing low-density products. The least popular scenario (B), which received a lower average rating than retaining the status quo, was the 44 tonne version of the longer-semi-trailer vehicle.

However, the ranking varies if measures other than the arithmetic mean are considered. This is shown by the disaggregate data and alternative descriptive statistics in Table 20, below.

Table 20. Individual ratings and descriptive statistics for focus group responses

Scenario	Number of respondants giving each ranking								Total number of respondants	Arithmetic mean rating	Mode rating
	1	2	3	4	5	6	7	8			
No change	13	2	2	5	1	8	4	3	38	3.9	1.0
18.75m 44 tonnes	5	14	4	4	6	3	4	2	42	3.6	2.0
18.75m c.46 tonnes	0	1	15	6	6	6	3	6	43	4.8	3.0
25.25m 44 tonnes	3	8	6	10	3	1	5	2	38	3.9	4.0
25.25m c.50 tonnes	0	4	6	7	14	3	7	2	43	4.8	5.0
25.25m 60 tonnes	3	4	3	1	2	17	10	7	47	5.6	6.0
34m c.63 tonnes	1	3	5	0	3	6	15	9	42	6.0	7.0
34m 82 tonnes	5	2	0	3	2	2	7	24	45	6.3	8.0

For example, while the participants were asked to rate each option independently, it is likely that their thinking was influenced by the presence of the other options such that some companies that would find additional volume very useful would have reserved the highest score for the largest increase, thus giving the 18.75m 44 tonne vehicle a lower score despite still finding it useful to some extent. This can be seen in the data above where the mode rating is calculated for each scenario. The mode rating is that with the most frequent response. It can be seen that the largest proportion of respondants simply rated the scenarios directly in line with vehicle capacity. In addition to this, although on average (arithmetic mean) the 18.75m 44 tonne vehicle received a lower score than maintaining the status quo the distribution of response differed considerably. In the main people tended to be for or against maintaining the status quo with 34% of respondants giving it the lowest possible score and 39% rating it at 6 or above. In contrast, only 12% of respondants gave the longer semi-trailer at 44 tonnes the lowest score and 21% scored it at 6 or above. These results suggest that a longer articulated vehicle at 44 tonnes would prove very useful to a smaller proportion of companies but would be of only low usefulness (compared with the other options evaluated) to a larger group of companies.

A general consensus from this group emerged that LHVs would have specific applications and not become a standard vehicle type. The number and extent of these applications would depend on any network restrictions and gross weight limits imposed on LHVs. According to focus group delegates from the road freight industry, it is likely that LHV operations would tend to have several characteristics:

- They would be used on longer hauls.
- They would mainly handle regular flows of products.
- They would cater mainly for lower density loads requiring greater volume.
- Most of their deliveries would be undertaken on a contractual basis for particular clients or as part of a network service.
- They would be applied mainly to primary movements between points of production and / or warehouses, with very limited use in secondary distribution to shops.
- They would tend to be used on routes with good back-loading opportunities, resulting in below average empty running.
- The 25.25m combinations would be used mainly on a point-to-point basis with limited coupling / decoupling of units en route.
- Coupling / decoupling would be much more common in the case of the 34m LHVs, particularly if their movements were confined to the motorway network.

There was a general belief that the 25.25m combinations would have a significantly higher capital cost than a standard 44 tonne artic and that few general hauliers would speculatively upgrade to this type of vehicle. Its specialist role combined with uncertainty about loading opportunities would deter hauliers from making a speculative investment for use in the spot haulage market. In comparison, these stakeholders considered that the 34m LHV would require minimal investment (mainly for a dolly) and, by combining two standard 13.6 metre semi-trailers, would offer greater flexibility.

Four types of constraint were discussed in the focus groups:

- Financial: LHVs would have a significantly higher capital cost. Most of this additional cost would be in the purchase of the trailer, dollies and linking equipment (the general view was that there would be little need to acquire new tractive-units with higher power ratings). The largest capital cost increment would be for the 25.25m B-double combination, which would require a special inter-link semi-trailer (£15,000-£20,000 was quoted by several firms).
- Operational: The main operational constraint was deemed to be average consignment size. The just-in-time (JIT) principle is now widely applied across UK production and distribution systems and has the effect of depressing average consignment size. This has reduced the proportion of loads requiring the greater capacity available in LHVs.
- Infrastructure: Companies were asked if they would be able to accommodate LHVs at collection and delivery points. A common response was that their own company had sufficient space but that some of the companies they trade with would not. It was generally considered that a 25.25m LHV capable of meeting current turning circle restrictions would present little problem, whereas manoeuvring a 34m LHV at many industrial and commercial

sites would be very difficult. Most delegates were more concerned about space limitations at truck stops, motorway service areas and lay-bys, thus supporting the views of other stakeholders reported in section 5.3.3. There was a general consensus that these facilities are currently inadequate and that substantial investment would be required to upgrade them for LHVs, especially if coupling / decoupling of LHV units became a common practice.

- Human-resources: Companies were generally confident that they would be able to find sufficient drivers willing and able to drive LHVs. They considered that experienced HGV drivers would require little extra training, particularly on the 25.25m combinations, and that there would be no need for a special LHV driver's license. Some delegates suggested that they would only allow better drivers with more than five years experience to drive LHVs.

There was general acceptance that it would be inappropriate to operate LHVs on urban roads or smaller rural roads. The majority of delegates also believed that if permitted, the 34m LHV would need to be confined to motorways and dual carriageways. Opinions varied on whether 25.25m combinations that meet current turning circle requirements would need to be restricted. Many delegates argued that they should be allowed on most single carriageway 'A' roads. Reference was made to Sweden and New Zealand where stakeholders believed that LHVs have been allowed to use such roads for many years without any apparent problems, although the differing traffic environment was also acknowledged.

Several delegates suggested that LHV networks (comprising Motorway, dual and single-carriageway roads) could be customised to particular companies. This was based on the assumption that much LHV usage would be for regular flows between a fixed set of origins and destinations. It was suggested that once a specific set of LHV routes had been approved for a company, telematics could be used to ensure that its vehicles did not stray from this network. It was conceded that this could involve a significant amount of bureaucracy and introduce 'rigidities' into companies' logistics systems.

The relative merits of LHVs were compared with those of double-deck / high cube vehicles currently operating in the UK. Many of the companies attending the focus groups currently operate double-deck vehicles. The main advantages of double-deck vehicles over 25.25 metres LHVs were seen to be their pallet capacity (accommodating up to 52 pallets), network accessibility and relative manoeuvrability / ease of reversing. Only 34m LHVs would offer similar pallet capacity, though it was acknowledged that their use would be likely to be restricted if they were permitted, and that driving and reversing them would require more skill. However, ultimate capacity was not the only factor that operators were interested in. Consignment size was also an important factor and some hauliers carry consignments that were too big for standard articulated vehicles but were not big enough to fill a double decked vehicle. Some stakeholders considered that a longer semi-trailer or a 25.25m vehicle may be more suitable for these mid-sized loads. The main disadvantage of double-deck vehicles was seen to be the need for specialist handling facilities and / or tail-lifts / hydraulic decks. This increases handling costs and, in the case of onboard lift equipment, incurs a weight penalty. For many companies the additional unladen weight does not constrain loading because most commodities transported in double-deck vehicles have a low density.

The information gathering exercise demonstrated varying levels of support for LHVs across the UK road haulage industry. The vast majority of hauliers who completed the online questionnaire or attended the focus groups were in favour of permitting LHVs. Those companies that see commercial benefit in operating LHVs had a stronger interest in participating and therefore this may have been unrepresentative of the level of support across the whole industry. Many hauliers doubted that the introduction of LHVs would be beneficial to the haulage industry. Among this group are several large intermodal operators who have aligned their operations with rail and, therefore, considered that they would be disadvantaged by any erosion of rail freight traffic to LHVs. The lack of support in sections of the haulage industry was attributed to:

- Uncertainty about the financial rewards: Past experience has shown that when weight and / or size limits are raised, most, if not all, of the economic benefit is realised by shippers rather than hauliers. Also, there would be a significant capital cost, particularly for some varieties of the 25.25 metre LHVs. Hauliers are uncertain whether they would earn an adequate return on these vehicles.

- Differential impact on the haulage industry: It was considered that LHVs would tend to discriminate against smaller operators with less access to capital and with fleets that are too small to exploit the potential benefits of LHVs.
- Public image: It was generally considered that LHVs would be unpopular with the public and that the haulage industry will be blamed for wanting them, despite the fact that there has been no co-ordinated campaign for them and many hauliers are sceptical.
- Operational restrictions: It was expected that LHV movements would be restricted, particularly the 34m combination which would have the lowest capital cost and greatest operational flexibility. The imposition of network restrictions and other specific regulations would make LHVs less attractive and make it harder to operate them profitably.

6.2 Effects of Imposing Network Restrictions on LHVs

This section summarises the effect of imposing network restrictions on LHVs. More details can be found in the infrastructure appendix (Appendix D) and the detailed description of a modelling exercise carried out based on existing CSRGT trip data (Appendix G).

6.2.1 The need for network restrictions

Virtually all of the stakeholders involved in the fact finding exercise, including infrastructure owners, enforcement agencies, representatives of other road users, safety organisations, freight shippers and hauliers, agreed that it would be undesirable to permit all types of LHV on all road types. The safety analysis showed that a number of the physical risks, particularly those relating to manoeuvring and field of view, would be more of a problem on urban or minor roads. Analysis of accident data suggested that larger vehicles had disproportionately higher casualty rates on minor roads and suggested that restricting access for LHVs to motorways and rural trunk “A” roads would result in an LHV casualty rate comparable to the current overall accident rate for all HGVs on all roads.

The analysis of infrastructure impacts also raises concern about general access. Although LHVs (with the exception of vehicle 8 at 82 tonnes) were generally found to pose little threat to bridges built to modern trunk road standards in terms of loading, the risk of bridge damage in a collision with an LHV with a GVW >44 tonnes could possibly increase and there was no data available to assess whether local authority roads would be built to comparable standards. Infrastructure owners expressed concern that they would not be built to such standards. Local authority pavements are much less likely to be constructed to “long life” standards and road wear may become an issue. Some literature also highlighted potential congestion and network capacity impacts in areas where there were a large number of junctions and cross-roads. These effects increased with vehicle length.

Experience in other countries also supports network restrictions. The trials in Germany and the Netherlands all imposed route restrictions and it is routine practice in countries such as the USA, Canada, Australia and New Zealand to restrict LHV access. Sweden and Finland allow 25m vehicles on many of their roads but do prohibit such vehicles from urban areas.

It is important to note that there is a strong interaction between vehicle design and the route restrictions applied to any vehicle. Whilst the information gathering exercise has highlighted a number of concerns in terms of safety, congestion, and the ability to negotiate junctions, it should be noted that these could be controlled either through route restrictions, vehicle construction requirements or through a combination of both. An example of this is the performance based standards under development in Australia (Brown, 2007). This defines a series of vehicle performance tests and four performance levels. Route restrictions are applied depending on which of the four performance levels the vehicle satisfies. This would mean that the road network would also need to be categorised into several levels according to risk. Such a system offers the potential to optimise the use and capacity of vehicles while minimising any impacts on safety or infrastructure. However, at present, the European regulatory framework would prevent such an approach in the UK .

6.2.2 Definitions of networks

A range of road network definitions are in existence and these are described below with an indication of their suitability for use as part of a definition of road restrictions.

- Motorways – Motorways are defined by a legal act, the motorway regulations, and are thus very clearly defined. Most motorways are expected to be suitable for LHVs but some risks remain and some junctions built to older standards may still present difficulties.
- Dual carriageways are easily defined in a technical sense but are not separately defined in any legal act. In most cases it is likely that dual carriage ways would also be suitable for LHVs but dual carriageways often only form part of any route along the same road with transitions between single and dual carriageways
- Trunk roads – Trunk roads are defined as any road where the Secretary of State is defined as the road authority. In theory this could be any road but in practice all trunk roads are "A" roads or motorways. Not all of the trunk road network was considered likely to be suitable for LHVs because it includes lots of single carriageways and small roundabouts and can pass through urban areas and villages. There are two additional complications with defining LHV use on the trunk road network:
    - The identity of the road authority is not clear and there is no visible clue for hauliers and drivers such that it would be difficult for them to know what roads were permitted and what were not.
    - In some specific cases, such as the M6 toll road, the Secretary of State is the road authority but not the owner of the road. In the case of the M6 toll, the road is privately owned by a company that then has a contract with the Secretary of State and the owner could possibly have the power to restrict the use of LHVs on their roads.
- Principal roads – Principal roads are generally defined as all "A" class roads, regardless of whether they are under HA or Local Authority control. Many "A" roads can be found in towns and city centres so it is unlikely that this would be a suitable definition for an LHV road network, if LHVs were to be permitted.
- Primary Route Network – This is defined in signing regulations. All non-motorway roads on the primary route network will have white on green signs whereas other non motorway roads will have black on white signs. Roads on the Primary Route Network are also shown in green on road maps. In terms of an LHV network this would have a key advantage in terms of the fact that it would be obvious to drivers and hauliers whether they were on a permitted route. However, not all of the roads on the primary route network would be of a high quality and many are likely to be unsuitable for use by the larger (>18.75m) and/or less manoeuvrable LHVs.
- Urban/Rural roads – Many different definitions of an urban or rural road exist and these can be very subjective. It was, therefore, considered that such definitions would be unsuitable for use in defining an LHV road network.
- The Trans-European Road Network (TERN) – The TERN is defined by an EC Directive and is intended to cover the routes considered essential to international movements, for example between ports and airports. It is, therefore, possible to use this definition for an LHV road network but this would not necessarily be desirable:
    - Firstly, some very poor quality roads are included in the TERN, although actions to improve this network are being undertaken.

- Secondly, the roads defined in the TERN may not be those that the UK freight industry would gain most benefit from operating LHVs on.

Based on the safety and infrastructure analyses as well as the views of stakeholders, it is considered that, if LHVs >18.75m in length were to be permitted, the most suitable restrictions would be to motorways and rural trunk “A” roads that were principally dual carriageway. However, such a definition would have to be created, probably on a road by road basis and would possibly need to be applied through a legal Act. The central estimates in the analysis of costs and benefits have been made using an approximation to this definition which essentially includes all rural “A” roads because single and dual carriageway cannot be easily separated in current freight and traffic data. However, the analysis also showed that there was considerably less justification for restricting the routes that an 18.75m articulated vehicle conforming to current manoeuvrability criteria could travel on, thus, the central estimates of costs and benefits assessed this vehicle on the basis of access to all roads that current 44 tonne vehicles are permitted on.

One substantial difficulty that was identified with respect to defining a sub-network of roads that could be suitable for LHVs was that if such a network was defined there could still be a problem with diversions in the event of accidents or roadworks. Stakeholders from the road user group indicated that there were difficulties associated with current HGVs being diverted onto roads that were not well suited to them. This also causes problems in relation to drivers’ hour’s regulations where drivers may not be able to stop at the place they originally planned. It was considered likely that these existing problems would be substantially exacerbated if LHVs were to be permitted, although the extent of the problem depends on the type of LHV under consideration and whether they were to be capable of meeting current manoeuvrability criteria. Longer articulated vehicles would cause few problems over and above those already caused by standard 44 tonne vehicles but 34m, 82 tonne vehicles could cause very substantial problems, with other vehicle types falling between these boundaries.

6.2.3 Effect of restrictions on LHV use

In order to further inform the estimates of the take up rate of LHVs (as used as inputs to the parametric cost model), data from real haulage operations was used to model the road freight routes in GB and to assess how, in theory, the number of candidate trips that could be replaced with an LHV would be affected by different route restrictions. Seven vehicle operating scenarios (referred to here as strategies to avoid confusion with the scenarios discussed elsewhere in the report) were considered, which are described in more detail in Appendix G.

It is worth noting that strategy 3 involves coupling / decoupling points on the road network, which at present do not exist. It was considered important to understand the effect this strategy could have on the potential use of LHVs, because it was an idea often discussed by representatives of the road freight industry at focus groups and many proposals/studies elsewhere in Europe have referred to the concept. While regulatory issues relating to network restrictions have been considered in section 5.8 and Appendix E, the cost and feasibility of coupling / de coupling points and land availability and planning constraints would of course need to be considered in detail if there were grounds to consider this strategy further.

The results from the different strategies are shown in Table 21, below.

Table 21. Proportion of 2004/5 CSRGT recorded trips able to be replaced by LHVs

	Trip Records	% diff
All HGV's over 32 tonnes	245,000	
32 - 43 tonnes weight / volume constrained & all 44 tonnes	140,829	57.5%
Candidate trips for LHV use	77,073	31.5%
Strategy 1 - LHV's allowed on all roads	77,073	31.5%
Strategy 2 - LHV's allowed on routes within 20km of a m'way	20,362	8.3%
Strategy 3 - LHV's allowed on motorways only	47,241	19.3%
Strategy 4 - LHV's within 20km of a m'way or dual carr.	47,240	19.3%
Strategy 5 - LHV's allowed on m'ways, dual carr. & primary	24,650	10.1%
Strategy 6 - Port ISO vehicles	3,170	1.3%
Strategy 7 - 4 goods group & 2 mode of appearance	12,156	5.0%

Each of the trip records contained the:

- Origin and destination (OD) using NUTS4 classification[1]
- Type of intermodal location, if applicable (i.e. port, rail interchange, airport)
- Gross vehicle weight and carrying capacity
- Vehicle characteristics such as body type and axle configuration
- Industry sector / type of goods
- Mode of appearance (pallet, bulk, etc)
- Weight moved between the origin and destination

In total, 77,073 trips (over a 2 year period 2004/5) were included in the analysis. Of these, 16.7% were weight constrained, 33.5% volume constrained, 39.9% weight and volume constrained, and 9.9% (all on 44 tonne vehicles) unconstrained.

A digitised road network was used to produce routes for each origin and destination pair. Average speeds for each road category were used to calculate the travel time on each link and the quickest route between each OD pair was found using a shortest path algorithm.

The capacity of LHVs was based on the maximum number of pallets on the LHV divided by 26 (the number of pallets assumed to be carried by an existing articulated vehicle). If the resultant weight exceeded the maximum payload of the LHV, the volume on the LHV was reduced accordingly. For weight constrained trips, the weight carried by the LHV was increased by the maximum payload of the LHV divided by the maximum payload of the existing vehicle. Weight constrained trips were ignored if the LHV was payload negative (i.e. the maximum payload weight was lower than that of

[1] NUTS stands for Nomenclature of Territorial Units for Statistics and is a European Union classification, used for statistical purposes, which divides European countries into areas at different hierarchical levels. Level 3 equates approximately to county and unitary authority boundaries. NUTS4 is a more detailed subdivision of these boundaries.

the existing vehicle undertaking the trip). For trips that were neither weight nor volume constrained, both options were considered and the greater increase used.

The network restriction strategies included permitting LHVs on:

- All roads
- Routes within 20km of a Motorway or dual carriageway (at least 20km of motorway travel)
- Routes within 20km of a Motorway (origin and destination less than 20km from a motorway, and at least 20km motorway travel)

Table 22 shows the relative impacts of the different route restrictions, assuming the maximum possible take-up of LHVs (the factors discussed in Section 6.1 would restrict the actual take-up substantially) and assuming that the effect of road restrictions is not mitigated by coupling and decoupling at strategic points in the network. These figures include trips by the LHVs and any trips that would continue to be undertaken by existing vehicles.

Table 22: Relative impacts of different route restrictions

Vehicle Case	Gross Vehicle Weight (tonnes) and number of axles	% reduction in vehicle travel compared with base case (assuming maximum possible take-up)		
		All roads	Motorway and dual carriageway	Motorway
3 (longer semi-trailer)	44 tonnes / 6 axles	9%	8%	3%
4 (B-double)	44 tonnes / 8 axles	14%	13%	4%
5 (rigid + semi-trailer)	44 tonnes / 8 axles	15%	13%	4%
6 (B-double)	60 tonnes / 8 axles	34%	27%	9%
7 (rigid + semi-trailer)	60 tonnes / 8 axles	34%	27%	9%
8 (C-train)	82 tonnes / 11 axles	52%	41%	13%

The modelling indicated that the more roads available to LHVs, the greater the possible reductions in trips would be, in the absence of mode shift or induced demand (which were assessed separately). The greatest reductions for travel would be for 82-tonne LHVs allowed on all roads, with a 52% reduction in distance travelled. The lowest impacts for this strategy were for the longer semi-trailer – the reductions were between 8% and 9%. Restricting LHVs to Motorways (and routes within 20km of Motorways) would reduce these figures by 65%-75%. Restricting them to motorways and dual carriageways only would be a much smaller limitation of 11%-21%.

One further restriction on routes that could be considered would be to prevent LHVs from carrying ISO containers on routes to and from ports, in order to help minimise any modal shift from rail. If this type of policy were to be implemented, the analysis suggests that the reduction in trips if LHVs were allowed on all roads would be approximately 4.3% lower than suggested above.

6.3 Vehicle utilisation and average loads

A general view expressed at the road freight focus groups was that the load factor on laden LHV trips would be higher than for current HGVs, and the level of empty running lower. This was based on the reasoning that, given their higher capital cost and tighter route restrictions, LHVs would tend only to be used on routes offering good loading potential in both directions. A conflicting view was that the network restrictions imposed on LHVs would limit their ability to deviate from approved routes to collect backloads. This could have the effect of increasing their level of empty running.

The CSRGT has no measures of volume utilisation. The only available volumetric statistics (relating to deck area / pallet slot utilisation) come from the transport key performance indicator (KPI) surveys undertaken in the food, non-food retailing, pallet-load and parcel sectors (DfT, 2005, 2006a, 2006b, 2006c). For articulated vehicles, the average deck area utilisation figures for these sectors are, respectively 69%, 74%, 80% and 69%, significantly above the comparable weight-based utilisation factors. These sectors, however, are characterised by lower density products and tend to 'cube-out' before they 'weigh out'. Their average deck area utilisation is therefore likely to be above the average for all road freight, though it is not known by how much.

Deriving predictions of the vehicle utilisation for a range of vehicles which offer either increases in volume and a decrease in payload, an increase in volume only, or an increase in both volume and payload while introducing new, untested, route restrictions is, therefore, very complex. The views from the stakeholders suggested that the fact that route restrictions might limit backloading opportunities was likely to contribute to a lower take up rate rather than an increased level of empty running. It is also likely that, although stakeholders suggested that LHVs would tend to be used on trips with higher than average utilisation, many of those trips would be replacing trips with standard articulated vehicles with higher than average utilisation. Thus, it would be expected that the average load of those trips that were still carried out by standard articulated vehicles would decrease. However, this would not always be the case.

The stakeholders have also expressed the view that many loads are not constrained by volume or weight directly but by the size of the consignment. This can be related to the concept of just-in-time delivery where it is possible, for example, that there is a need to deliver 39 pallet loads of goods at a specified time. Currently, this would require two articulated vehicles or one double decked articulated vehicle, each of which would be 75% full. The same load could be carried on a single 25.25m LHV, which would be 98% full, a 30% increase in load factor. Equally, the size of the consignment can relate to the physical size and mass of each unit of load. For example, steel is often shipped in large coils. If a steel coil weighs 19 tonnes it may be carried on a 38 tonne articulated vehicle, which would be approximately 73% of its maximum payload weight. However, if 60 tonne LHVs were permitted it is likely that two coils could be shipped on the same vehicle, which would mean that the LHV was 96% full, a 32% increase in load factor. Thus it could be argued that having a greater selection of vehicle types available would improve the ability of the road haulage industry to use the right sized vehicle for each load, thus increasing load factors.

However, it has also been noted that backloads can be difficult to source and are often only partial loads that do not fill the vehicle. It is possible that an LHV could be used on a route where the outbound load factor is very good but the return load is no bigger than it would have been if a standard articulated vehicle was used. This would have the effect of reducing the average load.

The factors influencing vehicle utilisation are, therefore, finely balanced. For this reason, the later analysis of costs and benefits (see Appendix H) has assumed that empty running and average load would be the same in percentage terms as for current single decked articulated vehicles.

6.4 Estimating take-up rate

If LHVs were to be permitted in the UK it is likely that goods would be transferred mainly from current single decked articulated vehicles. The analysis of CSRGT trip data (see section 6.2) has shown that the amount of freight transferred would be limited to a maximum of approximately one-third because the remaining trips would be unsuitable for transfer to LHVs. Restrictions to certain classes of roads would reduce the maximum possible transfer considerably more.

The information gathered from the road freight industry has also suggested that the take-up of LHVs would be relatively low and that they were likely to be used in niche applications in particular markets such as pallet networks, primary distribution of fast-moving consumer goods (FMCG) etc.

The experience of operating LHVs in other countries can provide important contextual information. In Sweden, Vierth *et al* (2008) showed that 74% of tonne kms were transported by LHVs (defined as vehicles in excess of 40 tonnes and with 7 or more axles). In Australia, Moore (2007) shows that more than half of all tonne kms are transported by B-doubles and road trains. These are both very high proportions of road freight that are carried by LHVs. However, this is likely to reflect the fact that the use of very large vehicles is quite mature in both countries and both will have freight routes travelling long distances through sparsely populated areas. Arcadis (2006) describes the result of the recent trials in the Netherlands, which led to an estimate that between 7% and 31% of those tonne kms currently carried by vehicles with a GVW in excess of 20 tonnes would transfer to 25.25m vehicles at 60 tonnes. In the USA, Craft (undated) reports that in 1994 just 2% of articulated vehicle-kms (which will translate into a higher proportion of tonne-kms) were transported by what they define as 'longer combination vehicles'. The restrictions applied in terms of access to the road network were cited as one of the reasons for the relatively low distance travelled by such vehicles, although it is worth noting that the standard combination vehicle in the USA is permitted to be longer than those in the UK. The proportion may also have grown since 1994.

Analysis of CSRGT statistics identifies commodity classes subject to high levels of load weight- and volume- constraint. The commodity classes most likely to benefit from the volume only or payload neutral LHV scenarios correspond quite closely to sectors identified by the industry fact-finding exercise as being likely to adopt LHVs. Only five commodity groups have 40% or more of their laden-kms constrained by volume but less than 20% constrained partly or wholly by weight:

- *Miscellaneous articles*: this category contains parcel and pallet-load movements as well as mixed retail supplies in the Fast Moving Consumer Goods (FMCG) sector.
- *Other foodstuffs*: including grocery products
- *Miscellaneous manufacturers:*
- *Machinery and transport equipment:*
- *Other metal products*

Collectively these five commodity groups account for 61.25 billion tonne-kms, which represents 53% of all tonne kms transported by articulated vehicles and 68% of tonne-kms transported by articulated vehicles that were subject to a volume constraint but not a weight constraint. In keeping with the expressed view that LHVs will have niche applications, it has been estimated that the degree of volume-constrained load migration to LHVs at 44 tonnes in these commodity groups would vary between approximately 5% and 10%. This approximately translates to a transfer of between 2.75% and 5.5% of all tonne kms currently carried by articulated vehicles (2.1% to 4.2% of all goods moved by HGVs>3.5 tonnes).

Partly on the basis of the fact-finding exercise, five sectors have been identified as the potential beneficiaries of an increase in weight carrying capacity:

- beverages
- wood, timber and cork,
- iron and steel products,
- other building materials
- agricultural products

These commodity groups represent a total of 29.52 billion tonne-kms. A similar range of 5-10% constrained-load migration to LHV has been estimated for these commodity groups. This has been assumed to represent a 5%-10% transfer to 60 tonne plus LHVs of all tonne kms currently carried by articulated vehicles when the volume benefits have also been considered.

The discussions with the freight industry suggested that fewer companies would benefit from a longer semi-trailer. It has, therefore, been assumed that the take-up of this vehicle would be half that of the volume constrained transfer to larger LHVs at 44 tonnes. This translates to an estimate of between

1.38% and 2.75% of all articulated vehicle tonne kms, a proportion broadly comparable to the current share of drawbar vehicles.

6.5 Estimating Modal Shift

If LHVs were to be permitted they would reduce the cost of road transport, which has the potential to lead to transfers of freight traffic from rail or water to road. Discussions have been held with the main rail freight operating companies, current rail freight users, shipping lines, port operators, relevant trade bodies and pressure groups. In addition to this, two of the main rail freight operators provided written reports to the project assessing the effects in their market sectors (predominantly bulk goods and maritime containers). These reports reflected the discussions in the focus groups and supported the views with various analyses. The first of these, by EWS, has been published on the internet and cited in a position paper from a consortium of European rail freight organisations.

The discussions with organisations in the shipping and ports sectors combined with the analysis of waterborne freight data has suggested the mode shift from waterborne freight to road is unlikely. The later analysis of costs and benefits has, therefore, assumed that there will be no shift of waterborne freight to LHVs.

The rail freight market can be divided into five parts:

- bulk commodities, (principally coal and aggregates, which have very different commercial characteristics)
- deep-sea containers,
- domestic intermodal,
- wagonload and rail-infrastructure traffic.

In 2005, approximately 88% of total rail tonnage fell into the first two categories (See Table 4). Domestic intermodal accounts for a relatively small, but substantially growing, quantity of rail freight. Wagonload is a very small and declining sector, while the internal infrastructure traffic carried for Network Rail, though accounting for a substantial tonnage, is not considered to be at risk of diversion to road. Attention was therefore focused on the likely impact of LHVs on the movement of bulk commodities and deep-sea containers, although operators working in the other sectors were also invited to contribute their views and a basic econometric analysis of the impact in the domestic intermodal market was undertaken.

6.5.1 Rail – bulk commodities

Bulk commodities, comprising mainly coal, metals, construction materials and oil, currently account for around two-thirds of rail tonne-kms. LHVs would only capture bulk rail freight traffic if their maximum payload weights were higher than those of existing vehicles. It was, therefore, considered that the 44 tonne and payload neutral scenarios would not lead to any significant transfers of bulk commodities from rail to road. There was a general consensus among rail freight users and a wider group of freight and logistics specialists that little, if any, coal, traffic would transfer from rail to heavier LHVs because of the integration of rail into the processes at origins and destinations as well as the price advantage for rail. There was evidence to suggest that some steel and aggregates traffic could transfer but the stakeholder views differed for these commodities. In particular, stakeholders in the aggregates industry considered that if a policy decision was made to restrict LHVs to the trunk or primary road network, this would deny them access to many of the sources and/or destinations of bulk traffic currently moved by rail. These conclusions were disputed by rail freight operators and written evidence from the rail industry did suggest, based on estimates of price elasticity, that significant quantities of bulk rail could move to road. Analysis was provided to support this conclusion, although it was based on estimates of cross price elasticity that were not empirically based and were derived from a figure for the price elasticity of demand for road freight that was based on the North American freight market of the 1970s and 1980s.

Table 23 shows the estimates of mode shift that have been applied to the bulk rail market in the later analysis of costs and benefits. These estimates were based upon consideration of the various subjective views expressed by stakeholders and the analytical evidence provided by the rail industry. TRL also undertook a simple, independent, econometric analysis based on the cost reductions identified within this research and published elasticity values (see Appendix section F.16.3.2 for details). This analysis showed the level of uncertainty inherent in the estimating methods but did suggest that, overall, the estimates shown in Table 23 were reasonable.

Table 23. Estimates of mode shift in the bulk rail market

Scenario	Proportion of bulk rail tonnekms moving to road (%)	Bulk rail as a proportion of all rail tonnekms (%)	Proportion of all rail tonne kms moving to road (%)
44 tonne	0	67	0
60+ tonne	5-10	67	3-7

6.5.2 Rail – deep-sea containers

Deep-sea container traffic through UK ports is expected to grow at a substantially faster rate than expected in other freight sectors and is, therefore, a very important current and future market. It was widely acknowledged in the information gathering exercise that the movement of deep-sea containers to and from ports (particularly Felixstowe and Southampton) is likely to be the existing major rail freight sector most vulnerable to mode shift if LHVs were to be permitted. At present it is possible to carry one 40 ft (12.2m) or two 20 ft (6.1m) containers on an existing 13.6m semi-trailer. A 25.25m LHV would be able to carry a 40ft and a 20ft container on the same vehicle, while the 34m LHV would be able to carry two 40ft containers. This would substantially reduce the road transport cost per container. The container haulage market has always been very price-sensitive – container shipping lines account for 80% of this market and their purchase decisions are essentially price-based.

The prediction of modal shift in this sector has been based on an econometric analysis using cross-elasticity values of 2 and 5. This is a slightly lower range than that of 2.5 from MDS transmodal (ORR, 2006) and the estimate of 6 provided to the project by the rail industry. However, these higher values have been moderated slightly to represent the fact that they will have related to the price sensitivity of a market characterised by the fewer constraints of standard articulated vehicles and that greater constraints would be likely to apply to LHVs. The elasticity values are applied to the estimated reduction in road vehicle operating costs per TEU (Twenty foot Equivalent Unit) from replacing an existing articulated HGV with a 25.25 m LHV operating at 60 tonnes. This suggests a potential loss of rail container traffic of between 22% and 54%.

The rail industry has also provided evidence that the average weight of a loaded 40’ container is 16.6 tonnes and it has, therefore, been assumed that the average weight of a loaded 20’ container will be 8.3 tonnes, giving a total of 24.9 tonnes in combination. The payload capacity of a 44 tonne 25.25m LHV would be approximately 23.5 tonnes. Although the distribution of container weights around the average is not known, it is reasonable to assume that it follows a normal distribution. This means, therefore, that it is likely that just less than half of all loaded containers could be carried by a 44 tonne 25.25m LHV.

None of the stakeholders considered that an 18.75m articulated vehicle with a longer semi-trailer would present a substantial risk of mode shift in the deep sea container market because it would not increase the number of 20 foot or 40 foot containers that could be carried.

The later analysis of costs and benefits has, therefore been based on the estimates of mode shift in the deep sea container market as shown in Table 24, below.

Table 24. Estimates of mode shift in the deep sea container market

Scenario	Proportion of container tonne kms moving to road (%)	Deep sea container tonne kms as a proportion of all rail tonne kms (%)	Proportion of all rail tonne kms moving to road (%)
18.75m articulated vehicle (44t)	0	21	0
25.25m (44t)	11-27	21	2.5-5.5
60+ tonne	22-54	21	5-11

TRL also undertook a simple, independent, econometric analysis, which again showed the uncertainty in the analysis, particularly in relation to the quantity of road hauliers in this sector that would choose to use LHVs given the constraints at origins and destinations and any route restrictions that might be applied if the vehicles were to be permitted. It was proposed, therefore, that the central estimates to be used in the later analysis of costs and benefits would be based on the values in Table 24. However, in order to test the boundaries of these uncertainties, additional input values were assessed in the model to represent, firstly, a situation where the take-up of LHVs in the road market for deep-sea containers was 100% and, secondly, where a take-up in the road industry of less than 100% meant that the mode shift was less (approximately 16%) than predicted in Table 24.

However, it should be noted that all of these estimates take limited or no account of the following factors:

- The possibility that the estimated mode shift could undermine the rail resource base, thus contributing to service closures and generating further mode shift.
- The proportion of 20ft containers is steadily declining. Over time this could reduce the opportunities for combining 20ft and 40ft containers on 25.25m LHVs, reducing the likely magnitude of mode shift.
- The major container ports have a preference for the surface movement of containers by rail because this helps to relieve congestion. A single container train can replace up to 50 separate road movements to and from a port, each of which has to be separately scheduled and registered.
- the working practices of ports in terms of the congestion effects within the port of loading a mixture of 20 foot and 40 foot containers onto one vehicle
- the effect of route or operational restrictions on the ability of LHVs to access ports and deliver containers directly to their destination without trans-shipment
- the adequacy of facilities at destinations for LHV deliveries

In addition to the above, it should be noted that concerns have been raised by some stakeholders that current rail infrastructure may not have the capacity to meet the projected increase in demand for container transport from ports. However, the Government paper “delivering a sustainable railway” (DfT, 2007) states that rail infrastructure improvements are currently under consideration that would relieve these congestion concerns and enable rail to meet the projected increased demand. It further states that Network Rail have set aside £200million of investment to facilitate these improvements which would be expected to be recovered from users over time. The Government have also announced that approximately £150million investment will be made available from the Transport Innovation Fund.

Road congestion in and around ports may also represent a substantial constraint on the use of existing HGVs in port operations. A report by MDS Transmodal (2007) examined port demand and suggested that, in the absence of capacity constraints, rail traffic from ports will increase by 140% by 2030 and road traffic from ports will increase by 106% in the same time period (note that this report took no account of the possibility of introducing LHVs). If, as many stakeholders have suggested, the ports are currently suffering substantial road congestion problems then major infrastructure changes may be required to accommodate the predicted 106% growth in road traffic. These constraints could substantially increase the modal preference for rail. Under these circumstances, it is possible that the use of LHVs could help to mitigate the congestion problems around ports without inducing the mode shift predicted by a purely econometric analysis.

In the later analysis of costs and benefits it has been assumed that rail will not suffer capacity restrictions. Also the investments in rail infrastructure have not been specifically included in the model. If the network rail investment is recovered via an increased use of the line and thus increased track access charge revenue then the investment cost is covered by the inclusion of running costs for rail, provided that track access charges do not increase as a result of the investment. However, if additional government investment is made and is not recovered from the track access charges then this would represent an additional cost that is not currently considered by the model. The potential investment that may be required in road infrastructure in order to accommodate the predicted growth in road traffic has also not been quantified in the analysis of the costs and benefits of a business as usual model. Quantifying and incorporating these investments has the potential to substantially change the outcome of the model.

6.5.3 Rail – domestic intermodal

The domestic intermodal market is currently small but is predicted to grow by as much as 225% or 746%, depending on the estimation method used (see Table 6). This represents a mode shift from road to rail that would result in rail having a share of the relevant long distance traffic on Midlands – Scotland routes of as much as 28% or 72% (depending on the estimate of growth). Mode shift for the larger vehicles assessed in this research (25.25m+) is likely to remain dominated by other markets but the effect that the 18.75m articulated vehicle could have in preventing this growth was assessed by assuming that the growth would take place and then assessing mode shift from rail to road on the basis of cost reduction and price elasticity. The mode shift factors were adapted to account for the fact that the cost model (see section 7.2) does not segregate the different rail markets from the total. This assessment suggested that mode shift estimates of 0.25% to 0.75% of all rail tonne kms would be appropriate to account both for the mode shift from rail to road of existing domestic intermodal traffic, and for the prevention of future mode shift from road to rail that would otherwise be expected to result in the growth of the domestic intermodal market.

6.5.4 Overall effect on rail traffic

The overall effects on rail traffic are generated by simply adding the effects on all rail tonne kms for each vehicle type from each market. On this basis, the overall impact of the LHV scenarios assessed on the total quantity of railfreight tonne-kms was estimated to be:

- 18.75m articulated vehicles with 44 tonne GVW: 0.25%-0.75%Tkm shift
- 25.25m, 44 tonne LHVs: 2.5%-5.5% Tkm shift
- 60 tonne+ LHVs: 8%-18% Tkm shift

It should be noted that these estimates are based on the best evidence that could be generated within the scope of this project. However, they do include substantial elements of subjective judgement to resolve the uncertainties remaining when the econometric analyses provided to the project by the rail industry, the views of other stakeholders, the independent econometric analyses and the potential additional constraints on LHV use, if permitted, are all considered.

The recent trial of LHVs in Holland, where 25.25m LHVs were permitted to operate on selected routes at 60 tonnes GVW, led to a prediction that a more widespread introduction of LHVs would result in a mode shift from rail to road of between 1.4% and 2.7%. It can be seen that this is considerably lower than the above estimates for the UK. While the trial meant that the Netherlands had considerably more objective evidence available with which to quantify the effects, it is also likely that fundamental differences in the freight markets in each country, for example the large proportion of international rail freight in the Netherlands, contribute to the difference in the magnitude of effects predicted.

6.5.5 Payload neutral scenarios

The concept of scenarios where the permitted GVW was increased but only by enough to give the vehicle the same payload capacity as a standard 44-tonne articulated vehicle was introduced part way through the project. As such, this concept could not be fully evaluated in the analysis of costs and benefits because the detailed assessments of impacts such as fuel consumption and emissions could not be carried out within the available resources. The effects expected for such vehicle combinations were, therefore, estimated on the basis of linear interpolation of the results derived from the model (see section 7.2).

However, in order to put the results in context and to assess their plausibility it is possible to apply the same interpolation techniques to the mode shift inputs defined above to give the equivalent mode shift percentages implied by the results for the payload neutral scenarios. These can then be compared with the information from stakeholders to assess their likely validity. The results are shown in Table 25, below, but it should be noted that the estimated mode shift percentages for the payload neutral scenarios shown were not used as inputs to the cost model.

Table 25. Mode shift percentages including interpolated estimates for payload neutral scenarios.

Scenario	Low	High
18.75m 44 tonnes	0.25%	0.75%
18.75m c.46 tonnes (payload neutral)	1.59%	3.68%
25.25m 44 tonnes	2.50%	5.50%
25.25m c. 50 tonnes (payload neutral)	4.40%	9.82%
25.25 60 tonnes	8.00%	18.00%
34m 63 tonnes	8.00%	18.00%
34m 82 tonnes	8.00%	18.00%

The 18.75m payload neutral scenario is an interpolation between the 18.75m 44-tonne articulated vehicle and the 25.25m 44 tonne vehicle, based on the change in weight. It can be seen that the mode shift implied by the interpolation technique is considerably higher than for the 44 tonne version of the same vehicle. If the mode shift had been estimated by assessing the reduction in cost derived from the additional weight capacity and multiplying by the same elasticity values used for the 44 tonne vehicle then it is likely that the predicted mode shift would be lower. This is because the interpolation technique applied to the 18.75m 46 tonne (payload neutral) vehicle effectively includes a proportion of the mode shift attributed to the 25m, 44 tonne vehicle, which was based on its ability to carry two maritime containers. The 18.75m vehicle can only carry one maritime container and as such, it is highly likely that the interpolation over-estimates the mode shift effect.

Similarly, the 25m payload neutral version is an interpolation of the 44 tonne and 60 tonne versions of the same vehicle, based on payload weight capacity. Thus, a proportion of the mode shift in both the bulk rail and deep sea container markets that is attributed to the 60 tonne vehicle is also attributed to the payload neutral version. The deep sea container mode shift is appropriate because a greater proportion of the full range of container weights could be carried on a payload neutral vehicle than on a 44-tonne version. However, the proportion of the bulk rail mode shift that is effectively attributed would not, in reality, be appropriate because, by definition, a payload neutral scenario does not offer any economic advantage to the carriage of goods that are already weight constrained on a 16.5m 44-tonne articulated vehicle. Thus, this also slightly over-estimates the mode shift effect.

6.6 Projected Traffic Generation

Reducing the cost of moving freight by road could generate additional freight movement. However, the predictions made by previous studies appear to have substantially over-estimated the level of traffic generation. Reviewing the impact of the 44 tonne lorry weight increase, three years after its introduction, McKinnon (2005) concluded that:

"There is little evidence .… that the truck weight increase has, as yet, generated much additional demand for road freight movement".

In the information gathering exercise stakeholders were asked whether transport cost reductions from the use of LHVs would be likely to encourage further centralisation of logistics and / or wider sourcing of supplies. Fewer than 5% of road freight industry representatives believed that the use of LHVs would promote structural change resulting in higher freight transport demand. One sector in which this might occur is forestry where the geographical extent of harvesting is constrained by the high cost of road transport relative to the sale price of the product transported. In most other sectors, companies' production and logistics systems were felt to be already highly centralised and their patterns of sourcing and distribution are already very extensive (both within the UK and internationally), leaving little scope for further geographical reorganisation. Many companies also argued that use of LHVs would be confined to particular routes and operations and therefore would be unlikely to induce much system-wide restructuring. The vast majority of the focus group delegates also doubted that LHV-related cost reductions would stimulate much additional freight traffic growth.

Nevertheless, allowance was made for some traffic generation in the parametric model described in section 7. A range of price elasticity of demand values for road freight between 0.02 and 0.04 was used in the analysis. These were only applied to those market segments that would be likely to use LHVs if they were permitted.

7 Estimated costs and benefits of LHVs

It can be seen from the evidence presented in this report that there are a large number of variables that could affect the costs and benefits if the use of LHVs were to be permitted in the UK. Wherever possible these effects have been enumerated and incorporated as inputs to a parametric model of the total on-going costs (i.e. both the internal operating costs and those of externalities such as road casualties and vehicle emissions) of domestic freight transported by rail and by articulated heavy goods vehicles. This enabled the costs to be evaluated for each of the vehicle types and scenarios described above given a range of different input variables. In addition to this, there are a range of risk or opportunity factors to which it has not been possible to assign monetary values. These are described in detail in Appendix H and summarised below.

Most of the factors that could not be quantified financially represented capital investments that might be required to resolve potential problems with the widespread implementation of LHVs. Thus the net effects on the on-going transport costs can be considered the "benefits" of permitting LHVs, subject to the risk of a small number of unquantified effects, while the capital investments that may be required can be considered as the costs of such a move. The fact that most of the capital investments required could not be quantified accurately within the scope of this work has meant that it was not possible to calculate reliable benefit to cost ratios and the final conclusions are based on subjective judgements as to whether or not the calculated benefits are likely to exceed the unquantified costs.

7.1 Effects which could not be financially valued within the scope of this project

During the analysis a number of potential effects were identified, which could not be evaluated financially within the constraints of this project. The main such effects are listed below:

- **Bridge loading:** Based upon a conservative analysis, a 34 metre vehicle at 82 tonnes GVW was found to exceed the HA bridge design loads, both vertical and longitudinal (braking) loads, for standard vehicles for certain mid-range spans of bridge that were not designed to accommodate Abnormal Indivisible Load vehicles. This presents a higher risk of causing wear and damage to a relatively small proportion of bridges on the trunk road network. A number of trunk road bridges may, therefore, require strengthening or increased maintenance if such vehicles were permitted. Assigning a cost to this activity would be a major exercise that was beyond the scope of this project. For the other vehicle types assessed loads were below the HA design loads and were, therefore, not expected to cause any additional problems for bridges conforming to the latest standards. However, there may be a large number of bridges in local authority control that do not meet those standards and a comprehensive review of bridge standards may be required if any LHVs were permitted where an increased GVW would lead to a greater load per metre of bridge. It may also be possible that many of these bridges would already be inadequate for existing 44 tonne vehicles and may, therefore, already be appropriately restricted to heavy traffic and appropriately signed. These issues have not been assigned a cost in the parametric model.

- **Collisions with bridge supports:** Vehicle types with an increased GVW would apply additional forces to bridge structures if they collided with them. However, the minimum standards to which bridge supports and their protective standards are designed contain lower force requirements than would be applied by current articulated vehicles travelling at 56 mile/h. If structures are built to just pass these minimum requirements then it is possible that permitting LHVs at higher maximum weights would not represent an additional risk. This issue would require further investigation, likely to include physical testing, if higher maximum weight vehicles were to be considered. The cost of such an investigation and, if applicable, any remedial work required has not been included in the cost model.

- **The feasibility of providing additional parking and/or interchange points for LHVs:** There is a risk that providing such improvements may be difficult, even if the financial investment were made available, because existing MSAs are often not owned by Government, there may be little incentive for private MSAs to invest in facilities for trucks, there is a scarcity of available land in areas likely to require facilities, and planning permission would be required. These problems are not considered likely to be insurmountable if Government policy was to develop such facilities for the benefit of the economy but will require further investigation if the possibility of permitting LHVs in excess of 18.75m is to be investigated further. It is considered that 18.75m articulated vehicles would not be substantially affected by this risk.

- **The interaction of UK regulations with EU Directives and the effects on the HGV fleet:** The options assessed in the parametric cost model were based on the assumption that the UK regulations could be amended independently. However, if UK regulations were amended without suitable amendments of European regulations then some changes could potentially result in even larger vehicles becoming permissible under Council Directive 96/53. This has not been quantified financially.

- **Undermining the rail resource base:** If the introduction of LHVs resulted in a substantial reduction in rail traffic then this could undermine the financial viability of some rail services such that they would have to be withdrawn completely. This could result in further mode shift, further undermining the resource base and so on. It has not been possible to fully assess the potential implications and the cost of such a process within the scope of this project.

- **Government investment in rail infrastructure:** The Government announced in October 2007 that it will provide capital investment of approximately £150million from the Transport

Innovation Fund to improve rail capacity through rail infrastructure improvements. However, this announcement was made after the cost benefit analysis had been completed and the cost of the investment could not be included in the model.

- **Port congestion:** Predictions of the use of the UKs sea ports has suggested that, in the absence of capacity restrictions, road freight traffic from UK ports will increase by 106% by 2020. Stakeholders report that the roads in and around the UKs main ports are already very congested. It is possible, therefore, that extensive investment in the road infrastructure around ports may be required to ease these congestion problems if other solutions could not be developed. If capacity limited growth that may have adverse economic effects. These capacity constraints may act to limit the predicted mode shift because of the need for all available capacity. It has not been possible to fully assess and cost these factors within the scope of this project.

7.2 Parametric cost model

7.2.1 Overview

The parametric model has been developed as a complex spreadsheet model. A more comprehensive description and a definition of the fields included and the relationship between fields is provided in Appendix H. The model is based on predictions of annual freight traffic by road and rail and the following input information for each of the different vehicle types and transport modes (i.e. road and rail), including:

- Operational costs
- Environmental costs
- Accident costs
- Infrastructure costs
- Miscellaneous costs (e.g. admin/enforcement costs)
- Take-up rate
- Mode shift
- Induced demand

Information on each of these inputs was generated by the analyses described in the other sections of this report. Many of these impacts can be assessed for different assumptions (e.g. euro emissions level, fuel cost, requirements for additional safety measures etc.).

The principle output of the analysis of each case is a total cost of UK freight transport for the years 2006-2020 but any of the main variables, such as number of fatalities or tonnes of CO_2, can be extracted. The different scenarios were analysed by subtracting key parameters in the baseline case from the key parameters in the policy option under consideration. These included the total transport costs, the volume of traffic by heavy goods vehicles (vehicle kms), the tonnes of CO_2 emitted, and the number of fatalities from accidents involving heavy goods vehicles. Negative values represent a benefit and positive values represent a dis-benefit.

7.2.2 Results

An analysis of the sensitivity of the model has, perhaps unsurprisingly, supported the views of stakeholders that the estimate of net changes in on-going costs are most sensitive to the input estimates of take up rate and mode shift. The impact analysis could not predict these inputs with certainty so the results have been expressed in terms of the effects if the take up rate and mode shift were at certain levels. This enables the potential effects of a decision to permit LHVs to be identified as well as the critical levels where benefits become disbenefits. The net on-going effects are then identified for a range of combined inputs reflecting the estimates of mode shift and take up on the basis of the analysis and the information gathered from stakeholders.

Factors such as the emissions level that engines are approved to (Euro 4 or 5 etc) and the price of diesel were found to have only a relatively small affect on the results, largely because the results were comparisons of scenarios that were all affected by such changes.

7.2.2.1 Sensitivity to take up rate

In this section, the take up rate has been considered in isolation in a manner intended to identify the level of benefit that could potentially be achieved if LHVs were permitted and any negative factors could be controlled. It has been assumed that for each level, LHVs will be restricted to motorways and all rural “A” roads, with the exception of the longer semi-trailer. The reason for this exclusion is that there was little evidence identified to suggest that a longer semi-trailer should be restricted any more tightly than current vehicles, provided that it could meet the manoeuvrability criteria already in existence.

It has also been assumed in this section that LHVs would be restricted to Euro 5 engines and the range of additional safety devices discussed in the report would become a requirement.

The take up rate was based on values categorised from very low to very high. However, there are fundamental factors affecting the likelihood of take-up rates for LHVs so, in order to provide a fair comparison of vehicles, the take up rates have not been applied uniformly to each vehicle type. For volume only increases, it has been assumed that such vehicles would only be adopted in sectors where volume constraints are common and, as such, it has been assumed that the take up of volume only increases would be only 55% of that of volume and weight increases. In addition to this, the longer semi-trailer was viewed less favourably than longer vehicles by industry stakeholders so it has been assumed that the take up of that vehicle will be only half of that of the 25.25m 44 tonne vehicle. The rates assumed are shown in Table 26, below. It should be noted that the “low” and “high” categories correspond to the best estimates of the actual likely take up proposed in F.16.1.

The model was based on a prediction that in the business as usual scenario the total quantity of goods moved by current articulated vehicles would be approximately 116 billion tonne kms in 2006 and approximately 121 billion tonne kms in 2020, giving an average per year of approximately 118 billion tonne kms per year. Thus if the take up rate of an LHV type was 10% then on average 11.8 billion tonne kms would be carried by the LHV.

Table 26. Take up rates assumed for sensitivity analysis

Scenario	Take up rate				
	Very low	Low	Medium	High	Very high
18.75m 44 tonnes	0.69%	1.38%	2.06%	2.75%	3.44%
18.75m Payload neutral	1.04%	2.07%	3.11%	4.14%	5.18%
25.25m 44 tonnes	1.38%	2.75%	4.13%	5.50%	6.88%
25.25m Payload neutral	1.76%	3.53%	5.29%	7.06%	8.82%
25.25 60 tonnes	2.50%	5.00%	7.50%	10.00%	12.50%
34m 63 tonnes	2.50%	5.00%	7.50%	10.00%	12.50%
34m 82 tonnes	2.50%	5.00%	7.50%	10.00%	12.50%

The total cost calculated by the parametric model includes the operation costs of vehicles and emissions for road and rail as well as the costs of road wear and accidents for the heavy vehicle fleet. As such it represents the net ongoing internal and external costs of road transport. However, it does not include any initial capital investments that may be required to enable LHVs to be permitted, for example, the costs of providing specific parking provision. An estimate of the additional costs of routine administration and enforcement that may be required for LHVs over and above that normally required for standard HGVs has been added. Not all parameters were calculated for rigid HGVs and none were calculated for light vans. The absolute total value may, therefore, not be consistent with other attempts to calculate the total cost of UK freight transport. However, as a comparative tool, the findings are expected to be reasonably accurate. The effects of each LHV scenario, in comparison with the 1st baseline condition (mix of current road vehicles remaining static), is shown in Figure 13, below.

It can be seen that the effect for all LHVs is to reduce the net ongoing costs of transport and that the reduction increases linearly with increasing take-up. As would be expected the larger increases in capacity have the greatest potential cost reductions. The total magnitude of reduction is relatively small in percentage terms. However, it is important to note that the 4.67% cost reduction for the 34 m vehicle at 82 tonnes represents an annual cost reduction in the steady state period (i.e. once the haulage industry has fully adapted and vehicle mix has become constant) of almost £742million per year. Even the 0.03% reduction offered by the very low estimate of take-up for the longer semi-trailer represents approximately £5.25million per year reductions.

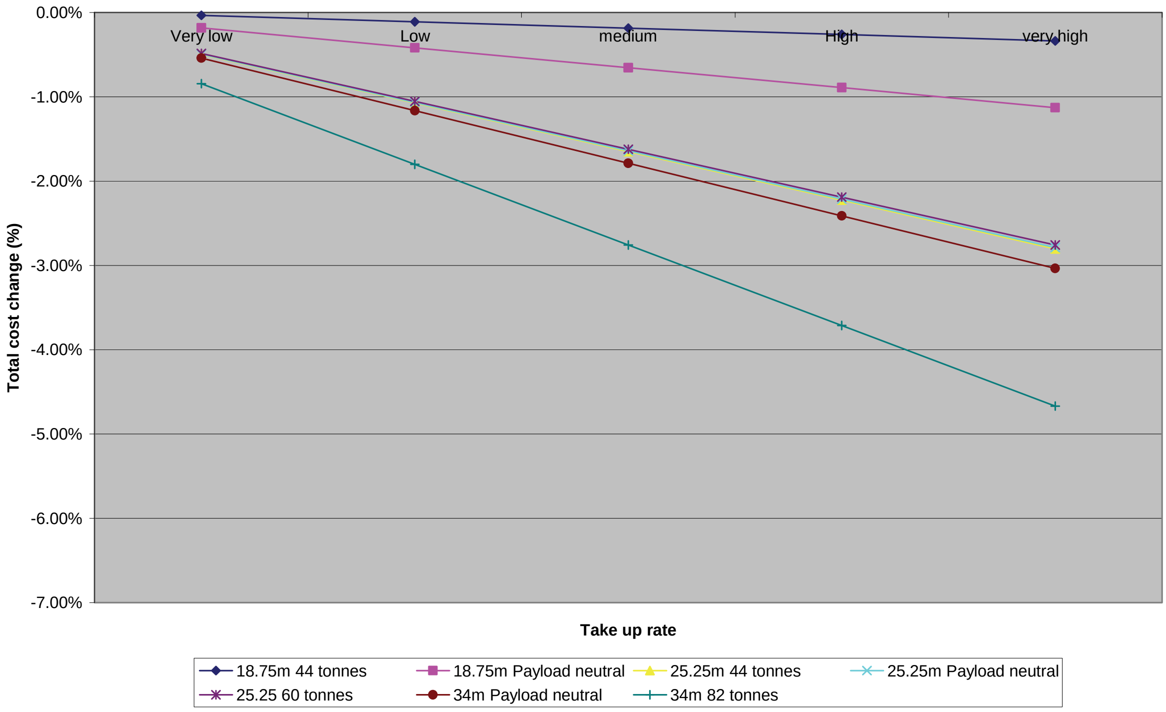

Figure 13. Effect of take-up rate of LHVs on total transport costs, assuming no mode shift or induced demand.

Although the total cost represents all of the main issues of economics, environment, safety and infrastructure using standard financial valuations, and is therefore a measure of the net effect of each of these, it is possible to consider each individually. For example, Figure 14, below, shows the effect on the number of fatalities in comparison with the business as usual scenario (fixed vehicle mix).

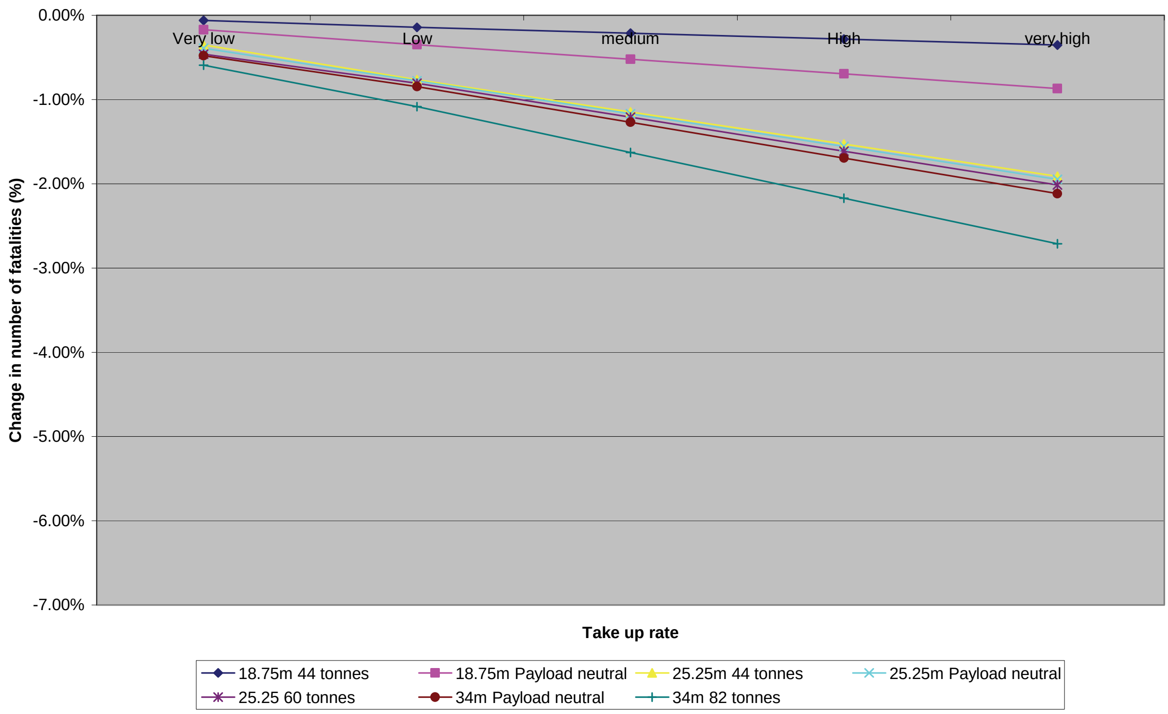

Figure 14. Effect of take up rate on fatalities, assuming no mode shift or induced demand.

There is also a reduction in the number of fatalities, although the magnitude in percentage terms is less than for the total costs. Again, the percentages are small and represent fatality reductions of between one every 2.5 years and 16 per year, depending on the take-up rate and LHV scenario considered. The effect on the other key parameters such as vehicle kms driven and CO_2 emitted is very similar.

It is clear that, in the absence of adverse economic effects on modal split and freight demand, LHVs offer the potential to achieve substantial benefits for safety, the environment and, in particular, the economy.

7.2.2.2 Sensitivity to modal shift from rail

In this section, the results from the analysis of take-up rate described above and the input quantifying mode shift from rail was varied within boundaries intended to represent the outer limits of what the preceding analyses suggested was feasible. The mode shift factors were expressed as a percentage of all rail tonne-kms that would be transferred to road and the entries tested are shown in Table 27, below. The total level of rail freight was predicted to be approximately 22 billion tonne kms in 2006 and 31 billion tonne kms in 2020 such that the average for the period assessed was approximately 26.5 billion tonne kms per year. It should be noted that the low and high categories in the table correspond to the range of effects estimated in F.16.3.5 that were then used in the overall estimate of effects described in Section 7.2.2.4.

Table 27. Mode shift factors evaluated

Scenario	Mode shift from rail				
	Very low	Low	Medium	High	Very high
18.75m 44 tonnes	0.00%	0.25%	0.50%	0.75%	1.00%
18.75m Payload neutral	0.55%	1.59%	2.64%	3.68%	4.73%
25.25m 44 tonnes	1.00%	2.50%	4.00%	5.50%	7.00%
25.25m Payload neutral	1.69%	4.40%	7.11%	9.82%	12.53%
25.25 60 tonnes	3.00%	8.00%	13.00%	18.00%	23.00%
34m 63 tonnes	3.00%	8.00%	13.00%	18.00%	23.00%
34m 82 tonnes	3.00%	8.00%	13.00%	18.00%	23.00%

The logic behind the selection of these values was as follows:

- The low and high estimates of mode shift for the 18.75m 44 tonne, the 25.25m 44 tonne and all 60+ tonne scenarios are based directly on the analysis of mode shift factors described in section F.16.3.
- The very low, medium and very high estimates are based on linear extrapolation and interpolation of the low and high values.
- The 18.75m payload neutral option is an interpolation between the 18.75m 44 tonne and the 25.25m 44 tonne vehicles and the 25.25m payload neutral is an interpolation between the 44 tonne and 60 tonne versions of the same vehicle.

The sensitivity of the CO_2 emitted by freight transport (which was shown to be the parameter most sensitive to modal shift) to these levels of mode shift are shown in Figure 15, below, based on the very high estimates of take-up rate as specified in Table 26.

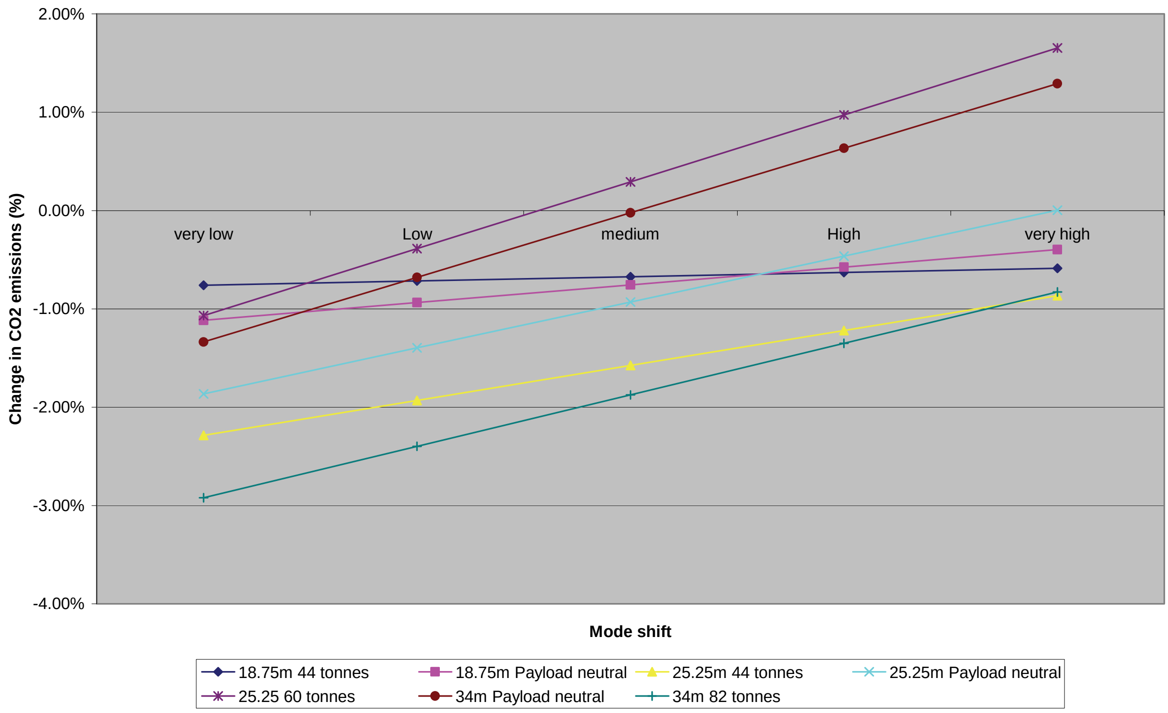

Figure 15. Effect of mode shift on CO_2 emitted assuming very high take-up and no induced demand

It can be seen that the effect of an increase in mode shift is always to increase the total amount of CO2 emitted but that the magnitude of the effect is quite different for different LHV scenarios. For the scenarios involving the 18.75m articulated vehicle the effect is small and the CO_2 emissions in this scenario are always lower than in the baseline case. This is mainly because the mode shift estimates were low because the evidence found during the course of the research suggested that the mode shift that this type of vehicle would actually be likely to cause would be confined to the small, albeit rapidly growing, domestic intermodal market. In fact with a high take-up rate of 3.44% a mode shift of approximately 4.5% would be required to negate the CO_2 savings as a result of consolidation within the road freight sector. For this scenario the highest estimate of mode shift derived by the simple econometric analysis was 1.1% so it is extremely unlikely that sufficient mode shift would occur to cause an adverse environmental effect.

For the 25.25m scenario at 60 tonnes and the 34m scenario at c.63 tonnes (payload neutral), the CO_2 emissions are very sensitive to mode shift and show an adverse effect when the estimate of mode shift is ”medium”. The boundary condition for a high take-up rate of 12.5% for a 25.25m 60-tonne vehicle is that there is zero CO_2 effect when the mode shift reaches approximately 11%.

The 25.25m scenarios with lower maximum weights are also sensitive to mode shift but adverse CO_2 effects were not predicted unless very high estimates of mode shift were entered. This is because of the lower risk of mode shift with these types (no migration from bulk rail or of above average weight containers from the deep sea container market).

For the 34m scenarios at 82 tonnes, the CO_2 emissions are very sensitive to mode shift but the boundary condition is not reached within the range of inputs tested. In fact, with the very high take up rate estimate of 12.5% the mode shift would need to reach approximately 31% to negate the CO_2 saving from consolidation within the road freight industry.

It should be noted that the main body of the analysis in this appendix uses mode shift estimates for the deep-sea container market based on price elasticity values of 2 and 5. The rail industry in this sector had suggested an upper value of 6 should be used. If a value of 6 was used the mode shift for a 60 tonne vehicle would have been approximately 21% instead of 18%. This higher value falls within the range tested in the sensitivity analysis (between high and very high) so the effects would be as described above.

The emissions of CO_2 are particularly sensitive to mode shift because the estimate of emissions per tonne-km calculated for rail is lower than even the lowest emission LHV option assessed. However, the differentials vary for all of the various parameters so it is important to consider the net on-going effects. This is shown in terms of the total transport costs in Figure 16, below, which is defined for the purposes of this model as the total net internal and external cost of freight transport but excludes initial capital investments in infrastructure and the other risks that could not be monetised (see section 7.1).

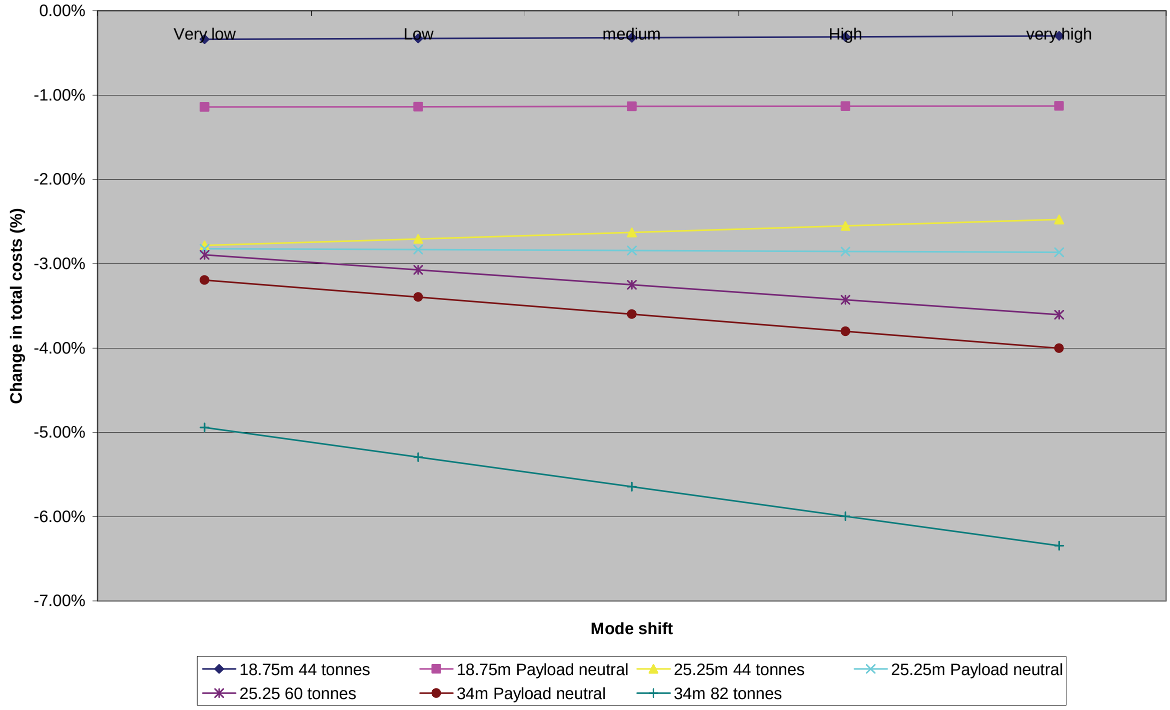

Figure 16. Effect of mode shift on net ongoing transport costs, assuming very high take-up by road hauliers and no induced demand

It can be seen that in all permutations assessed the net ongoing cost of the LHV scenarios is less than the baseline scenario.

The 18.75m options and the payload neutral version of the 25.25m vehicle remain almost unaffected by the estimates of mode shift assessed. For the 44 tonne version of the 25.25m scenario, modal shift reduces the magnitude of the cost reduction. However, the modal shift would have to reach almost 55% before the savings in transport costs were eliminated.

For the 60 tonne 25.25m scenario and both 34m scenarios increasing mode shift actually increases the magnitude of the cost reduction. This is because of the greater differential in terms of operating cost. This means that when the various parameters are monetised using standard valuations the analysis shows that the ongoing economic benefits outweigh the environmental disbenefits, providing there is no induced demand, even if all rail freight were to transfer to these vehicles. However, it should be noted that the heavier vehicles also involve a greater number of risks that could not be quantified financially (e.g. bridge loading, collisions with bridge supports as well as sharing the parking risks identified for all LHVs except the 18.75m articulated vehicle).

The trends and directions shown in the analysis above will remain valid for different estimates of take up rate but the boundary values where effects are neutralised (i.e. the mode shift required to produce an estimate of no net change to a parameter) will change. The boundary values of mode shift assuming a very low take-up rate by hauliers are shown in Table 28, below.

Table 28. Boundary values of mode shift assuming a very low take-up rate and no induced demand.

Vehicle length	Mode shift (%)	
	CO_2	Net ongoing cost
18.75m	0.9%	0.8%
25.25m 44 tonnes	2.15%	10.2%
25.25m 60 tonnes	2.2%	N/A*
34m 82 tonnes	6.2%	N/A*

* indicates boundary condition never reached i.e. there will always be an overall cost reduction irrespective of how much mode shift occurs

It can be assumed that mode shift factors below those for the CO_2 column in Table 28 would mean that benefits would be predicted for all key factors that could be modelled. This would be the case even if the take-up of the vehicles were lower than has been suggested on the basis of other elements of work. For the 18.75m and 25.25m vehicles at 44 tonnes or with a payload neutral weight increase, then values below those shown in the total cost column of the table will mean that the net ongoing benefits outweigh the disbenefits (excluding unquantified risk factors and any initial capital investment required). For the 60 tonne and bigger vehicles then the benefits are likely to outweigh the disbenefits at all levels of mode shift, at least for those factors that could be quantified in monetary terms.

7.2.2.3 Sensitivity to traffic generation (induced demand)

The analysis of traffic generation has been based on factors of price elasticity of demand. If the price elasticity of demand was 10 then a 10% reduction in the price of transport would lead to a 100% increase in the volume transported. However, it is important to note that the price elasticity of demand factor has only been applied to the quantity of goods moved by the LHV scenario under consideration because it is only the LHV under consideration that will offer a reduction in price and, as discussed elsewhere, a variety of other factors will limit the flows on which it can be used.

The effect in terms of trends and directions will be the same for each LHV scenario. This analysis has, therefore, simply assessed the price elasticity factor required to produce a zero effect on each of the key parameters, assuming zero mode shift. The factors required are shown in Table 29, below.

Table 29. Boundary values of price elasticity value assuming zero mode shift.

Scenario	Vehicle kms	CO_2	Fatalities	Total Cost
18.75m 44 tonnes	1.30	1.30	1.30	0.63
25.25m 44 tonnes	2.0	1.09	2.16	1.65
25.25m 60 tonnes	2.39	0.57	2.35	1.61
34m 82 tonnes	3.19	0.91	2.39	2.29

All of these values are substantially higher than would be expected based on the evidence from previous weight increases and the views of the freight industry. The overall conclusions are, therefore, unlikely to be particularly sensitive to any realistic estimate of price elasticity of demand.

7.2.2.4 Estimating the likely effects

It has not been possible to produce estimates of the key input parameters (take-up rate and mode shift) with full scientific confidence because there is very little empirical data to use and the wide range of possibilities under consideration has meant that the freight industry has not yet analysed their data to provide a comprehensive and uniform view of the likely usage of LHVs.

A range of plausible values has been subjectively defined based on the evidence available, which includes literature from other countries, the views of stakeholders, documentary evidence of analyses submitted directly to the project team from stakeholders and independent analysis of existing freight market data. These values have been combined into two cases intended to indicate a plausible range of the effects that could occur if LHVs were permitted. The key input variables used in these cases are shown below:

- **Case 1**
- **Average load:** equal load factors (%) as current articulated vehicles
- **Take-up rate**: Low end of range defined in F.16.1
- **Mode shift:** Low end of range defined in F.16.3
- **Traffic generation:** Low end of range defined in F.16.4
- **Accidents:** Assumed additional countermeasures are mandatory (B.9, Table 67)

- **Case 2**
- **Average load:** equal load factors (%) as current articulated vehicles
- **Take-up rate**: High end of range defined in F.16.1
- **Mode shift:** High end of range defined in F.16.3
- **Traffic generation:** High end of range defined in F.16.4
- **Accidents:** Assumed no additional countermeasures fitted (B.9, Table 65)

Further conditions have been included in the analysis because there is an important inconsistency in the way that estimates of take up rate and mode shift have been defined and this could potentially have a strong effect on the conclusions from the model. The analysis of CSRGT trip data identified an upper boundary for the level of take-up of LHVs and the estimates of the actual rate shown above were made based on both the objective analysis of the maximum rates, literature from countries where they are already used and the views expressed in the information gathering exercise. This estimate took account of all the practical constraints that would affect the take up such as just-in-time deliveries, route restrictions, available space at depots, the ability of small hauliers to access additional capital for the equipment, and the return on that capital investment. Conversely, the analysis of the mode shift effect was predominantly econometric relying on estimates of price elasticity that were based on the use of existing vehicles that are much less constrained.

The take up rate for LHVs was assumed to be 5% to 10% of the traffic generated by the sectors identified that were likely to take it up. For the payload neutral and 44-tonne 25.25m LHVs this was assumed to be 5-10% of the 55% of tonne kms that were carried by sectors including pallet networks, fast moving consumer goods, other foodstuffs and miscellaneous manufacturers as well as deep-sea containers. The aggregated nature of the estimate and the parametric model means that this has effectively assumed that the take-up rate will be 5% to 10% in each relevant sector. Thus, the model assumes that 5% to 10% of the deep sea containers currently moved by road will transfer to LHVs. However, the mode shift estimate assumes that 22% to 54% of all deep sea containers currently moved by rail will switch to LHVs. Despite the fact that the rail share of the market is much smaller than road (25% compared with 75% respectively) this means that the model predicts that if LHVs were permitted, approximately 70% of the shipping containers carried by LHVs would originally have come from rail. This is not particularly plausible. If there are practical constraints that mean only 5% to 10% of the containers currently moved by road can switch to LHVs there is no obvious explanation of why 22% to 54% of those currently carried by rail could switch to LHVs. Equally, if it is possible for 22% to 54% of containers currently transported by rail to move to LHVs there is no obvious reason why similar or even greater proportions of those moved by standard articulated vehicles could not move to LHVs.

There has been insufficient evidence presented during this project to enable this inconsistency to be accurately resolved. However, it is possible to test the extremes of the possible effects. It could be assumed that the econometric approach to the mode shift estimate is the correct approach and that, for some reason, the nature of the deep-sea container market means that the practical constraints limiting the take-up of LHVs in other sectors do not apply. In this case, the deep-sea container market would expect to see all current road traffic transferring to LHVs and 22% to 54% of rail traffic transferring. In order to embody this, case 2 above (previously the largest adverse effects) has been modified such that 5%-10% of all markets likely to adopt LHVs will use LHVs but 100% of the 7.3billion container tonne-kms currently moved by articulated vehicles will move to LHVs.

An alternative way to test the limits of the inconsistencies of different approaches to take-up in the road sector and mode shift from rail is to limit the mode shift from rail by a factor relating to the constraints that would be applied to LHVs if they were permitted. The analysis of CSRGT trip data suggested that limiting the routes that could be used to Motorways and dual carriageways would reduce the effectiveness of LHVs by 11% to 21% (Table 22).

The likely effects of permitting LHVs, including consideration of the inconsistencies described above has been summarised in percentage terms in Table 30 and in numerical terms in Table 31, below.

Table 30. Summary of potential effects if LHVs were permitted (%)

Scenario	Total cost change (%)		Total fatality change (%)		Total CO2 change (%)		Total vkms change (%)	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-0.23%	-0.15%	-0.25%	-0.17%	-0.55%	-0.37%	-0.29%	-0.20%
18.75m Payload neutral (c.46t)	-1.32%	-0.35%	-0.72%	-0.19%	-0.70%	-0.18%	-0.79%	-0.21%
25.25m 44t	-3.59%	-0.47%	-2.03%	-0.17%	-2.07%	0.20%	-2.15%	-0.16%
25.25m Payload neutral (c.50t)	-3.58%	-0.77%	-1.70%	-0.22%	-1.02%	0.60%	-1.85%	-0.24%
25.25 60t	-3.58%	-1.36%	-1.08%	-0.33%	0.52%	1.35%	-1.27%	-0.39%
34m Payload neutral (c.63t)	-3.98%	-1.51%	-1.22%	-0.38%	0.38%	1.07%	-1.52%	-0.48%
34m 82t	-6.30%	-2.41%	-2.05%	-0.70%	-1.46%	-0.43%	-2.96%	-1.04%

Table 31. Summary of potential effects if LHVs were permitted (Numerical)

Scenario	Total cost change (£)		Total fatality		Total CO2 change		Total vkms change	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-£37,165,147	-£23,218,367	-1.5	-1.0	-65,778	-44,557	-0.08	-0.06
18.75m Payload neutral (c.46t)	-£209,244,538	-£55,509,936	-4	-1	-83,867	-21,381	-0.23	-0.06
25.25m 44t	-£569,673,081	-£74,396,045	-12	-1	-246,709	24,375	-0.63	-0.05
25.25m Payload neutral (c.50t)	-£569,580,900	-£123,128,880	-10	-1	-121,746	71,586	-0.54	-0.07
25.25 60t	-£569,406,325	-£215,420,708	-6	-2	61,820	160,995	-0.37	-0.11
34m Payload neutral (c.63t)	-£632,081,610	-£239,737,293	-7	-2	45,401	127,343	-0.44	-0.14
34m 82t	-£1,000,298,913	-£382,597,225	-12	-4	-174,177	-51,059	-0.86	-0.30

Many measures that aim to reduce truck travel express the benefits in terms of the number of vehicle movements taken off the road. This can be derived from the data above by dividing the change in vehicle kms by the average length of haul for the vehicle. However, in the case of LHVs it is not known what the average length of haul would be. For standard articulated vehicles, which include those making urban deliveries to shops, the average length of haul is 124 km. For rail freight it is 208km. It is reasonable to assume that LHVs would fall somewhere between the two because they are unlikely to be used on the shorter of the journeys currently undertaken by standard articulated vehicles and highly unlikely to travel longer distances on average than trains. Using these figures as boundary conditions produces a range of reductions in vehicle movements as shown in Table 32, below.

Table 32. Summary of estimated changes in vehicle movements

Scenario	Low	High
18.75m 44t	-276,409	-681,812
18.75m Payload neutral (c.46t)	-293,427	-1,861,918
25.25m 44t	-217,036	-5,048,539
25.25m Payload neutral (c.50t)	-329,062	-4,333,073
25.25 60t	-541,220	-2,978,102
34m Payload neutral (c.63t)	-674,964	-3,556,902
34m 82t	-1,460,713	-6,957,357

It can be seen that the net financial values of all effects combined is always a cost reduction. However, for 25.25m LHVs at 44 or ~50 tonnes (payload neutral) the effect on CO_2, and thus other noxious emissions, could be either an increase or decrease. For 60 tonne vehicles, the model predicts an increase in emissions in all cases tested. Given current concerns regarding climate change, this represents a notable risk factor.

It has not been possible in this study of aggregate UK effects to estimate with certainty whether or not the mode shift effect would be sufficient to cause an overall adverse effect on the environment because of the lack of quantitative information and the methods used to estimate aggregate levels of UK take-up and mode shift. These would need to be studied in much more detail if it is considered necessary to quantify the overall effects more accurately. This would involve studying port activity in more detail and the constraints associated with the use of LHVs in a port/container transport context, and the effects that these constraints may have on existing price elasticity figures used in mode shift calculations, which are based predominantly on the lesser constraints of standard road vehicles. In addition to this, the critical levels at which rail services could no longer be supported if traffic was reduced may need to be identified as would the investments required to provide adequate capacity for both road and rail to cope with future demand.

The European Commission has defined the notion of *"co-modality"*, described as *"the efficient use of transport modes operating on their own or in multi-modal integration in the European transport systems to reach an optimal and sustainable utilisation of resources"*.

A blanket decision either to permit, or not to permit, LHVs greater than 18.75m in length could be considered counter to the notion of co-modality because, while the analysis suggests that permitting such LHVs in all sectors of the freight market would improve the efficiency of road freight on its own, there is a strong risk that it would have an adverse effect on the efficiency of freight transport on road and rail operating in a combined transport chain to the possible detriment of the environment. However, whilst a blanket decision not to permit LHVs in any sector of the freight market would not undermine current efficiencies achieved with road and rail working together, it would not improve the efficiency of road freight working on its own in sectors not competing directly with rail, such as overnight trunking on pallet load networks, because those sectors would be prevented from making improvements in efficiency that could otherwise be possible.

It may be possible to develop a mechanism that would prevent or limit mode shift in the deep-sea container market, particularly given the capacity constraints and predicted traffic growth at ports. If this resulted in as much port freight as efficiently possible being transported by rail and allowed what could not be carried by rail to be transported as efficiently as possible by road, such a mechanism would appear to be consistent with the notion of co-modality. If such a way could be found to implement LHVs then substantial benefits could potentially be achieved whilst avoiding the risk of adverse environmental effects. At this stage, potential methods for achieving this have not been investigated in detail but it is possible to envisage that the potential introduction of emissions trading or road charging schemes could present possible opportunities.

For the purposes of illustrating the potential, the concept has been assessed on the basis of excluding LHVs from the carriage of deep sea containers. Based on this assumption the model predicts that the effects would be expected to be in the range suggested in Table 33 and Table 34, below.

Table 33. Potential effects if LHVs were permitted but were excluded from the carriage of shipping containers (%).

Scenario	Total cost change (%)		Total fatality change (%)		Total CO2 change (%)		Total vkms change (%)	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-0.23%	-0.15%	-0.25%	-0.17%	-0.55%	-0.37%	-0.29%	-0.20%
18.75m Payload neutral (c.46t)	-0.67%	-0.35%	-0.47%	-0.27%	-0.61%	-0.38%	-0.53%	-0.31%
25.25m 44t	-1.17%	-0.57%	-0.81%	-0.41%	-1.05%	-0.54%	-0.88%	-0.45%
25.25m Payload neutral (c.50t)	-1.57%	-0.77%	-0.92%	-0.47%	-0.72%	-0.40%	-1.02%	-0.53%
25.25 60t	-2.33%	-1.13%	-1.11%	-0.59%	-0.14%	-0.10%	-1.29%	-0.69%
34m Payload neutral (c.63t)	-2.58%	-1.26%	-1.20%	-0.63%	-0.33%	-0.25%	-1.45%	-0.76%
34m 82t	-4.05%	-1.98%	-1.72%	-0.89%	-1.64%	-0.90%	-2.37%	-1.22%

It can be seen that all scenarios now show benefits for all of the key indicators assessed. It is likely that the benefits would be greater if a mechanism could be found to permit the use of LHVs in the deep-sea container market without causing the mode shift predicted. The same results are shown below in terms of the absolute values of change predicted, rather than percentage changes.

Table 34. Potential effects if LHVs were permitted but were excluded from the carriage of shipping containers (Numerical)

Scenario	Total cost change (£)		Total fatality change		Total CO2 change (tonnes)		Total vkms change (billion)	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-£37,165,147	-£23,218,367	-1	-1	-65,778	-44,557	-0.08	-0.06
18.75m Payload neutral (c.46t)	-£105,840,650	-£55,035,928	-3	-2	-72,373	-45,596	-0.15	-0.09
25.25m 44t	-£186,195,551	-£90,796,965	-5	-2	-125,201	-64,255	-0.26	-0.13
25.25m Payload neutral (c.50t)	-£249,647,999	-£121,662,293	-5	-3	-86,183	-47,770	-0.30	-0.15
25.25 60t	-£369,816,307	-£180,116,053	-7	-3	-16,550	-12,290	-0.38	-0.20
34m Payload neutral (c.63t)	-£409,721,196	-£199,708,603	-7	-4	-39,025	-29,765	-0.42	-0.22
34m 82t	-£644,162,422	-£314,814,832	-10	-5	-196,094	-107,403	-0.69	-0.35

Using the same assumptions as previously, the vehicle kms change can be translated to the reductions in the number of vehicle movements shown in Table 35, below.

Table 35. Estimated changes in vehicle movements if LHVs were excluded from the carriage of shipping containers

Scenario	Low	High
18.75m 44t	-276,409	-681,812
18.75m Payload neutral (c.46t)	-426,845	-1,238,760
25.25m 44t	-626,900	-2,074,666
25.25m Payload neutral (c.50t)	-741,860	-2,405,016
25.25 60t	-959,573	-3,030,644
34m Payload neutral (c.63t)	-1,067,358	-3,399,252
34m 82t	-1,700,592	-5,564,819

Modal shift was the only factor analysed in the parametric cost model that was found to have a sufficiently large effect to suggest that permitting LHVs could have net adverse consequences on any of the main key indicators and this depended heavily on the estimated take-up rate. This, and a wide range of other risks, are likely to require further investigation if the UK were to decide to further explore the possibility of permitting LHVs substantially greater than 18.75m in length.

7.2.2.5 *The potential for improvements within current limits*

The business as usual scenario used as the reference baseline in the preceding analysis assumed that the proportion of tonne-kms carried by articulated vehicles, drawbar combinations and double decked articulated vehicles remained fixed at the actual values recorded in 2005. Each of the LHV scenarios was also based on the same assumption.

The proportion of goods moved by drawbar combinations and double decked articulated vehicles is relatively small but has increased substantially in recent years, particularly since the weight limits were increased to 41 tonnes and then 44 tonnes. Both these types of vehicles offer increased loading length compared with a standard articulated vehicle. A second business as usual scenario was, therefore, modelled based on the assumption that the use of double decked vehicles and drawbar combinations increased in line with current trends. This method produced the estimates of vehicle proportions shown in Table 36, below.

Table 36. Proportions of goods carried by different vehicles in the second "business as usual" scenario

Year	Proportion of tonne kms carried by….			
	Rigid	Single decked articulated	Double decked articulated	Drawbar combination
2006	21.7%	73.7%	2.3%	2.3%
2020	21.8%	67.2%	5.2%	5.7%

It should be emphasised that these predictions were intended as an alternative baseline case and not as an alternative to LHV types. The analysis was, therefore, based on simple extrapolation of trends over time and was not a step change approach comparable with the LHV scenarios. It was also not tested in terms of feasibility with the industry stakeholders and is assumed not to suffer from mode shift or induced demand effects, despite the fact that a double deck vehicle represents a very large step change in price per pallet km (almost halved) for very lightweight volume constrained goods compared with standard articulated vehicles. The parametric model predicts the following changes compared with the baseline condition where the proportion of these vehicle types remains constant:

- Total cost reduced by 1.8%
- Total vehicle kms reduced by 1.2%
- Total CO_2 reduced by 2.35%
- Number of fatalities increased by 1%

It can be seen that in three of four key indicators, the increased use of drawbar and double decked vehicles was found to be substantially beneficial. These benefits were comparable to, or in excess of, those of some of the LHV scenarios. However, an adverse effect on safety would be expected if this occurred. This is as a result of the accident rate derived for drawbar vehicles in the analysis of safety which was very high but was poorly based with a small sample size and problems of differing coding definitions in different databases.

This analysis shows that substantial further benefits may be possible from an appropriate increase in the use of higher volume capacity vehicles that are already permitted, particularly double decked vehicles. However, this should not necessarily be considered as a direct alternative to any of the LHV scenarios because the research has suggested that each different type of vehicle (including the LHV types assessed) has different advantages and disadvantages. Use of drawbars and double decked vehicles may, therefore, continue to rise even if LHVs were to be permitted, thus meaning that the effects of this scenario will be mixed with the effects of LHV scenarios. In fact, many stakeholders have suggested permitting double decked LHVs but this has not been evaluated at this time.

7.3 Investments

The research has highlighted a number of areas where capital investment in infrastructure may be required. The research has suggested that capital investment will be required on rail infrastructure in order to deliver the capacity required to be able to deliver the predicted growth in this area, which forms part of the business as usual scenario. For this scenario it was assumed that rail capacity would not limit the growth. It is expected that much of this investment will come from within the rail industry but some schemes are being considered for funding from the Transport Innovation Fund. In terms of roads, investment may be required for the development of suitable parking facilities, reviews and modifications to bridge structures, classifying and signing permitted and diversionary routes, research activity and regulatory processes.

It has not been possible to reliably quantify the scale of investment required for these areas within the scope of this project. However, in order to inform decision makers about the order of magnitude of the investment that could be made for a benefit to cost ratio of one, a simplistic discounted cash flow calculation has been carried out. The results are shown in Table 37, below. This has assumed that the benefit each year is the average total cost reduction in the steady state period, as calculated by the parametric cost model for different scenarios where it is assumed that LHVs would be prohibited from carrying deep-sea containers from ports. This implementation scenario was chosen because it avoids some of the uncertainty in the analysis of this sector and estimates changes generally found in the mid range of the different effects assessed.

Inflation of 2% per annum and a discount factor of 3.5% have been applied. The calculation has been carried out for different pay-back periods. In a commercial environment, business cases for capital investment will usually be expected to show a return within 5 years. The effect over 15 years has also been calculated because this was the time period that the parametric model assessed. Major road schemes are usually evaluated over a 60 year period so this has also been considered.

Table 37. Investment that can be made for a benefit to cost ratio of one

Scenario		**Net present value of benefits in payback period (£million)**		
		5	**15**	**60**
18.75m 44t	upper	£175.53	£359.27	£386.22
	lower	£109.66	£224.45	£241.28
18.75m Payload neutral (c.46t)	upper	£988.25	£2,022.76	£2,174.44
	lower	£262.17	£536.61	£576.85
25.25m 44t	upper	£2,690.54	£5,507.01	£5,919.97
	lower	£351.37	£719.18	£773.11
25.25m Payload neutral (c.50t)	upper	£2,690.11	£5,506.12	£5,919.01
	lower	£581.53	£1,190.28	£1,279.54
25.25 60t	upper	£2,689.28	£5,504.43	£5,917.20
	lower	£1,017.42	£2,082.47	£2,238.62
34m Payload neutral (c.63t)	upper	£2,985.29	£6,110.31	£6,568.51
	lower	£1,132.27	£2,317.53	£2,491.32
34m 82t	upper	£4,724.37	£9,669.86	£10,394.98
	lower	£1,806.99	£3,698.56	£3,975.90

It can be seen that the level of investment that would result in a benefit to cost ratio of 1 (i.e. where the investment in year 1 equals the net present value of benefits in a defined time period) varies considerably with vehicle type and spans the range of approximately £110million to £10.4billion. The investment required for each scenario could not be accurately quantified within the scope of this project but has been broadly categorised. If permitted, the 18.75m articulated vehicle is unlikely to require any substantial capital investment in the infrastructure and can be categorised as very low. It is, therefore, highly likely that a benefit to cost ratio in excess of one would be achieved. If LHVs of 25.25 m were to be permitted at 44 tonnes then substantial investment in parking facilities would be required and this could be categorised as medium. If payload neutral versions were to be permitted then a limited amount of additional investment may be required to assess bridge structures that would be considered marginal for 44 tonne vehicles. However, this could still be categorised as medium. If 60 tonne versions were to be permitted then a larger investment would be required to assess and/or strengthen local authority bridges and the small percentage of trunk road bridges not up to HA standard. This could be categorised as a high investment. If 34m 82 tonne vehicles were to be permitted then a larger investment would be needed in parking facilities to accommodate the additional length and a much larger review of bridge structures and consequent improvements would be required for both local authority and up to a maximum 25% of trunk road bridges. This could be categorised as very high. For all investment levels categorised as medium or higher, the benefit to cost ratio is uncertain because it has been shown that the investment required in parking facilities could potentially be measured in £billions, although that would assume that a large number of new, dedicated, LHV facilities would have to be built from scratch.

8 Discussion

The analysis undertaken during this project has shown that predicting the effects that would be likely if longer and/or longer and heavier goods vehicles (LHVs) were to be permitted in the UK is an extremely difficult and complex matter. A wide range of vehicle types and potential applications have been investigated to determine the likely effects on the economy, the atmospheric and the built environment, and road safety. The research took the form of a desk study, which included reviews of relevant scientific literature, analysis of freight data, information gathering from a wide range of stakeholders, modelling of existing road freight flows, and computer simulation of some vehicle performance characteristics. Wherever possible the results were monetised and formed inputs to a parametric model of costs and benefits. Given the breadth of scope in both the scenarios and the variables to be assessed, and the inherent limitations of a desk-based approach, it was not possible to consider every variable in depth. For example, the research attempted to quantify the likely take-up of different LHVs and to identify what route restrictions might be required if different LHVs were to be permitted. However, these questions are strongly inter-dependent and also depend on factors such as the level of taxation, which cannot be predicted at this time. An iterative exercise would be required to fully resolve these issues. Similarly, the likely mode shift would depend on the take-up in the relevant road sector, the actual cost reduction including any changes in taxation, the route restrictions applied, operational constraints in and around ports, and the viability of key rail freight routes.

These complex and inter-dependent variables, combined with a lack of data in some areas, conflicting data in others and the disparate views of stakeholders, have meant that some of the most important variables had to be estimated using relatively crude techniques involving some significant elements of subjective judgement to balance competing or conflicting evidence. In addition, the estimates of effects for “payload neutral” scenarios were based on the interpolation of the results for other scenarios. While this is expected to be reasonably representative for 50 tonne vehicle scenarios, where two boundary cases were directly investigated, estimates for 46 tonne and 63 tonne scenarios are of lower confidence. As far as possible, it was ensured that all of the estimates and approximations were balanced in order to avoid introducing any systematic bias either for or against any particular outcome. However, these limitations mean that this report should be seen as an initial quantitative assessment of the likely effects of LHVs in the UK if they were to be permitted. If the evidence presented in this report is considered sufficient to warrant further investigation of LHVs, then a focus on a smaller set of specific scenarios and types or characteristics of LHV would allow the issues identified to be analysed in greater detail. The main findings of this study, and the additional work that may be required if further consideration was to be given to introducing LHVs, are described below.

There was evidence to suggest that the previous increase in the maximum permitted weights of goods vehicles from 41 tonnes to 44 tonnes in 2001 had reduced goods vehicle traffic, freight transport costs and goods vehicle emmissions relative to what they would otherwise have been. There is little evidence to suggest that the move has, as yet, generated much additional demand for freight movement. It is difficult to assess the effect on modal split because of other changes that also occurred during this period. However, rail's share of the freight market has increased from approximately 7% in 2000 to approximately 9% in 2005, with rail freight transport increasing by 22% from 18 to 22 billion tonne kms, and road freight transport increasing by 3% from 159 to 163 billion tonne kms. Given that continued freight growth is expected, maintaining current regulations on weights and dimensions would, with all other things being equal, be expected to result in an increase in the number of goods vehicle movements with a growth in road freight tonne kms of between 0.6% and 1% per year. This would result in a relative increase in the pollution, accidents and congestion arising from those movements.

It is generally considered that in recent years the average density of loads has reduced notably. Coupled with increased maximum vehicle weights, this has meant that a larger proportion of loads shipped are now constrained by the available volume or deck area rather than the available payload weight. This is considered to be a factor that at least partially explains the long-term trend of lighter average loads on articulated vehicles.

Currently, the standard UK heavy goods vehicle (HGV) is a 16.5m long, 44 tonne articulated vehicle. However, vehicles that offer greater volume and/or deck area are also currently used. These include the 18.75m long drawbar combination at 44 tonnes and taller, double decked, versions of the standard 16.5m, 44 tonne articulated vehicle. An increase in the appropriate use of such vehicles, particularly for double decked vehicles, would provide net monetary benefits. However, there is a risk of an adverse effect on safety, particularly if the use of standard 18.75m drawbar combinations increases substantially, especially if the trailers used are short wheelbase "full" drawbar trailers. Further specific investigation would be required if it was considered necessary to confirm and more accurately quantify the risks associated with existing high volume vehicles.

If LHVs were to be permitted, European legislation would be very likely to substantially constrain the UKs ability to permit only those specific types of LHV with features considered desirable to protect the UK infrastructure. The current European legislation would also be likely to make it difficult to require the fitting of specific additional safety equipment that could mitigate any increased accident risks. This is because the European legislation permits operators to use standard vehicles in different combinations so that they may achieve at least the same *"loading length"* as permitted nationally. Whilst it might be possible to draft UK regulations in such a way as to protect the infrastructure and guard against safety risks, suitable amendments to the European legislation would be required to be certain of the outcome. Amending this legislation would require the agreement of a qualified majority of the 27 Member States and, if successful, would be likely to take some time to achieve. The UK regulations on speed limits for multi-trailer combinations would also be likely to require amendment, even if such vehicles were to be permitted by Special Order, because their speed would otherwise be limited to 40 mile/h on motorways and 20 mile/h on all other roads.

In comparison to standard HGVs, permitting LHVs would be likely to have a range of effects on the road infrastructure and these would be likely to vary according to the types and characteristics of the vehicles and the constraints of the parts of the road network to which they were permitted access:

- Despite the fact that none of the vehicle types assessed involved changing the maximum permitted axle weight, the different vehicle types were found to affect the structural road wear factors per unit of goods moved when typical lading patterns were considered;
    - Single deck articulated vehicles of 18.75m in length would slightly increase road wear factors, by an amount comparable to that of existing double decked vehicles, because of the increased unladen weight.
    - 25.25m vehicles at 44 or 50 tonnes (payload neutral) would substantially decrease road wear factors because of the greater number of axles, which results in lower axle loads.
    - 25.25m vehicles at 60 tonnes would slightly increase the factors because of a higher average load per axle and a greater proportion of the total weight being due to the unladen weight of the vehicle.

   - 34m vehicles at 82 tonnes would slightly decrease the road wear factor, again because of the increased number of axles resulting in lower average axle loads.

- Parking facilities are required to enable drivers to rest and to comply with driver's hour's regulations. There was some evidence to suggest that some multi-trailer vehicles cause more fatigue than standard articulated vehicles, and that LHVs in excess of 18.75metres in length would exacerbate the inadequacies of current parking provision. This is because the bays at many existing facilities would be too small to accommodate such vehicles and some existing facilities would not be accessible to vehicles that were less manoeuvrable than required by current regulatory standards. Providing these essential facilities for the larger (>18.75m) types of LHV would require substantial investment in improved facilities, which could range from alterations to marked bays at existing sites to the construction of a large number of new or expanded facilities. The investment cost could not be accurately quantified because of a lack of data regarding the capabilities of current facilities and the extent to which they are used. However, if large numbers of new, dedicated facilities were to be required the investment has the potential to be measured in the low £billions. Improvements could be difficult to achieve because of constraints on land availability, planning permission and the ownership of current facilities. The investment required for 82 tonne vehicles could be greater than that for other types if coupling and decoupling points were to be provided at strategic locations on the motorway network. Vehicles of up to 18.75m in length would not be expected to have any adverse effect on parking.

- A conservative analysis of bridge loading has identified some risk that 82 tonne vehicles could overload a relatively small proportion of medium span trunk road bridges and a larger proportion of such bridges away from the trunk road network. However, some of these may also be unsuitable for 44 tonne vehicles such that they should already be appropriately restricted and signed. Resolving this problem would require specific bridges at risk to be identified, and either a substantial investment in strengthening the affected bridges, or a lesser investment in restricting access and erecting signage, both for the bridges and the alternative routes that avoid them. Restricting access to bridges would yield either a reduction in the availability of suitable routes or an increase in the distance driven to reach destinations, both of which would reduce the monetary benefits achievable.

- It is possible that vehicles exceeding 44 tonnes could represent an increased risk if they collide with bridge supports. However, existing minimum standards are not based on existing worst case collisions (44 tonnes at 56 miles/h, or at STGO weights). The existence of this risk therefore depends on whether current bridge supports and their protective structures are capable of exceeding minimum standards and, if so, by how much. Further research, likely to include physical testing of the protective structures, would be required if it was considered necessary to assess and quantify this risk more accurately.

- Longer vehicles, in excess of 18.75m, would have implications for the management of the road network. For example, traffic light phasing may need to be changed to ensure safety but this would reduce junction capacity. In addition, if LHVs that are less manoeuvrable than current vehicles were to be allowed unlimited access to the road network, this would increase damage to infrastructure, such as kerbs and roadside furniture on smaller roads and junctions, and increase the risk of blocked roads because of vehicles becoming trapped by the road geometry. The problems could be minimised or prevented by using more manoeuvrable vehicles or by limiting access to only those routes that are suitable, for example, by prohibiting access to urban areas through the use of Traffic Regulation Orders. Such route restrictions can be difficult and costly to enforce. However, advanced technology such as CCTV, number plate recognition, and dedicated satellite navigation and telematics systems specifically for trucks is either in existence or under development and could potentially form a cost-effective solution. In London, traffic authorities already have powers to enforce 7.5 tonne and 18 tonne weight restrictions using CCTV equipment, and new legislation extending that option to the rest of England is expected to be available in 2009. More advanced tracking systems could enable vehicle routing to be recorded and enforced by subsequent inspection of the record in a manner similar to that where tachographs are used to record and enforce driver's hours. However, if problems associated with road closures and diversionary routes are to be avoided, it would be necessary for vehicles to be capable of meeting minimum standards of safety and manoeuvrability commensurate with use on lesser roads.

Discussions with company managers from the UK freight industry indicated that, if permitted, LHVs would likely be used:

- Mainly for regular flows of lower density products on longer hauls as part of contracts with particular clients or as part of a network service.
- For primary distribution (i.e. factory to distribution centre) rather than secondary distribution (i.e. distribution centre to shop).
- Mainly in sectors such as pallet-load networks, fast-moving consumer goods, deep-sea container movements and forest products (provided access could be gained to forests in remote rural areas as it can in Scandinavia).

Wide variations were found in the attitudes of road hauliers to LHVs, ranging from enthusiastic support to deep scepticism. Some saw large potential savings and opportunities to gain competitive advantage while others doubted that the use of LHVs would enhance their profitability because they considered that much of the economic benefit would be captured by shippers. It was also thought that permitting some types of LHV might put smaller operators, such as owner drivers, at a relative disadvantage because many would lack both the capital to acquire them and the contractual work to ensure that the investment was recovered profitably.

The industry identified conflicting pressures on vehicle utilisation. Firstly, it was considered that permitting LHVs would improve the ability of the road haulage industry to use the most appropriate size of vehicle for each load, thus increasing average load when laden. However, it was also likely that potential route restrictions would make backloads more difficult to source and that the size of available backloads may be better suited to a standard vehicle. This could increase empty running and/or reduce the average load when laden. However, during discussions the view was often expressed that such problems would instead reduce take-up rate rather than utilisation because industry would not sanction additional investment in LHVs unless they were confident of a proportionate return. For these reasons the individual analyses of impacts and the input to the parametric cost model were based on the assumption that the competing pressures would have equal effects and result in a utilisation of LHVs equivalent to that of standard articulated vehicles.

The discussions with the industry very strongly suggested that if permitted, LHVs would be specialist vehicles working in "niche" operations and would not replace the 44 tonne articulated vehicle as the standard "workhorse" of the industry. This was seen to be a consequence of many factors, including type of load, consignment size, journey distance and the availability of suitable routes.

In other countries where LHVs are used, or have been trialled, the proportion of tonne kms transported by LHVs varies considerably. For example, in Sweden 74% of tonnekms are transported by vehicles with a gross vehicle weight (GVW) in excess of 40 tonnes and 7 or more axles. In Australia more than half of all tonne kms are transported by B-doubles or road trains, the Dutch study predicted that between 7% and 31% of all tonne kms transported by vehicles with a GVW>20 tonnes would transfer to LHVs and in the USA, one study suggested that just 2% of the distance travelled by articulated vehicles involved longer combinations, although this would represent a higher proportion of tonne kms and standard vehicles (tractor/semi-trailers up to c.21m in length) in the USA can be larger than those permitted in the UK.

An analysis of a large sample of UK data on individual trips suggested that at most approximately one-third of articulated vehicle trips could be candidates for transfer to LHVs if such vehicles were permitted on all roads. However, if routes were restricted the number of candidate trips would be further reduced. For example, a hypothetical restriction where LHVs could only use primary routes with no allowance for local access or coupling or decoupling points would limit the number of candidate trips to around 10%.

On the basis of the information supplied, the experience in other countries and the theoretical effects of route restrictions, it was estimated that a take-up rate of up to 5% to 10% of the tonne-kms carried by articulated vehicles could move to LHVs of 60 tonnes or more (vehicles offering an increase in both volume and payload). This represents a migration of up to a maximum of approximately 11.8 billion tonne-kms per year. This estimate is at the low end of the range of experiences in other countries, which reflects the different road networks, different freight markets and the views of the UK freight industry. Lesser migration would be expected for 50 and 46 tonne scenarios, where volume is increased but the payload is the same as for existing vehicle, and particularly for 44 tonne vehicles where volume is increased but payload is less than that of current vehicles.

Permitting LHVs would be likely to introduce new safety risks. These risks would vary depending on the type and characteristics of the vehicle(s) and the roads on which they might be permitted. For 18.75m articulated vehicles there would be few, if any additional safety risks provided they complied with current manoeuvrability requirements. If 25.25m vehicles were permitted the risks would vary considerably depending on the type of vehicle used. If vehicles with low values of rearward amplification that met current manoeuvrability requirements were considered the increased risks would be relatively small. If other combinations with higher rearward amplification values and less manoeuvrability were considered the risks would be greater. Permitting vehicles with substantial weight increases would considerably increase the risk of injury in a small number of specific accident types (i.e those involving collisions with other heavy vehicles or fixed objects, and those involving multi-vehicle collisions with passenger cars). The analysis suggested that there is evidence that would justify restricting the larger and/or less manoeuvrable LHV types to primary routes outside urban areas, if they were to be permitted. A conservative analysis suggested that for most, but not all, LHV types assessed the casualty rate per unit of distance travelled would increase. However, for all options the casualty rate per unit of goods moved was found to decrease slightly, even where an increased risk per vehicle km was identified.

Furthermore, many of the additional risks could potentially be mitigated or eliminated by the use of advanced vehicle design and new technologies. For example, risks associated with poor manoeuvrability could be mitigated by sophisticated steering axle systems, stability problems could be reduced with electronic stability control (ESC), and increases in collision severity could be lessened or even eliminated with collision mitigating braking systems (CMBS). If EU legislation could be amended so as to clearly allow Member States to mandate such safety features for LHVs, the varying increases in risk per vehicle km predicted, particularly for the larger, less manoeuvrable types, could be substantially reduced such that the slight reduction in risk per unit of goods moved could be increased. It is likely that mandating such safety features for LHVs would also accelerate their introduction into the wider goods vehicle fleet because of their likely use in both standard and LHV configurations. The potential benefit of this wider penetration of safety features was not quantified in order to limit the complexity of the analyses.

There is a strong interaction between the types and characteristics of vehicles assessed, their safety performance, effects on infrastructure and vehicle usage (take-up). Adverse effects on safety or infrastructure can be mitigated either by restricting the types and characteristics of vehicles or by restricting the routes to which they can gain access. Each of these approaches will have an influence on the extent to which vehicles are used. In some countries outside Europe performance based standards for vehicles are being implemented, and whilst European legislation currently prevents such an approach in the UK, performance based standards offer the potential to authorise vehicles in a more flexible manner that allows the capacity and use of larger vehicles to be optimised whilst simultaneously minimising safety and infrastructure risks.

Assuming that vehicle utilisation was equivalent to that of standard articulated vehicles, permitting LHVs would have the effect of increasing the fuel consumed by between 0.06% (18.75m articulated vehicle) and 71% (34m, 82 tonne vehicle) with the associated increases in exhaust gases emitted and operational costs per vehicle km. However, the increased carrying capacity of such vehicles would reduce fuel consumption and emissions per unit of goods moved by between 8% and 28%, depending on the scenario. This would contribute to a reduction in internal operational costs per unit of goods moved of between 18% and 43%. These internal operational costs include fixed costs such as the likely vehicle purchase price and variable costs such as fuel but do not include external costs such as accidents. Note that the operational cost calculations were based on the bulk price of fuel at the start of the project and the analysis has not been adapted to assess the effect of price changes during the project. Based on reviews of the actual effects of the most recent changes in permitted weights, as well as the views of industry on how such vehicles would be used, it was considered that this cost reduction would, overall, generate only a very small amount of additional freight movement as a result of the price elasticity of demand.

Permitting LHVs would be likely to induce modal shift from rail but would be unlikely to induce any notable modal shift from waterborne transport. In particular, LHVs of 25.25 m in length or greater would be likely to present a substantial threat to rail operations in the deep sea container market. Including both the deep-sea container and bulk rail markets in the analysis led to an estimate, based on the current characteristics of these markets, that a maximum of between 8% and 18% of all rail tonne kms (including the overall forecast growth) would migrate to LHVs of 60 tonnes or more maximum weight. Much reduced migration would be expected for smaller increases in capacity with the 18.75m articulated vehicle expected to have little, if any, mode shift effect on current rail markets. However, the rail industry predicts strong future growth in the domestic intermodal rail market, representing a significant mode shift from road to rail on particular freight routes, mainly in retail markets. Permitting LHVs could limit such future growth. The analysis carried out was predominantly econometric and the estimates of mode shift produced could be subject to other factors that could not be quantified. For example, if mode shift was sufficiently high it would undermine the viability of rail in the deep sea container market by contributing to service closures which could, in turn, lead to greater mode shift. Alternatively, the rapid growth in container traffic coupled with the congestion of the road infrastructure in and around the key ports may act to mitigate or prevent mode shift. Further in-depth research would be required if it was considered necessary to quantify these issues more precisely.

The risk of mode shift described above is that which would be expected if LHVs were to be permitted for general haulage on inter-urban freight routes. However, it may be possible to devise a means of permitting LHVs in a manner, which minimised or eliminated the risk of mode shift whilst benefiting road freight sectors not competing with rail. It is not known if, or exactly how, this could be achieved without contravening competition rules, and this has not been studied in detail in this research. However, it is possible to envisage potential methods, such as emissions trading, that could be investigated if further consideration were to be given to permitting LHVs. If such an approach could be devised it would appear to be consistent with the European Commission's notion of co-modality, which aims to improve the efficiency of each freight mode when working alone as well as when working together.

The opinion of the general public has not been directly surveyed in this study because it was considered that doing so would only be sensible when the findings of the research were known and the public could be properly informed of the issues. However, it is worth noting that stakeholders from groups representing other road users were included in the information gathering exercise. Several of these expressed concern about public perception and one provided the results of an NOP survey, commissioned by a rail campaign group, which found that 75% would be opposed to the introduction of 60 tonne "road-trains". However, this poll only considered 25.25m 60 tonne LHVs and cannot necessarily be considered applicable to all scenarios and vehicle types evaluated in this study. Also, it is not known whether those questioned were objectively informed of all the issues before responding. In contrast, a survey of 1,000 drivers in the Netherlands, taken during their trials, indicated "*substantial*" support for the introduction of LHVs. Motorists were found to have a "*reasonably positive attitude*" and were able to cite a "*sufficient number of advantages*" arising from the use of such vehicles. Although respondents indicated that they felt slightly less safe when interacting with heavy goods vehicles, there was no significant difference reported between standard HGVs and LHVs at 25.25m and 60 tonnes.

It is clear that, depending on the characteristics of the vehicles considered, permitting LHVs could require much further work in terms of additional research, legislative action (particularly at the European level) and, most significantly, estimation of the capital investment required in parking facilities and network infrastructure. An analysis of the internal and external costs of freight transport has suggested that the ongoing costs could be substantially reduced. This is because of a predicted net reduction of between approximately 276 thousand and 6.96 million goods vehicle movements per year and the associated changes in operating costs, road wear, accidents and emissions. An analysis of net present value has suggested that the levels of investment that could be sustained before the costs outweighed these benefits would be between £110million and £10.4 billion depending on the scenario and the time period over which the measure was assessed (5, 15 or 60 years). However, the potential benefits, the level of investment required to achieve those benefits, and the risks introduced vary considerably for different scenarios, each of which should be considered separately, as set out below:

- Increasing the length of current 16.5m 44 tonne articulated vehicles to 18.75m, the limit for current drawbar combinations, is likely to represent a “low risk-low reward” option. The increase in volume is relatively small and the take up by industry could be relatively low compared with the other scenarios assessed. Few, if any, additional safety risks, no additional parking problems, and no adverse effect on bridges would be expected. There is a risk of some mode shift from rail to road and, more notably, of limiting predicted future mode shift from road to rail in the domestic intermodal market where strong growth is currently expected. However, overall, the analysis predicted a saving of between approximately 276 thousand and 682 thousand goods vehicle movements per year, resulting in an annual reduction of between 45 thousand and 66 thousand tonnes of carbon dioxide, 57 million to 85 million vehicle kms, one or two fatalities, and £23 million to £37 million in net internal and external freight transport costs. The investment required would be confined to any validation exercises that might be required and the necessary regulatory amendments. The net present value of the accumulated benefits would be expected to be between £110million (low estimate, 5 years) and £386million (high estimate, 60 years) such that a benefit to cost ratio substantially in excess of one would be likely. Additional worthwhile benefits would be likely if such vehicles were both longer and slightly heavier (a payload neutral weight increase to approximately 46 tonnes), but further work would be needed to estimate the effects with a confidence similar to that for the 18.75m, 44 tonne scenario.

- 25.25m vehicles at 44 tonnes, or with a payload neutral weight increase to approximately 50 tonnes, could attract greater reductions in on-going costs. However, in addition to a likely greater effect of limiting predicted future mode shift from road to rail in domestic intermodal markets, there would be a risk of mode shift from rail to road in the deep sea container market, which would have the potential to cause adverse environmental effects. It might be possible to devise a means of limiting such a shift, particularly given the capacity constraints and predicted traffic growth at ports. If this resulted in as much port freight as efficiently possible being transported by rail and allowed what could not be carried by rail to be transported as efficiently as possible by road, such an approach would appear to be consistent with the European Commission’s notion of co-modality,. Substantial investment would be required in parking facilities. This could range from alterations to marked bays at existing sites to the construction of a large number of new or expanded facilities. There is a possibility that further investment would be required to increase the collision protection around bridge supports for 50 tonne vehicles, although such vehicles would not be expected to increase vertical bridge loads because of a lower axle load at maximum weight and a lower load per metre length than current 44 tonne vehicles. Depending on the extent to which routes would be restricted, there would be additional safety and infrastructure risks, such as overtaking and junction blocking, that could not be quantified in the cost analysis. Although it is possible to minimise the risks through innovative vehicle design, the European rules that govern the weights, dimensions and construction of goods vehicles would need to be amended to allow Member States to permit only the use of vehicles with those characteristics. The UK regulations on speed limits for multi-trailer combinations would also require amendment. For these types of LHV, the model predicted a saving in vehicle movements of between approximately 217 thousand and 4.3 million per year resulting in benefits with a net present value of between £351 million (low estimate, 5 years) and £5.9 billion (high estimate, 60 years). However, the potentially large but unquantified capital investment that would be required means that it is uncertain, at this time, as to whether the benefit to cost ratio would exceed one.

- 60, 63 and 82 tonne vehicles would incur similar risks and investments to those described above for 25.25m vehicles at 44 and 50 tonnes except that there would be a much greater risk of adverse environmental effects as a result of limiting predicted future mode shift from road to rail in domestic intermodal markets and inducing mode shift from rail to road in bulk goods markets as well as the deep sea container market. Increased investment would be required to protect bridge supports, if further research confirmed the risks, and 82 tonne vehicles may require some trunk road bridges to be strengthened or such vehicles to be prohibited from using them. 63 and 82 tonne vehicles would also be likely to require a larger investment in parking facilities because of their greater size and the potential need for coupling and de-coupling points. The model predicts that 60/63 tonne vehicles would produce a saving in vehicle movements of between 541 thousand and 3.56 million per year, resulting in benefits with a net present value of between £1.02 billion (low estimate, 5 years) and £6.57 billion (high estimate, 60 years). 82 tonne vehicles could save between 1.46 million and 6.96 million vehicle movements per year, resulting in benefits with a net present value of between £1.8billion (low estimate, 5 years) and £10.4billion (high estimate, 60 years). However, given that the cost of the necessary infrastructure improvements is likely to be very high, but could not be reliably quantified, it is uncertain as to whether the benefit to cost ratio would exceed one.

If further consideration is given to permitting LHVs, then it is recommended that more detailed study in a range of different areas would be necessary. The nature of this work would vary depending on the scenario and the types and characteristics of the vehicles to be considered. Specifically:

1. In the case of articulated vehicles with longer semi-trailers then it may be necessary to:

   a. Validate the findings of this report with respect to their safety and manoeuvrability, and assess whether permitting different loading and overall lengths, high cube or double decked variants would change the level of risk and/or monetary benefit predicted.

   b. Validate the estimates of the proportion of tonne-kms that would migrate from existing articulated vehicles, double deck vehicles and drawbar combinations.

   c. Study the safety effects of drawbar combinations, particularly those using short wheelbase "full" trailers, in order to improve the confidence in the "business as usual" scenario and better assess the relative effects of changes.

   d. Assess in more detail the costs and benefits of permitting small increases in maximum weight such that the payload capacity of the longer vehicle was equivalent to that of current articulated vehicles (a payload neutral weight increase).

   e. Assess in more detail the potential effects of the predicted mode shift in the domestic intermodal, in particular the extent to which it might limit the expected growth of that market and how that would affect the businesses that operate within it.

   f. Resolve the legal issues identified in this report, if vehicles were to be considered where the loading length exceeded the maximum permitted for a conventional drawbar combination.

2. In the case of 25.25m vehicles at 44 tonnes then it would be appropriate to study the following in addition to those items in 1 above:

   a. The feasibility and likely cost of providing adequate LHV parking facilities.

   b. The suitability of specific routes for vehicles complying with different manoeuvrability standards to further develop the assessments carried out for this project, including identifying the cost of any infrastructure improvements and/or additional signage that might be required.

   c. The effectiveness of safety measures specific to the types or characteristics of vehicles to be considered.

d. Validation of the mode shift predictions for the deep-sea container market and consideration of how to minimise or avoid mode shift in order to deliver a positive environmental outcome.

3. In the case of 25.25m vehicles with payload neutral weight increases (c.50 tonnes) then the following additional work would be appropriate:

   a. Assessing the effects of collisions between vehicles and bridge supports and their protective structures to determine whether or not the increased mass does represent an increased risk and, if so, identify the level of investment required to implement the improvements that would be needed to maintain the current level of risk.

4. In the case of vehicles at 60 tonnes then the following additional work would be required:

   a. A survey of the number of bridges that could not be used by vehicles with a GVW > 44 tonnes and are not already signed and restricted to <44 tonnes (this would not be needed for 25.25m vehicles at c.50 tonnes because of the lower maximum axle loads and load per metre of bridge)

   b. Validation of the predictions of mode shift in the bulk rail market and consideration of how to minimise or avoid mode shift in order to deliver a positive environmental outcome.

5. In the case of 34m vehicles at 82 tonnes then the following additional work would be required:

   a. More detailed evaluation of the effects of 82 tonne vehicles on bridge loading.

   b. The feasibility and costs of providing coupling and decoupling points.

The methods required for each of the above investigations would be different. Some, but not all, could be assessed in trials similar to those in the Netherlands. These trials would have to be sufficiently large if the results were to be statistically significant. However, some of the investigations described above such as parking provision, route and bridge suitability, and specific safety risks and countermeasures would need to be carried out before in-service trials could be considered. In addition to this, the speed limits for vehicles with more than one trailer would need to be amended in order for trials of such vehicles to be meaningful.

Finally, certain aspects of the analysis of the likely effects of LHVs, if they were to be permitted, could be greatly improved if additional data were available. In particular:

- adding volumetric measures of loading to the CSRGT
- obtaining equivalent data on foreign vehicle activity
- Standardising and improving vehicle definitions in CSRGT, traffic census, STATS 19 and DVLA data sources. This would improve consistency and increase the scope and rigour of possible analyses, particularly with respect to double decked vehicles and drawbar vehicle combinations.

9 Conclusions

1. Recent increases in the sizes of goods vehicles have helped to reduce emissions of carbon dioxide, vehicle kms and the cost of freight transport relative to what it otherwise would have been. Further increases might, therefore, be expected to deliver additional worthwhile reductions, but the findings of the study show that if goods vehicles significantly larger than 18.75m and 44 tonnes were to be allowed they would be likely to have serious adverse effects unless:

   a. investment was made in improved parking facilities to provide for statutory rest periods, which could be substantial if a new nationwide network of dedicated facilities are deemed to be necessary;

   b. investment was made in network infrastructure to establish suitable routes and procedures to manage diversions and enforce restrictions, and/or vehicles conformed with certain weight limits and manoeuvrability characteristics that reduce risk to the infrastructure. However, for such vehicles it does not currently appear to be possible to mandate standard manoeuvrability requirements on account of European trade rules.

   c. the speed limits for combinations with more than one trailer were increased (currently these are 40 mile/h on motorways and 20 mile/h on other roads).

2. A blanket decision to permit 60 tonne vehicles with more than one trailer for general haulage would present a substantial risk of adverse environmental effects mainly because of likely mode shift from rail to road, especially in the deep sea container market. If such multi-trailer vehicles were restricted to around 50 tonnes, or less, the likely magnitude of mode shift would be much reduced and largely confined to the deep sea container market. The risk of adverse environmental affects would, therefore, be much lower.

3. Vehicles significantly larger than 18.75m and 44 tonnes would be likely to increase safety risks per vehicle km, but decrease safety risks per unit of goods moved. If such vehicles were to be allowed, it would be advantageous for certain safety features to be fitted in order to minimise the risks and maximise the casualty reduction potential. However, once again, requiring this does not appear to be possible within the current European regulatory framework.

4. Although an analysis of the internal and external costs of freight transport suggests that such vehicles offer substantial ongoing benefits, the potentially large but unknown investment costs means that it is not certain as to whether the benefit cost ratio would exceed one. Further work would therefore be needed to determine whether addressing the above issues would deliver worthwhile net benefits.

5. However, in the case of 18.75m 44 tonne articulated goods vehicles with semi trailers longer than those currently permitted, few of the problems or additional risks identified above would apply. The reductions such vehicles would offer in terms of the internal and external costs are likely to be smaller than those offered by vehicles with significantly higher capacity but the minimal investments required mean that a benefit cost ratio substantially in excess of one would be likely, with the model predicting annual savings of around:

   a. 45 thousand to 66 thousand tonnes of carbon dioxide,

   b. 57 million to 85 million vehicle kms,

   c. 276 thousand to 682 thousand goods vehicle movements,

   d. one or two fatalities, and

   e. £23 million to £37 million in net internal and external freight transport costs.

6. If the net present value of the benefits for 18.75m 44 tonne articulated goods vehicles with longer semi-trailers are evaluated over 5 years, they would be expected to be between approximately £110 million and £176 million. If the evaluation period was extended to 15 years the net present value of the benefits would be expected to be between £224 million and £359 million and over 60 years would be approximately £241 million to £386 million. Additional worthwhile benefits

would be likely if the weight of such vehicles were to be increased to approximately 46 tonnes to compensate for the increase in unladen weight (a payload neutral weight increase).

7. If further consideration is given to permitting these longer articulated vehicles then more detailed study may be necessary to:

   a. validate the costs and benefits with respect to uptake by the industry, the effects of small (payload neutral) weight increases, legal issues, safety, manoeuvrability, and the effects on current and future rail markets; and

   b. assess whether additional worthwhile benefits could be achieved, relative to existing vehicles, by variations to the length, height and configuration of the longer semi-trailer.

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Appendix A. Identification and selection of vehicle types for analysis

A.1 Introduction

There are a wide range of vehicles in use around the world that are longer or longer and heavier than currently permitted in the UK. There has also been a range of proposals promoting different vehicle combinations from within the UK and the EU. The intention of this aspect of the study was to identify as many of these different combinations as possible, provide basic categorisation and definitions of their characteristics and, acknowledging the large number of possibilities, to select a short list of vehicle types on which more detailed analysis could be undertaken to provide the basis for much of the further analysis described in this report.

A.2 Methods

The vehicles were identified, typical characteristics were defined and vehicles selections were made on the basis of the literature review and discussions with the vehicle manufacturing, freight and logistics industries.

A.3 Results

A.3.1 Identification of EU combinations, proposals and vehicle characteristics

Each of the vehicle configuration options described in this section can have at least four possible sub-categories:

- Increased length only with single deck loading units
- Increased length with double or triple deck loading units
- Increased weight and length with single deck loading units
- Increased weight and length with double or triple deck loading units

A.3.1.1 Configuration A, Rigid vehicle and semi-trailer combination

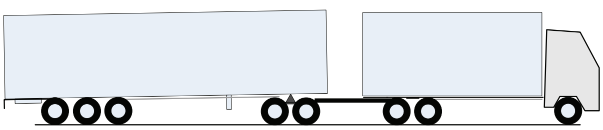


Figure 17: Rigid vehicle and semi-trailer combination

Configuration A consists of a rigid vehicle, a dolly and a semi-trailer. The rigid vehicle tows a tandem axle A-frame dolly with fifth wheel coupling, which in turn tows a conventional semi-trailer (for diagram of A-frame dolly see Figure 20 in configuration C). This vehicle combination is made up from standard loading units, where the unit load carrier on the rigid vehicle has a length of 7.82 m and the semi-trailer has a length of 13.6 m, with an overall length of 25.25 m. This vehicle combination consists of 8 axles with a configuration of 3+2+3 and two points of articulation. This type of vehicle combination has been in operation in Sweden and Finland since 1997 and the weights and dimensions described here are based on these existing vehicles.

Table 38 shows the possible maximum lengths and weights for configuration A and the maximum number of CEN and ISO pallets that this vehicle combination can carry. Both the double deck and triple deck options assume all decks in the trailer are full length decks.

Table 38: Configuration A lengths, weights and pallet capacity

Configuration A variations	Length (m)	Weight (T)	CEN Pallets	ISO Pallets
Increased length only, single deck	25.25	44	52	40
Increased length only, double deck	25.25	44	104	80
Increased length only, triple deck	25.25	44	156	120
Increased weight and length, single deck	25.25	60	52	40
Increased weight and length, double deck	25.25	60	104	80
Increased weight and length, triple deck	25.25	60	156	120

A.3.1.2 Configuration B, Articulated vehicle and drawbar trailer combination

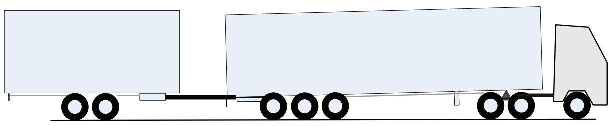


Figure 18: Articulated vehicle and drawbar trailer combination

Configuration B consists of an articulated vehicle and centre axle drawbar trailer. The articulated vehicle includes a standard tractor unit and semi-trailer and the rear trailer is connected to the semi-trailer via a drawbar coupling. This combination consists of standard loading units. The semi-trailer has a length of 13.6 m and the drawbar trailer has a length of 7.82 m, with an overall vehicle length of 25.25 m. This vehicle combination consists of 8 axles with a configuration of 3+3+2. Again this type of vehicle combination has been used in Sweden and Finland for almost 10 years and the weights and dimensions are based on these existing vehicles.

Table 39 shows the possible maximum lengths and weights for configuration B and the maximum number of CEN and ISO pallets that this vehicle combination can carry. Both the double deck and triple deck options assume all decks in the trailer are full length decks.

Table 39: Configuration B lengths, weights and pallet capacity

Configuration B variations	Length (m)	Weight (T)	CEN Pallets	ISO Pallets
Increased length only, single deck	25.25	44	52	40
Increased length only, double deck	25.25	44	104	80
Increased length only, triple deck	25.25	44	156	120
Increased weight and length, single deck	25.25	60	52	40
Increased weight and length, double deck	25.25	60	104	80
Increased weight and length, triple deck	25.25	60	156	120

A.3.1.3 Configuration C, A-Train

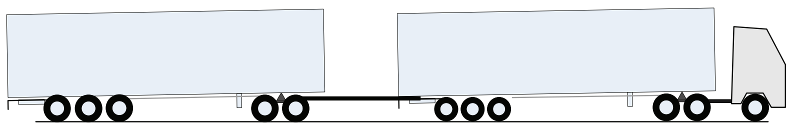


Figure 19: A-Train

Configuration C consists of two standard loading units, an articulated vehicle towing an additional semi-trailer. This combination is known as an A-train because the rear semi-trailer is attached to a fifth wheel that is mounted on an A-dolly. The A-dolly is connected to the front semi-trailer via a single drawbar. Twin airlines can be fitted to the tractor unit, so each trailers braking can be independent of the other. The airlines operate simultaneously. An illustration of an A-dolly is shown in Figure 20, below.

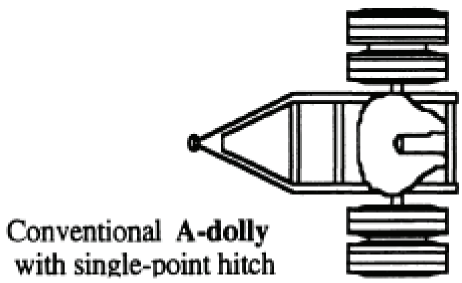


Figure 20: A-frame dolly

This type of vehicle has been in use in countries outside of Europe for some time and has been proposed by a UK haulier as a candidate for use in the UK. The weights and dimensions stated here are based on the UK proposal, which is claimed to be based on the dimensions of standard loading units and the GVW achievable without exceeding current axle weight limits. Both semi-trailers have a length of 13.6 m, giving the vehicle a maximum overall length of 34 m. This combination consists of 11 axles with a configuration of 3+3+2+3 and has three points of articulation.

Table 40 shows the possible maximum lengths and weights for Configuration C and the maximum number of CEN and ISO pallets that this vehicle combination can carry. Both the double deck and triple deck options assume all decks in the trailer are full length decks.

Table 40: Configuration C; lengths, weights and pallet capacity

Configuration C variations	Length (m)	Weight (T)	CEN Pallets	ISO Pallets
Increased length only, single deck	34	44	68	52
Increased length only, double deck	34	44	136	104
Increased length only, triple deck	34	44	204	156
Increased weight and length, single deck	34	82	68	52
Increased weight and length, double deck	34	82	136	104
Increased weight and length, triple deck	34	82	204	156

A.3.1.4 Configuration D, C-Train

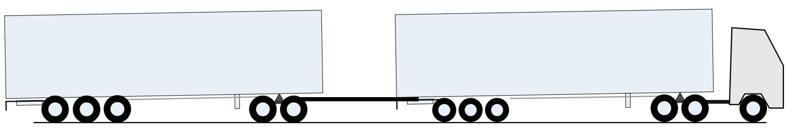


Figure 21: C-Train

Just like configuration C, the A-train, configuration D consists of an articulated vehicle towing an additional semi-trailer. However, this combination is known as a C-train because the rear semi-trailer is attached to a fifth wheel mounted on a C-dolly. The C-dolly is connected to the first semi-trailer with two drawbars. This eliminates one of the points of articulation, so to limit tyre wear at least one of the axles on the C-dolly must be self-steering. C-trains are prohibited in Australia because Australian rules require articulation between axle groups in order to limit tyre scrub. The C-dolly prevents articulation between the wheels of the dolly and the axles of the trailer in front of the dolly. However, this combination is permitted in North America. An illustration of a C-dolly is shown in Figure 22, below.

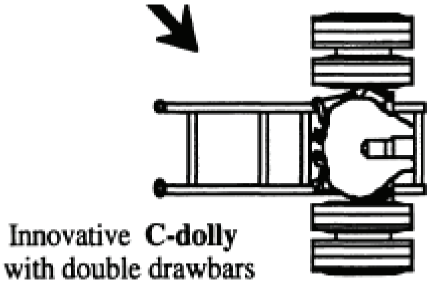


Figure 22: C-dolly

The weights and dimensions of this vehicle are based on the proposal from a UK haulier for the candidate A-train vehicle for the same reasons. Both semi-trailers have a length of 13.6 m, giving the vehicle a maximum overall length of 34 m. This combination consists of 11 axles with a configuration of 3+3+2+3 and has two points of articulation.

Table 41 shows the possible maximum lengths and weights for configuration D and the maximum number of CEN and ISO pallets that this vehicle combination can carry. Both the double deck and triple deck options assume all decks in the trailer are full length decks.

Table 41: Configuration D lengths, weights and pallet capacity

Configuration D variations	Length (m)	Weight (T)	CEN Pallets	ISO Pallets
Increased length only, single deck	34	44	68	52
Increased length only, double deck	34	44	136	104
Increased length only, triple deck	34	44	204	156
Increased weight and length, single deck	34	82	68	52
Increased weight and length, double deck	34	82	136	104
Increased weight and length, triple deck	34	82	204	156

A.3.1.5 Configuration E, B-double/ B-train

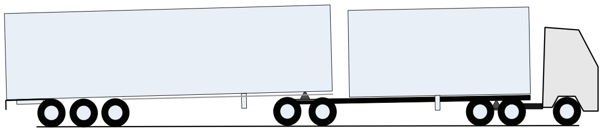


Figure 23: B-double/ B-train

Configuration E consists of two standard loading units, semi-trailers, coupled together. This combination includes a tractor unit towing an ‘interlink’ semi-trailer. A fifth wheel coupling is mounted directly on the rear of the ‘interlink’ trailer, which then carries the rear semi-trailer. A haulier in the UK has proposed using this vehicle combination with a steered bogie at the rear of the interlink trailer to enable it to meet current turning circle requirements. The weights and dimensions of this vehicle are based on the UK hauliers proposal and are claimed to match standard loading units well and reflect the maximum GVW achievable without exceeding current axle weight limits.

Both semi-trailers have a length of 13.6 m. However, the unit load carrier on the ‘interlink’ trailer only has a length of 7.82 m, because of the space required for the fifth wheel mounted at its rear. The vehicle has a combined length of 25.25 m. This vehicle combination consists of 8 axles with a configuration of 3+2+3 and has two points of articulation.

Table 42 shows the possible maximum lengths and weights for configuration E and the maximum number of CEN and ISO pallets that this vehicle combination can carry. Both the double deck and triple deck options assume that all decks in the trailer are full length decks.

Table 42: Configuration E lengths, weights and pallet capacity

Configuration E variations	Length (m)	Weight (T)	CEN Pallets	ISO Pallets
Increased length only, single deck	25.25	44	52	40
Increased length only, double deck	25.25	44	104	80
Increased length only, triple deck	25.25	44	156	120
Increased weight and length, single deck	25.25	60	52	40
Increased weight and length, double deck	25.25	60	104	80
Increased weight and length, triple deck	25.25	60	156	120

A.3.1.6 Configuration F, Longer semi-trailer

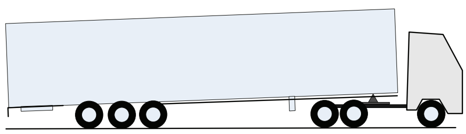


Figure 24: Longer (16 m) semi-trailer

Configuration F consists of the standard articulated combination, but has a longer semi-trailer than currently permitted. In Europe it has been proposed that this type of vehicle would be equipped with a tandem or tri-axle steering bogie at the rear of the trailer in order to enable it to meet manoeuvrability requirements. A European vehicle manufacturer has proposed this type of vehicle and the weights and dimensions are based on that proposal. This is also claimed to provide more flexibility in terms of matching the dimensions of standard loading units. The semi-trailer has a length of 16 m compared to a standard semi-trailer with a length of 13.6m. The combined length of this articulated vehicle is expected to be approximately 18.75m. Some sections of the road freight industry have suggested that this length is more suited to pallet dimensions such that the relatively small increase in length can accommodate 6 additional pallets on a single deck. This vehicle combination would consist of 6 axles with a configuration of 3+3 and has one point of articulation.

Table 43 shows the possible maximum lengths and weights for configuration F and the maximum number of CEN and ISO pallets that this vehicle combination can carry. Both the double deck and triple deck options assume that all decks in the trailer are full length decks.

Table 43: Configuration F lengths, weights and pallet capacity

Configuration F variations	Length (m)	Weight (T)	CEN Pallets	ISO Pallets
Increased length only, single deck	18.75	44	40	32
Increased length only, double deck	18.75	44	80	64
Increased length only, triple deck	18.75	44	120	96

A.3.1.7 Configuration G, Rigid Vehicle and Two Centre Axle Trailers

Configuration G is a modular truck combination that consists of a rigid vehicle coupled with two centre axle drawbar trailers with an overall length of approximately 27.25 m.

Table 44 shows the possible maximum lengths and weights for configuration G and the maximum number of CEN and ISO pallets that this vehicle combination can carry. Both the double deck and triple deck options assume all decks in the trailer are full length decks.

Table 44: Configuration G lengths, weights and pallet capacity

Configuration G variations	Length (m)	Weight (T)	CEN Pallets	ISO Pallets
Increased length only, single deck	27.25	44	54	42
Increased length only, double deck	27.25	44	108	84
Increased length only, triple deck	27.25	44	162	126
Increased weight and length, single deck	27.25	60	54	42
Increased weight and length, double deck	27.25	60	108	84
Increased weight and length, triple deck	27.25	60	162	126

A.3.2 Other existing LHV combinations

A.3.2.1 Australian Combinations

There are a wide range of LHV combinations used in Australia. Although the types can be categorised in a similar manner to those vehicles described above the specific numbers of axles, weights and dimensions can very widely and triple trailer combinations can also be used. Some examples of these combinations are described below:

- A rigid vehicle and two semi-trailers. The rigid vehicle is coupled to a tandem axle A-dolly, which in turn is coupled to the first semi-trailer. This in turns tows a second tandem axle A-dolly, which is coupled to the rear semi-trailer. This vehicle has an axle configuration of 3+2+3+2+3.
- An articulated vehicle and two semi-trailers. The articulated vehicle tows a tandem axle A-dolly, which is coupled via a fifth wheel to the second semi-trailer. The second semi-trailer in turn tows the second tandem axle A-dolly and the rear semi-trailer.
- B-double with axle configuration 3+3+3. This vehicle is the same as configuration E, except that the ‘interlink’ trailer has three axles rather than two.
- B-triple, this is a tractor unit towing two ‘interlink’ semi-trailers and a standard semi-trailer. This vehicle has an axle configuration of 3+3+3+3.
- AB-triple, this vehicle is an articulated vehicle towing an ‘interlink’ semi-trailer and standard semi-trailer. The articulated vehicle is coupled to a triple axle A-dolly. The ‘interlink’ trailer is coupled to the fifth wheel mounted on the dolly. The rear semi-trailer is then coupled with the fifth wheel mounted on the ‘interlink’ trailer. The vehicle has an axle configuration of 3+3+3+3+3

A.3.2.2 North American Combinations

- A-Trains
    - Eight axle, articulated vehicle with single axle A-dolly and semi-trailer. The axle configuration for this vehicle is 3+2+1+3 and the vehicle has three points of articulation.
    - Nine axle, articulated vehicle with tandem A-dolly and semi-trailer. The axle configuration for this vehicle is 3+2+2+2 and has three points of articulation.
    - Nine axle, articulated vehicle with single axle A-frame dolly and semi-trailer. This vehicle has an axle configuration of 3+2+1+3 and again has three points of articulation.
    - Ten axle, articulated vehicle with tandem A-dolly and semi-trailer. The axle configuration for this vehicle is 3+2+2+3 and once again this vehicle has three points of articulation.

There are a number of examples of this type of LHV with the number of axles on both semi-trailers varying between two and three and the number of axles on the A-frame dolly varying between one and three.

- B-Trains
    - Eight axle, articulated vehicle with ‘interlink’ semi-trailer and second semi-trailer. This vehicle has two points of articulation and the axle configuration 3+3+2.

- Nine axle, articulated vehicle with 'interlink' semi-trailer and second semi-trailer. This vehicle has two points of articulation and the axle configuration 3+3+3.
- Seven axle B-Train with sliding axle assembly. This vehicle consists of an articulated vehicle with 'interlink' semi trailer and a second semi-trailer. The vehicle has an axle configuration of 3+2+2 and two points of articulation.

As with the A-Train there are various axle combinations of the B-Train.

- C-Trains (with self steering dolly)
  - Eight axle, articulated vehicle with single axle C-dolly and semi-trailer. This vehicle has two points of articulation and an axle configuration of 3+2+1+2.

Like both the A-Trains and B-trains, the C-Train has a number of axle combinations.

A.3.3 Engine Power

Vehicle manufacturers with experience of supplying tractive units for LHVs have suggested that 480 hp to 660 hp of engine power would be needed for LHVs where the GVW has been increased to 60 or 80 tonnes. Scania has suggested both 6x2 and 6x4 tractor units with engine power between 480hp to 580 hp would be necessary. Volvo has also suggested both 6x2 and 6x4 tractor units with engine power between 480 hp and 660 hp would be required. It was suggested that current power levels would be adequate for combinations where the GVW was not increased. Table 45, below, highlights engines from various manufacturers with suitable power ratings for 60 tonne plus vehicles.

Table 45: Examples of vehicles meeting engine power requirements

Manufacturer	Engine	Horse Power	Power (KW)	Torque (Nm)
DAF	XE 390 C	530	390	2350
	XE 355 C	483	355	2100
Mercedes-Benz	OM501LA	476	350	2300
	OM502LA	510	375	2400
	OM502LA	550	405	2600
Scania	R580	580	426	2700
	R560	560	412	2700
	R500	500	368	2400
	R480	480	353	2250
Volvo	FH16 D16E660	660	485	3100
	FH16 D16E580	580	426	2800
	FH D13A520	520	382	2500
	FH D13A480	480	353	2400

A.3.4 Initial selection of vehicle types for detailed analysis

The exercise of cataloguing vehicle types described above resulted in a possible matrix of several hundred vehicles that were longer and/or heavier than current UK regulations permit. It was not possible within the constraints of this project to carry out detailed analysis of the impacts of each and every one of these vehicles, hence it was necessary to filter the extensive list down to a manageable group of vehicle types that appeared to most closely match the preferences of those sections of the road freight industry calling for LHVs..

The vehicle types that were selected for further analysis were as defined below:

- Vehicle 1: Six axle articulated vehicle, 16.5m overall length, 44 tonnes GVW (Standard reference baseline)
- Vehicle 2: As vehicle 1 but double decked (Option for improvement within current regulation)
- Vehicle 3: Tractor, extended semi-trailer (16m), 6 axles, 18.75m, 44 tonnes (longer semi)
- Vehicle 4: Rigid truck, converter dolly (A), semi-trailer, 8 axles (3+2+3), 25.25m, 44 tonnes (Rigid/A/Semi 44)
- Vehicle 5: Tractor, interlink semi-trailer, semi-trailer, 8 axles (3+2+3), 25.25m, 44 tonnes (B-double 44)
- Vehicle 6: Rigid truck, converter dolly (A), semi-trailer, 8 axles (3+2+3), 25.25m, 60 tonnes (Rigid/A/Semi 60)
- Vehicle 7: Tractor, interlink semi-trailer, semi-trailer, 8 axles (3+2+3), 25.25m, 60 tonnes (B-double 60)
- Vehicle 8: Tractor, semi-trailer, converter dolly (C), semi-trailer, 11 axles (3+3+2+3), 34m, 82 tonnes (C-train)

These vehicle types are defined in more detail in Table 46, below.

Table 46. Detailed specifications of vehicle types for analysis

Vehicle reference number	Description	Maximum length (m)	Axle	Weight (kg) Unladen (kg)	Maximum (kg)	Payload (kg)	Height (m)	Volume (cubic metres)	Pallet capacity (ISO)	Engine power (kw)
1	Standard articulated (reference baseline)	16.5	Axle 1	5,573	7,100	29,109	4	100.9	26	335.6
			Axle 2	1,859	7,100					
			Axle 3	3,010	10,500					
			Axle 4	1,483	8,000					
			Axle 5	1,483	8,000					
			Axle 6	1,483	8,000					
			Total	14,891	44,000					
2	Double decked articulated vehicle (improvement within current limits)	16.5	Axle 1	5,618	7,100	26,130	4.9	131.5	52	335.6
			Axle 2	2,357	7,100					
			Axle 3	3,508	10,500					
			Axle 4	2,129	8,000					
			Axle 5	2,129	8,000					
			Axle 6	2,129	8,000					
			Total	17,870	44,000					
3	Longer articulated vehicle	16.5	Axle 1	5,603	7,100	27,322	4	118.9	32	335.6
			Axle 2	2,187	7,100					
			Axle 3	3,338	10,500					
			Axle 4	1,850	8,000					
			Axle 5	1,850	8,000					
			Axle 6	1,850	8,000					
			Total	16,678	44,000					
4	Rigid/A/Semi 44	25.25	Axle 1	5,860	8,000	23,651	4	158.9	40	335.6
			Axle 2	3,486	10,500					
			Axle 3	2,274	7,500					
			Axle 4	2,140	8,000					
			Axle 5	2,140	8,000					
			Axle 6	1,483	8,000					
			Axle 7	1,483	8,000					
			Axle 8	1,483	8,000					
			Total	20,349	44,000					
5	B-Double 44	25.25	Axle 1	5,573	7,100	23,349	4	158.9	40	335.6
			Axle 2	1,859	7,100					
			Axle 3	3,010	10,500					
			Axle 4	2,880	9,000					
			Axle 5	2,880	9,000					
			Axle 6	1,483	8,000					
			Axle 7	1,483	8,000					
			Axle 8	1,483	8,000					
			Total	20,651	44,000					
6	Rigid/A/Semi 60	25.25	Axle 1	5,860	8,000	39,651	4	158.9	40	425
			Axle 2	3,486	10,500					
			Axle 3	2,274	7,500					
			Axle 4	2,140	8,000					
			Axle 5	2,140	8,000					
			Axle 6	1,483	8,000					
			Axle 7	1,483	8,000					
			Axle 8	1,483	8,000					
			Total	20,349	60,000					
7	B-Double 60	25.25	Axle 1	5,573	7,100	39,349	4	158.9	40	425
			Axle 2	1,859	7,100					
			Axle 3	3,010	10,500					
			Axle 4	2,880	9,000					
			Axle 5	2,880	9,000					
			Axle 6	1,483	8,000					
			Axle 7	1,483	8,000					
			Axle 8	1,483	8,000					
			Total	20,651	60,000					
8	C-train	34	Axle 1	5,573	7,100	58,380	4	158.9	40	425
			Axle 2	1,859	7,100					
			Axle 3	3,010	10,500					
			Axle 4	1,483	8,000					
			Axle 5	1,483	8,000					
			Axle 6	1,483	8,000					
			Axle 7	2,140	8,000					
			Axle 8	2,140	8,000					
			Axle 9	1,483	8,000					
			Axle 10	1,483	8,000					
			Axle 11	1,483	8,000					
			Total	23,620	82,000					

The rationale for the choices was as rigorous as was possible, accepting that at the stage of the research that the selection was made, little analysis of the characteristics and impacts of the vehicle types had been carried out. The objective therefore was to produce a balanced selection that reflected preliminary findings about the requirements of the UK freight market (e.g. inclusion of volume only changes to reflect the current level of volume constrained loads), the UK vehicle fleet (e.g. less emphasis on drawbar trailers due to low levels of use in the UK) and those that had potentially the least adverse safety impact. It was considered important to include vehicles that would closely match the requirements of the UK road freight industry because including vehicles unsuited to the UK would bias the research toward the status quo from the start and would be of little value.

The baseline vehicle was selected as the largest currently permitted vehicle and, therefore, the most likely to be replaced by LHVs. The choices for a larger vehicle within current limits were either a drawbar combination or a double decked vehicle. The double decked vehicle was chosen because it offered greater volume and because its first introduction was more recent than drawbar combinations, meaning that there may be more scope for encouraging further take up of the option.

In terms of safety, little analysis had been completed at the time of the selection so this assessment was based mainly upon information on the phenomena known as Rearward Amplification (RA) and at this time the only information was single sourced from a paper by Volvo Trucks (Aurell, 2003). It was already known at the time of selection that dynamic stability was one of the concerns with longer vehicles, and that rearward amplification was a particularly important aspect. However, different test manoeuvres may produce different values and possibly even different ranking of vehicle types so the initial selection on safety has to be considered as indicative only. A graph showing the rearward amplification factors for different vehicle types, based on the data presented by Aurell (2003) is shown in Figure 25, below.

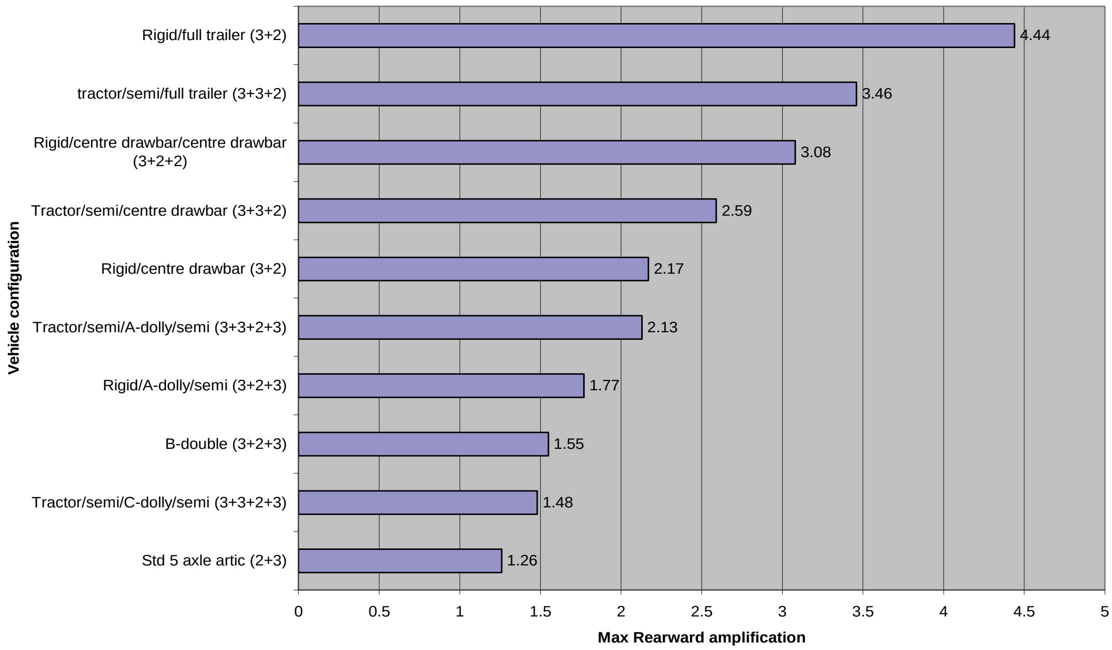


Figure 25. Rearward amplification factors for different vehicle types (based on data extracted from Aurell, 2003)

It can be seen that the least stable vehicle in terms of rearward amplification is actually legally permissible under current UK regulations, a rigid vehicle towing a twin axle “full” trailer, although it should be noted that the above analysis excludes the larger 3+ trailer combinations often used in countries such as Australia, Canada and the USA, which may well record higher values. A full trailer is one with a steered axle at the front and one or two fixed axles at the rear rather than fixed axles in the centre of the trailer. However, the use of drawbar trailers is very low in the UK at approximately 2% of truck tonne-kilometres. Although there is no objective data available, it is perceived that within this 2%, centre axle drawbar trailers are considerably more popular than full trailers, suggesting that the use of full trailers is likely to represent less than 1% of UK road tonne-kms. Vehicle combinations allowing the possible use of full trailers were, therefore, thought to be particularly unfavourable, not only because of their possible effect on stability of the LHV combination they were part of but also because should they be permitted with LHVs, this could encourage wider use of full trailers in standard 18.75m combinations with rigid trucks.

Combinations involving centre axle drawbar trailers were more stable than those involving full trailers but still less stable than those involving semi-trailers. Therefore, these were viewed slightly less favourably than semi-trailers but more favourably than full trailers from a safety point of view.

It was considered that substantial investment may be required by UK business if LHVs involving drawbar trailers were to be used in significant numbers because of their relatively low current usage, whereas standard semi-trailers are already available in plentiful supply. The interlink trailer of a B-double could also require substantial investment because there are none currently in use in the UK, making it less favourable from a business point of view. However, it was one of the best performing combinations in terms of rearward amplifications, making it more favourable from a safety point of view.

When considering a tractor with two semi-trailers it was seen as favourable from a business point of view because it used standard semi-trailers readily available in the UK and offered the biggest increase in load capacity. In terms of rearward amplification it also rated better than existing centre axle drawbar combinations. However, there was a choice between the use of an “A” or “C” dolly. A C-dolly was selected because of the twin reasons that it further improved the dynamic stability and that the A-dolly could be assessed as part of the rigid/semi combination.

It is very important to emphasise that this selection process, undertaken near the beginning of the study, was based on very limited analysis of the available data in order to provide a manageable set of vehicle types for more detailed analysis. It does not constitute a recommendation that the vehicles not selected for the further analysis could not be suitable candidates if LHVs were to be permitted in the UK.

Appendix B. Analysis of impacts on safety

When considering the safety of LHVs there are a number of areas to be investigated including:

- Manoeuvrability, including the swept path of the vehicle
- Field of view
- Braking
- Stability
- Collision severity

There has been extensive research in countries such as Canada, the USA and Australia on the safety of LHV combinations in these countries, and in many cases the configuration and use of such vehicles is governed by performance based standards. There is also experience of LHV use and accident records in Sweden and Finland and trials have been carried out in the Netherlands and Germany. A review of past research and performance based standards has been carried out and, where necessary, the findings have been extended using theoretical and analytical methods to ensure they are applicable to the types of LHV being assessed.

The safety of heavy vehicles has been improved considerably in the past with the development of new safety features and technologies. In recent years sophisticated electronic control systems have been developed that appear likely to deliver substantial additional casual saving benefits. While many of these are not yet standard on all vehicles, this is quite likely to change in coming years, and a number of systems such as stability control and other advanced braking systems may well become mandatory on all new vehicles. For this reason, it was considered that these could not be ignored as part of the safety assessment. It is important to note however, that the question of whether such features could be required on all vehicle modules used as part of an LHV at the present time (and in particular LHV combinations operated by foreign companies), was considered as part of a separate assessment of legal issues (see Appendix E).

B.1 Manoeuvrability

With increased length and/or mass of vehicle combinations, controls upon their movements are necessary, because additional length is likely to reduce manoeuvrability of the vehicle and inconvenience other road users. When assessing the manoeuvrability of a vehicle combination a number of factors have to be taken into consideration. These include:

- Low speed off-tracking
- Out-swing
- Swept path

B.1.1 Low speed off-tracking

When a vehicle combination turns at low speed, it is possible that the trailer(s) may not take the same path as the tractor unit. If this occurs then the trailer(s) will take a path that can be up to several metres to the inside path of the curve of the tractor unit and this is known as low speed off-tracking. Off-tracking can be described as a phenomenon that occurs when the trailing axles of a turning vehicle migrate from the curve described by the leading axle. At low speeds, the off-tracking will be towards the centre of the curve (Harkey et al.). At high speeds the off-tracking will be outwards from the centre of the curve. This is commonly called high-speed off-tracking (Sweatman, 1993) and is considered separately.

At low speeds, off-tracking increases gradually as a vehicle proceeds through a turning manoeuvre. This increasing off-tracking is termed partially developed off-tracking (Transport Research Board, 2003). As the vehicle continues to move in a constant radius curve, the off-tracking eventually reaches what is termed its fully developed off-tracking value (sometimes referred to as steady-state off-tracking).

There are two commonly used measures of off-tracking. One is the off-tracking amount, defined as the radial offset between the path of the centreline of the front axle and the path of the centreline of a following axle. The other, and more important measure, is the swept path width and is equal to the width of the vehicle plus the off-tracking distance.

High values of off-tracking can be a problem because this means that the vehicle will require more road space when performing a turning manoeuvre. Problems that may occur with high values of off-tracking include the trailer(s) encroaching into an adjacent lane, this means that the trailer(s) could collide with another vehicle of another object along the inside path of the turning vehicle or at worst could endanger a vulnerable road user. Figure 26 illustrates the low speed off-tracking of an articulated vehicle turning left.

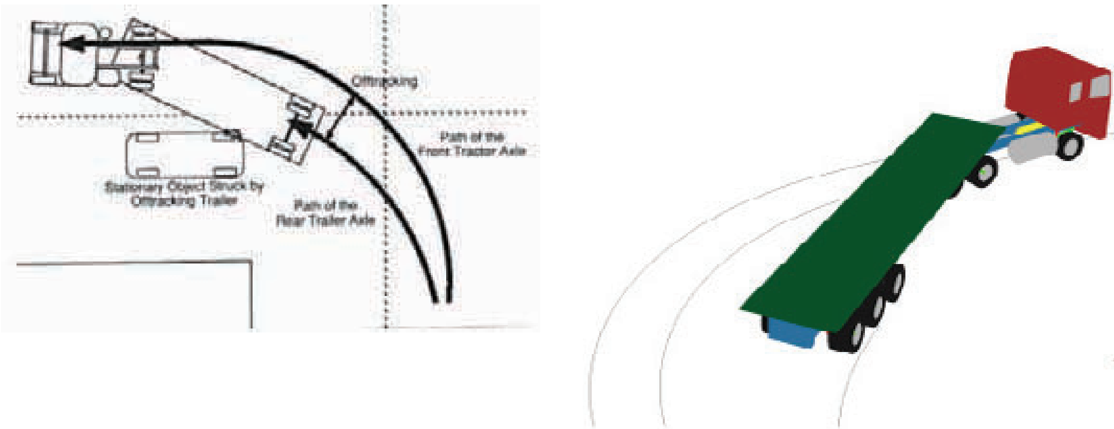


Figure 26: Illustration of low speed off-tracking

Low speed off-tracking is related to the size of trailer wheelbase e.g. the distance from the fifth-wheel coupling/kingpin to the centre of the rear axle. Low speed off-tracking increases significantly as wheelbase increases. However, increasing the number of articulation points in a vehicle decreases the low speed off-tracking (Prem at al, 2000). As a solution to low speed off-tracking steered trailers can be used. Prem et al (2000) suggests that the evaluation of low speed off-tracking is most commonly based on the maximum lateral excursion of the centre axle of the last axle group of the vehicle combination, relative to the path followed by the steered axle of the tractor unit, when the vehicle negotiates a 90^{o} turn at a speed of almost zero. However, in Europe it is typically measured in a full 360 degree turn. The dimensions used to measure the swept path of a vehicle in a 90 degree turn are illustrated in Figure 27.

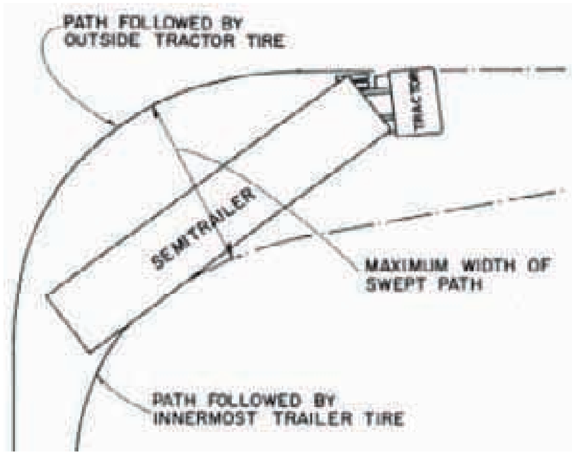


Figure 27: Illustration of swing out during a 90° turn Source: Ervin et al, 1986

Out-swing or tail swing is the lateral distance that a point on a vehicle moves outwards, perpendicular to its initial orientation, when the vehicle commences a small-radius turn at low speed. Out swing is influenced by the amount of rear overhang on the vehicle and the wheelbase. Figure 28 illustrates the out-swing phenomenon, and it shows how the rear corner of a tractor and semi-trailer may swing-out into the path of opposing or adjacent traffic during a turn. The position of trailer couplings has a lesser effect on out-swing (Sweatman et al, 1999), whilst the use of steerable trailer axles reduces the effective wheelbase producing higher values of out-swing (Jujnovich and Cebon, 2002), given the same axle positions and rear overhang.

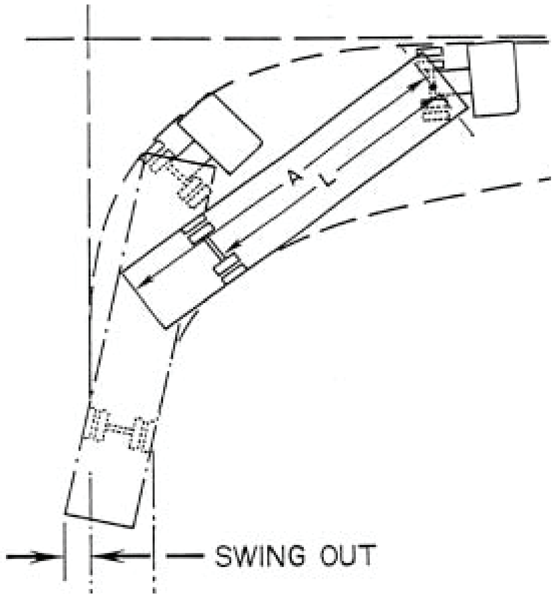


Figure 28: Illustration of tail swing in a 90° intersection turn (Ervin and Guy, 1986).

Off-tracking and out-swing can be measured in the field with some inconvenience. Out-swing is amenable to assessment via measurement of key dimensions and use of formulae or software.

For both off-tracking and out-swing, disparities between the performance of the vehicle fleet and the adequacy and design of infrastructure (e.g. maximum swept path is greater than the width of the travel lane) lead to the potential for crashes with roadside objects, parked cars etc. This can also cause damage to roadside infra-structure such as kerbs, verges and signs.

B.1.2 Performance Limits

The performance of the current European vehicle fleet, in terms of off-tracking and out-swing, is defined by performance based criteria.

Council Directive 96/53/EC lays down maximum dimensions and specific manoeuvrability requirements for all vehicles for national and international operations. The permitted maximum length for drawbar combinations is 18.75m and for articulated vehicles is 16.5m as long as the vehicle combination is able to turn within a swept circle having an outer radius of 12.50 metres and an inner radius of 5.30 metres (Figure 29).

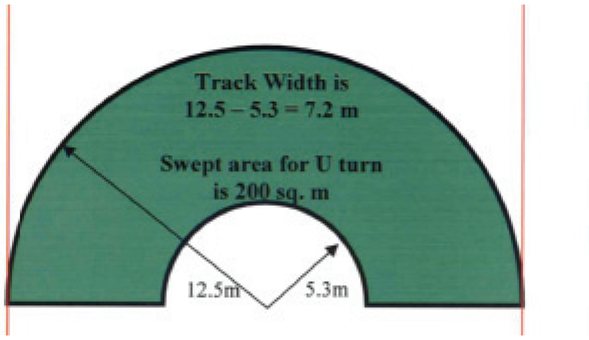


Figure 29: Standard for 16.5m E.U. articulated vehicles.

Directive 96/53/EC permits vehicles to deviate from these requirements within their own domestic territory provided that it does not adversely affect international competition. Member States such as Sweden and Finland have taken advantage of this permission and routinely operate vehicle combinations of up to 25.25m in length, based on the “modular concept” where combinations are formed of components that individually conform with the dimensional requirements of the Directive. In these countries, minimum standards for manoeuvrability of the longer combinations are set nationally and these require a less onerous turning circle requirement. In Sweden, the performance requirement for these longer combination vehicles is fulfilled if the vehicle stays within a circular ring with the outer and inner radii being 12.5 m and 2.0 m respectively when driven in a 360-degree turn (Figure 30). Modular concept vehicle combinations are able to conform with these lesser requirements and, thus, it cannot be said that the Swedish national standard affects international competition.

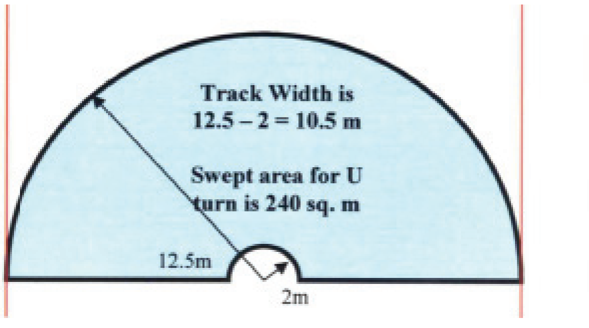


Figure 30: Standard for 25.25m articulated vehicles in Sweden .

Directive 96/53 does not prescribe maximum values of outswing for heavy goods vehicles of category N2 or N3, only for large buses (M2/3). However, Directive 97/27/EC (relating to weights and dimensions of vehicles for type approval rather than for use in national and international traffic) does prescribe limits for outswing. The Directive states that when a vehicle is stationary with its wheels so directed that if the vehicle moved its front outer corner would describe a circle of 12.5m radius, a vertical plane tangential to the outer side of the vehicle must be marked on the ground. When the vehicle moves forward following the 12.5m outer circle, no part of the vehicle may move outside of the vertical plane by more than 0.8m.

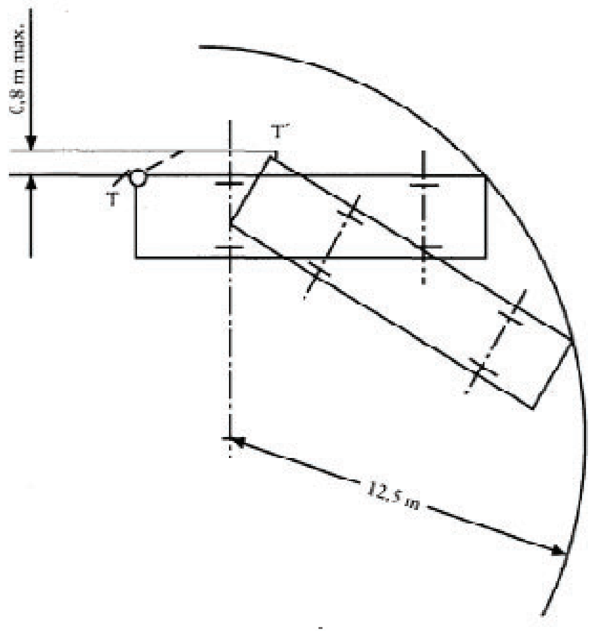


Figure 31: Out-swing requirement 97/27/EC.

B.1.3 Evaluation of off-tracking and out-swing for the LHV types assessed

Eight vehicles have been defined for assessment as part of this research (see Table 10). However, for some of these 8 vehicle types, only variables such as permitted mass, which do not affect manoeuvrability, are different to other vehicle types. This means that for the purposes of assessing the manoeuvrability some of these 8 vehicles can be grouped together and considered as one. However, the 8 defined vehicles include two that are assumed to be fitted with steering axles. For these vehicle types, assessments have also been made of the manoeuvrability if they were not equipped with steering axles.

B.1.3.1 Off-tracking

Tractor / semi-trailer (6 axles) – max length 16.5m – The Type Approval regulations ensure that all such combinations should meet the off-tracking requirements of Directive 96/53. Performance trials conducted by the British Transport Advisory Consortium (BTAC, 2005) show that the requirements can be comfortably exceeded with tests using a typical tractor producing a swept path of 6.84 metres compared to the permitted 7.2 metres. This was further reduced to 6.74 metres when a tag-axle tractor unit was employed.

Tractor / 16m semi trailer with fixed bogie (6 axles) – max length 18.75m - Results presented by Iveco (Consano and Werner, 2006) show that a combination vehicle of up to 17.8m in length is capable of meeting the off-tracking performance requirement without steering axles but that combinations in excess of this length cannot. A series of simulations were performed by TRL for this research using the AutoTrack swept path analysis package. Modelling of a 16m trailer with fixed axles determined that it was possible for this combination to meet the off-tracking requirements by positioning the wheels such that there was a 5.1m overhang at the rear of the trailer. This configuration was highly sensitive to the location of the trailer wheels and the scope for positioning them to balance axle and kingpin loading was very limited. In addition to this, the outswing produced at the rear of this configuration was in excess of the 800mm permitted by Directive 97/27/EC, although it was within the 1.2m allowed for 15m buses. In practical terms, it will therefore, be necessary for an 18.75m articulated vehicle to be fitted with steering axles toward the rear of the vehicle in order to meet both the off-tracking and outswing requirements. Achieving any extension of semi-trailer length without additional off-tracking response is likely to require semi-trailers having their axles set substantially forward of the rear extremity, such that the ratio A/L in Figure 28 becomes rather large. This will increase out-swing of the rear of the semi-trailer and may have implications for the ability to load the vehicle to maximum GVW without exceeding axle load limits.

An 18.75m tractor and semi-trailer combination was tested as part of the British Transport Advisory Consortium Technical Trials (BTAC, 2005). The 16-metre semi-trailer was equipped with a self-steering bogie right at the back and had been developed by Silvertip Design. Coupled to a 6x2 tractor to form an 18.75-metre rig, the trailer stayed within the turning corridor, with 1.3m to spare. The outswing in these trials was not recorded but the rear overhang was extremely low and it is highly unlikely that the outswing would have exceeded regulatory requirements.

Rigid truck / converter dolly (A) / semi-trailer (8 axles) – max length 25.25m - The rigid/A/semi combination cannot, without steering axles, meet the legally prescribed turning circle requirements. A 25m outfit comprising a 7.8m rigid towing a 13.6m trailer described a swept path width greater than the allowed 7.2m (Pilskog et al., 2006). Similar findings about the inability of this vehicle combination to meet the legal turning circle have been reported by John Dixon-Simpson (Commercial Motor, 2006), the German foreign trade association (B.G.A) and by Prof Hans-Christian Pflug of Daimler Chrysler (2006). However, the combination is compliant with the national requirements in countries where it is permitted which allow vehicle combinations up to 25.25m in length to have a swept path width of 10.5m. Pilksog (2006) also noted that the difference compared with a standard vehicle was much smaller if only a 90 degree turn was tested and the author considered that this would be more representative of real driving.

Tractor / interlink semi trailer / semi trailer (8 axles) – max length 25.25m - A 25m B-double with a steering bogie at the rear of the interlink trailer was tested as part of the British Transport Advisory Consortium Technical Trials (BTAC, 2005). This vehicle combination complied with the requirements of Directive 96/53 with 0.31m to spare on the inner circle when coupled to a typical tractor unit. When the articulated trailers were coupled to a steered tag-axle tractor, the outfit tracked within the 5.3m radius circle with 2.04m to spare. The steered tag-axle tractor turned more tightly because its virtual wheelbase was 770mm less, and because its coupling was 300mm behind the driving axle.

Research in Australia (Prem *et al, 2002)* has shown that only 4% of the B-double fleet could meet the low speed off-tracking requirement of a swept path of 7.4m, despite the less onerous test method requiring only a 90 degree turn. It is, therefore, extremely unlikely that a B-double combination without steered axles could meet the current EC requirements (96/53/EC) of a swept path of 7.2m in a 360 degree turn.

Tractor / semi trailer / converter dolly (C) / semi trailer (11 axles) – length 34m - No vehicle of the described combination and tested according to the EC-Regulation was found in the literature review. However, a study by Winkler et al (1993), using the RTAC performance measure[2], found that changing to C-Dollies produced only a modest improvement in low-speed off-tracking for doubles relative to A-Dollies. Typically improvements were in the region of 0.3 metres with a maximum value of 0.6 metres. Based on this observation, results for double semi-trailer combinations using an A-dolly as opposed to a C-Dolly to connect the two trailers are reported here because it is highly unlikely that the small improvement obtained with a C-dolly will substantially change the conclusion.

A double semi-trailer combination using an A-dolly to connect the two trailers was tested as part of the British Transport Advisory Consortium technical trials (BTAC, 2005). The overall length of the vehicle combination was recorded as 31m, three metres less than the given maximum length. The vehicle encroached into the 5.3m inner radius by more than 2m. Similar combinations are in use in the United States (turnpike double) and Australia (type 1 road train). A study of longer combination vehicles by the California Department of Transportation (Caltrans, 1984) found that a turnpike double combination (overall length 36m) described a turning circle[3] with an inside radius of 6m and an outer

[2] Low-speed turn of 90 degrees with a 32.15 foot (9.8 m) radius as measured from the tractor front axle.
[3] Angle of turn 180 degrees

radius of 18m. It is therefore unlikely that this combination would meet the EC requirements of 5.3m inner and 12.5m outer radius. Similarly, a study by Cox for the Queensland Department of Main Roads found that a type 1 road train (overall length 36m) would describe a circle turning circle[4] of 1.2m inside radius when the outer radius is set at 12.5m.

B.1.4 Out-swing

The out-swing performance is dependent on the ratio of the load area to wheelbase (A/L in Figure 28). Higher values result in greater out-swing. The following results have been found from a review of the available literature, as described below.

Simulations using the Simulink programme (Jujnovich and Cebon, 2002) looked at the balance between off-tracking and out-swing for a typical European articulated vehicle that complies with current UK legislation (A/L = 1.3). It found that for a swept path width of 6.3m (for a turn radius of 11.25m), the maximum lateral distance the rear of the trailer travelled outside the path of the front wheel upon entering the turn was 0.08m.

A study of the performance characteristics of the Australian heavy vehicle fleet (Prem et al, 2002) evaluated rear out-swing for a number of different vehicle combinations when commencing an 11.25m radius turn. A summary table of the results from this study is shown (Table 47). It should be noted that the Australian heavy vehicle fleet comprises a wide variety of vehicle configurations, weights and dimensions and many of the combinations assessed in the study by Prem *et* al (2002) were very different to the LHV types considered in this report.

Tail swing for the majority of fleet vehicles was found to be quite small. The single largest value for tail swing (333 mm) was for a car carrying prime-mover and semi-trailer combination with a rear overhang dimension of 4.9 m (A/L = 1.5).

Table 47: Out-swing values for Australian heavy vehicle fleet study

Vehicle Combination	Combination Length	Rear Overhang (last unit)	Out-swing*
Prime mover and semi-trailer (n=43)	Min 13m Max 25m	Min 1.5m Max 4.9m	Min 9mm Max 333mm Mean 63mm
Rigid truck and trailer (n=14)	Min 16m Max 22m	Min 1.0m Max 2.5m	Min 13mm Max 46mm Mean 22mm
B-double (n=23)	Min 23m Max 28m	Min 1.6m Max 3.0m	Min 2mm Max 33mm Mean 18mm
A-double (n=12)	Min 26m Max 37m	Min 2.0m Max 3.7m	Min 10mm Max 134mm Mean 47mm

*Note that not all the combinations evaluated meet the off-tracking requirement. Low-speed off-tracking was evaluated based on maximum swept path width when the combination negotiates a path comprising a straight entry segment that is tangent to a 11.25 m radius 90º circular arc followed by a straight exit segment. Combinations with an overall length greater than 19m require a swept path width greater than the 7.2m specified by EU-regulation 96/53/EC. In addition, in a 90-degree slow turn, as used here, the last axle will not necessarily have travelled far enough to reach the steady-state value.

Jujnovich and Cebon (2002) undertook a comparative performance assessment of semi-trailer steering systems. A number of simulations were performed using the computer simulation and a typical European articulated vehicle that complies with current UK legislation (A/L = 1.3). It was found that the out-swing varied from 0.08m for the fixed axle trailer up to 0.68m for a trailer equipped with a pivotal bogie. In general, it was found that all trailer steering axle systems increased the amount of tailswing on the entry to a corner and the pivotal bogie systems showed the greatest increase.

[4] Angle of turn 180 degrees

TRL performed additional simulations using standard models from the AutoTrack library to compare with the Australian out-swing test results reported by Prem et al (2002). This comparison confirmed that the modelled out-swing performance of the vehicles was similar to those found during the testing. The out-swing of a 16.5m combination was found to be 278mm which was within the test range of 9-333mm. Similarly the modelled out-swing for the B-double was 0mm, compared with 2-33mm in tests.

Although the research identified does not relate directly to the exact dimensions of the LHV types being assessed, the general findings suggest that most of the LHV types considered should not have any difficulty meeting the outswing requirement in Directive 97/27/EC of 0.8m. However, those that use steering axles to achieve the swept path requirements are likely to have greater outswings unless the steered axles are positioned such that the rear overhang is very low.

B.1.5 Summary

A summary of the compliance of the proposed LHV options with the off-tracking and out-swing performance criteria are provided in Table 48 and Table 49.

Table 48: Off-tracking performance

Performance Limit: Swept path width < 7.2 m for 12.5 m radius turn	**Demonstrated swept path width**	**AutoTrack analysis**	**Conforms with 96/53**
Tractor / semi-trailer – max length 16.5m	6.74-6.84m	-	Yes
Tractor / 16m semi trailer (fixed rear axles 5.1m rear overhang) – max length 18.75m	No test data	7.2m	Yes
Tractor / 16m semi trailer (steered rear bogie v.low rear overhang) – max length 18.75m	4.8 – 5.9	-	Yes
Rigid truck / converter dolly (A-train) / semi-trailer – max length 25.25m	7.2-10.5m	-	No
Tractor / interlink semi trailer (fixed axles) / semi trailer	>7.4m	-	No
Tractor / interlink semi trailer (steered bogie) / semi trailer (8 axles) – max length 25.25m	5.16 - 6.89m	-	Yes
Tractor / semi trailer / converter dolly (C-train) / semi trailer (11 axles) – max length 34m	Approx 9.2m	-	No

Table 49: Out-swing performance

	Australian test	AutoTrack simulation of Australian test	Out-swing in 96/53/EC
Tractor / semi-trailer (6 axles) – max length 16.5m	9-333 mm**	278 mm	<800mm
Tractor / 16m semi trailer (fixed axles) – max length 18.75m	9-333 mm**	846 mm	1160mm
Rigid truck / converter dolly (A-train) / semi-trailer (8 axles) – max length 25.25m	13-46 mm**	-	-
Tractor / interlink semi trailer / semi trailer (8 axles) – max length 25.25m	2-33 mm**	0 mm	-
Tractor / semi trailer / converter dolly (C-train) / semi trailer (11 axles) – max length 34m	10-134 mm**	-	-

** Australian test values are as presented in Table 47. A variety of different vehicle lengths were considered in these tests therefore a range is presented for each configuration

It can be seen that for most vehicles it would not be a problem to comply with the 800mm outswing limit in 97/27/EC. However, the analysis shows that the longer semi-trailer option could not achieve both the swept path requirements and an outswing limit of 800mm unless it was equipped with steering axles as has been assumed for the vehicle defined in this research. The longer semi-trailer equipped with a fully steered bogies appears capable of better manoeuvrability than standard articulated vehicles.

The main risks associated with poor low speed off-tracking and outswing problems are incursions of parts of the vehicle into adjacent or oncoming traffic lanes and over kerbs when cornering and manoeuvring. This increased incursion places greater demands on the driver to be able to simultaneously view several different areas around the vehicle and judge that it is safe for the incursion to happen, so manoeuvrability can be intuitively linked to field of view. The net result is that the risk of collisions between the vehicle manoeuvring and other road users is increased.

Some countries around the world, including some countries within Europe, have permitted vehicles which do not conform with the EC manoeuvrability criteria. However, in most of these countries the operation of such vehicles is limited to roads that are considered less likely to require sharp cornering or manoeuvring, thus minimising any increase in risk. It is worth noting that the Australian manoeuvrability requirements for vehicles to gain access to arterial roads are similar to the European requirements, although the test method is slightly less demanding.

B.2 Field of view

The field of view consideration for LHVs may be different to those of current HGVs. LHVs are likely to have the same or similar cabs to existing HGVs, therefore direct vision (vision through glazed areas) is expected to remain largely unaltered. However, the amount of the vehicle combination which can be seen through indirect vision, using mirrors or alternative optical devices, could be substantially altered by changes to the combination geometry.

B.2.1 Indirect vision requirements

Under the recent EU Directive 2003/97 newly registered vehicles of 7.5 tonnes and above (and Directive 2005/27 extended this to certain vehicles above 3.5 tonnes) are required to be fitted with mirrors providing vision in four areas:

- Class II – Main exterior rear-view mirror
- Class IV – Wide-angle exterior rear-view mirror
- Class V – Close-proximity exterior rear-view mirror
- Class VI – Front mirror

If the area field of vision for the Class V mirror is met through a combination of the Class IV and Class VI mirrors then the Class V close proximity mirror is not compulsory.

Figure 32 to Figure 35 show the area on the ground plane which must be visible to meet the requirements of the Directive.

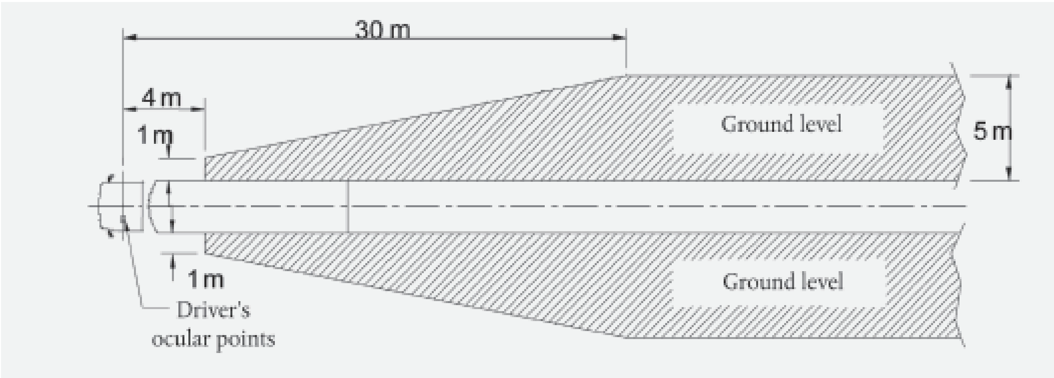


Figure 32: Field of vision from Class II mirror

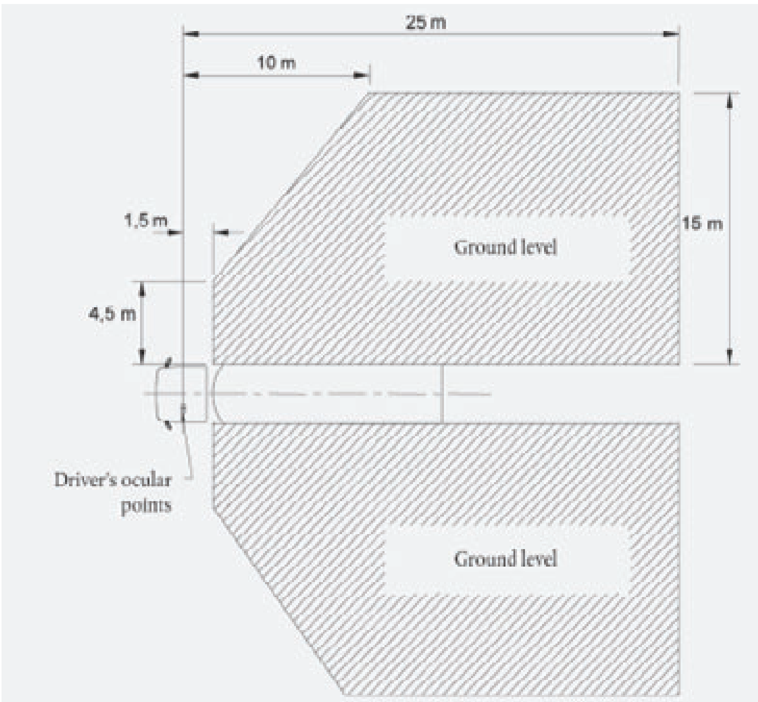


Figure 33: Field of vision from Class IV mirror

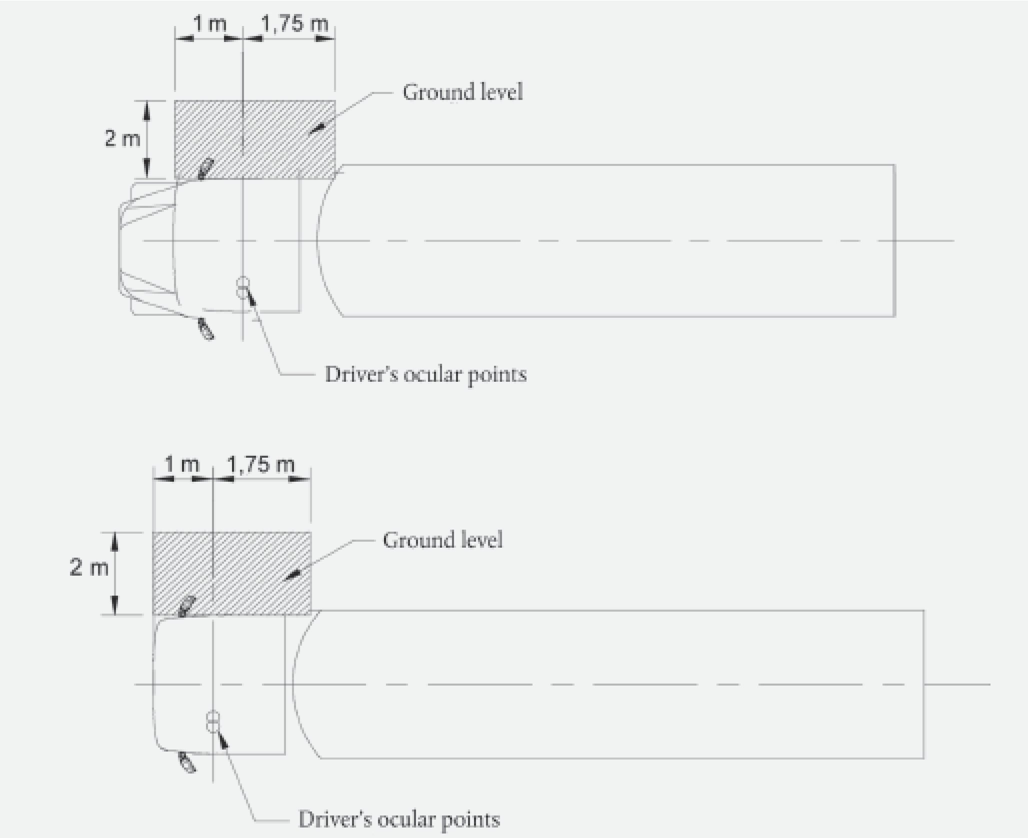


Figure 34: Field of vision from Class V mirror

Note that the above figure is extracted from the relevant Directive and therefore represents a left hand drive vehicle.

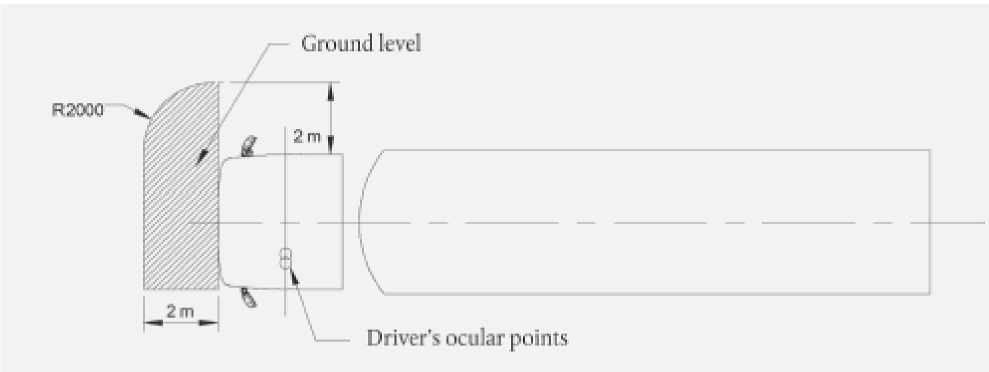


Figure 35: Field of vision from Class VI mirror

Note that the above figure is extracted from the relevant Directive and therefore represents a left hand drive vehicle.

A camera and monitor set-up is accepted as an alternative to the fitment of the Class VI mirror, provided the system meets additional requirements concerned with the resolution of the image and the mounting position of the monitor. It is necessary for the camera/monitor system to be able to show the field of vision whilst the vehicle is moving forwards at up to 30km/h.

Prior to the introduction of EU Directive 2003/97, mirror requirements were controlled through Directive 71/127. The required field of vision under the earlier directive was smaller for the Class II, Class IV and Class V mirrors. Directive 71/127 had no requirement for the fitment of a Class VI mirror, although it permitted national discretion and the UK did introduce this requirement. The area of the road surface which must be visible according to the two directives is shown in Table 50. The values are based on an N_3 class vehicle of width 2.5m.

Table 50: Comparison of road surface area seen from mirrors

Mirror Class	Area to be seen in mirror(m^2)			
	71/127/EEC		Directive 2003/97	
	Offside	Nearside	Offside	Nearside
II*	250	308.6	428	428
IV	-	215	314.6	314.6
V	-	1.8	-	5.5
VI	-		8.1	
Total	775.4		1,498.8	

* Assuming field of view extends to 100m behind driver's ocular points

B.2.2 Existing research

Research has been conducted previously to evaluate the field of view from existing vehicles when fitted with mirrors compliant with either of the Directives listed above (Tait & Southall, 1998 and Fenn *et al.*, 2005). Fenn *et al*. were primarily concerned with the area alongside the cab which is covered by the Class V mirror. CAD analysis determined that it was possible for a car to be located in an adjacent lane to the HGV but not be visible in mirrors compliant with Directive 71/127, however, whilst Directive 2003/97 compliant mirrors reduced this blind spot significantly a car in the adjacent lane may still not be visible. Assuming the same cabs would be used, the view of this area would be unchanged for LHVs.

It can be concluded from the previous work that there are no significant field of view restrictions alongside the load area on current rigid and articulated HGVs.

No existing literature that is concerned with the field of view from LHVs has been identified during this review. The only specific requirement identified is a requirement defined for the trial LHVs in the Netherlands that "the area of view on the right side of the combination has a width of at least 5m, while the combination is turning to the right in a turn with a 15.5m maximum radius" (Concept conditions of test LZVs). It is anticipated that vehicles fitted with mirrors minimally compliant with Directive 2003/97 will be able to meet this requirements, whereas mirrors minimally compliant with Directive 71/127 would be insufficient.

B.2.3 Geometrical analysis – assuming 2003/97 compliant mirrors

In previous research for DfT by Southall *et al.* (1998) and Fenn *et al.* (2005) CAD models were developed of vehicles determined to be representative of the HGV fleet. These models were used to analyse the indirect field of view when the vehicle was fitted with different mirrors and with drivers of different stature.

The vehicle combinations which were considered for geometric analysis are:

- Baseline (tractor, semi-trailer) – 16.5m long
- Tractor, 16m semi-trailer – 18.75m long

- Rigid truck, converter dolly, semi-trailer – 25.25m long
- B-double (tractor, interlink semi-trailer, semi-trailer) – 25.25m long
- Tractor, semi-trailer, converter dolly, semi-trailer – 34m long

B.2.3.1 Baseline – 6 axle articulated vehicle

As identified through previous research, there are no field of view issues around the trailer in this configuration. This is illustrated in Figure 36, where the trailer is positioned at 45 degrees to the tractor unit. The side of the trailer which would present the greatest danger (as the wheels cut across) is fully visible, while the protruding edge of the trailer on the other side is also visible.

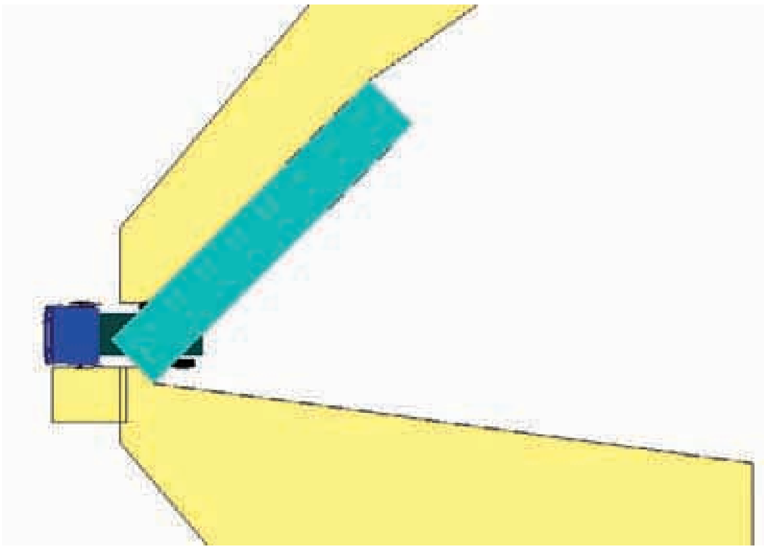


Figure 36: Field of view for baseline vehicle with trailer at 45 degrees to tractor unit

It is necessary for the angle between the tractor and trailer to reach 70 degrees before the inside wheels of the trailer cannot be seen during the manoeuvre.

The area directly behind the trailer cannot be seen at any time using the existing mirrors, which presents a risk during reversing manoeuvres.

B.2.3.2 Rigid truck, converter dolly, semi-trailer

Figure 37 shows the combination performing a manoeuvre approximately equivalent to a turn of radius 14.5m. The dolly is at 25degrees to the rigid unit and the trailer at 25 degrees to the dolly. The entirety of the right side of the combination can be seen during the manoeuvre. However, the nearside wheels of the dolly and the front edge of the semi-trailer are not visible in any of the mirrors. The risk that this could present to other road users is illustrated in Figure 38, where a cyclist has been placed in the area obscured from the driver's view.

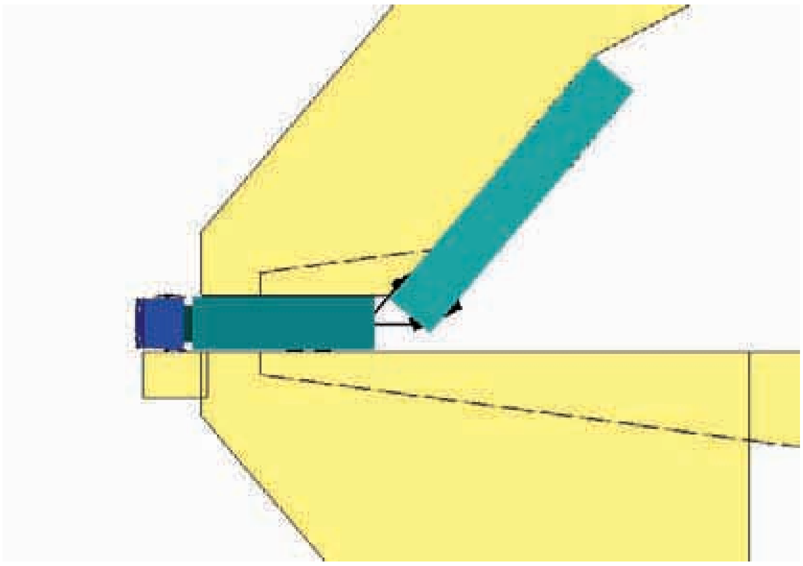


Figure 37: Field of view for rigid/A/semi, dolly at 25 degrees and trailer at 50 degrees to rigid unit

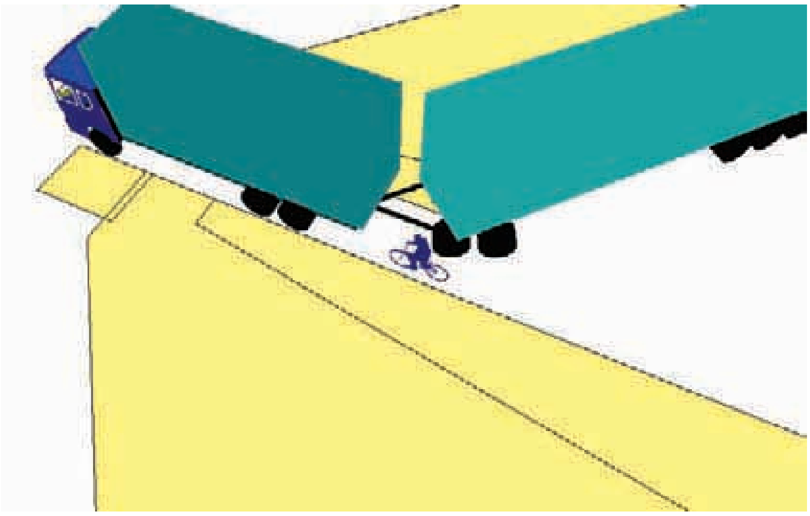


Figure 38: Configuration as Figure 37, with bicycle in potential danger area

B.2.3.3 Tractor, semi-trailer, converter dolly, semi-trailer

The restrictions to the field of view for the tractor, semi-trailer, converter dolly, semi-trailer combination are shown in Figure 39. The areas which cannot be seen by the driver are similar to those in the previous configuration. This combination is the longest being considered and the rear corner of the rear trailer is not visible by indirect vision during relatively shallow turns.

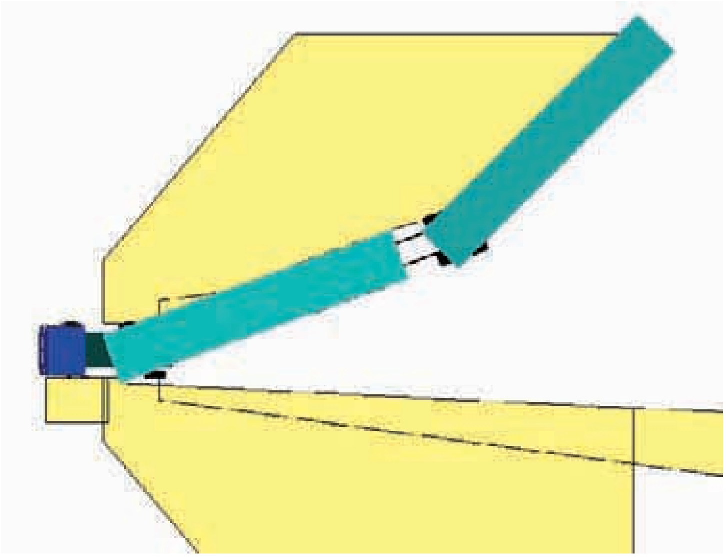


Figure 39: Field of view with first semi-trailer at 20 degrees and second semi-trailer at 45 degrees to tractor unit

B.2.3.4 B-double

The B-double configuration has similar visibility restrictions to the previous combinations, as shown in Figure 40. However, because this combination does not have a converter dolly the risk to vulnerable road users may be reduced.

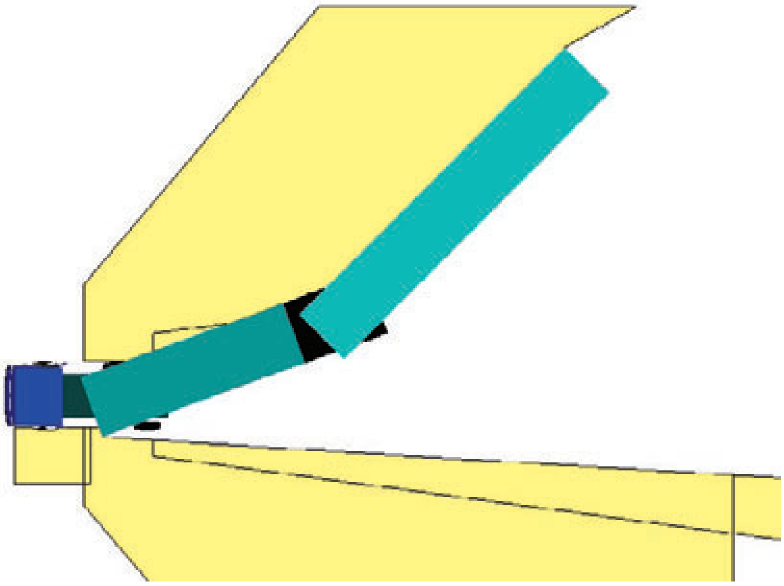


Figure 40: Field of view with first (interlink) semi-trailer at 20 degrees and second semi-trailer at 45 degrees to tractor unit

B.2.3.5 Articulated with 16m semi-trailer

Increasing the length of the semi-trailer from 13.6m to 16m does not result in a substantial change in the field of view. The angle between the tractor unit and the trailer has to reach 65 degrees before the outside edge of the trailer wheels cannot be seen in the wide-angle mirror, as shown in Figure 41. By comparison, with a 13.6m semi-trailer, an angle of 70 degrees is necessary before the wheels cannot be seen. Therefore, the 16m semi-trailer cannot turn as tight a corner safely however the difference in angle is small. This angle is dependent on the position of the trailer wheels, i.e. if mounted further forward the angle will be greater.

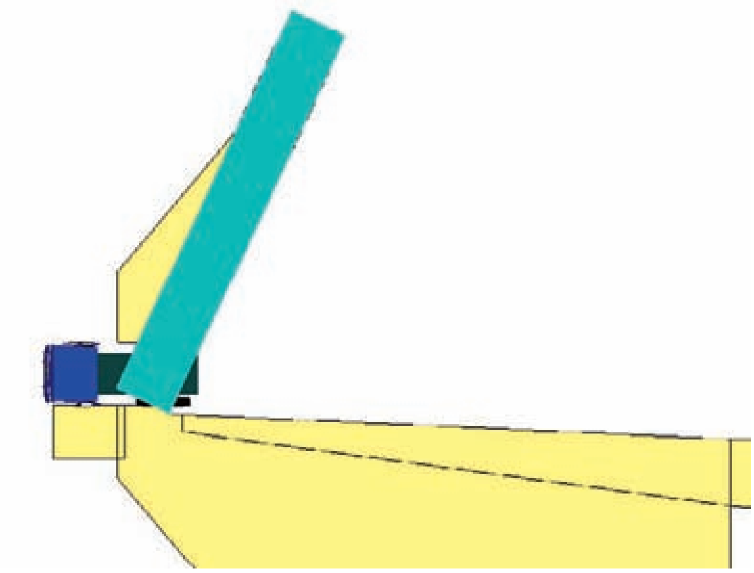


Figure 41: Articulated vehicle with 16m semi-trailer at 65 degrees to the tractor unit

B.2.4 Geometric analysis summary

The geometric analysis has identified that there are significant areas of the ground plane that cannot be seen using standard vehicle mirrors and that there is potential for other road users to enter these areas without the driver being aware.

Generally, all of the combinations which involve two trailers or a trailer behind a rigid vehicle have the same field of view limitations. In the configurations that include a dolly there is an increased risk presented by wheels without any bodywork above them. During a turn these wheels are exposed and one pair cannot be viewed by the driver. The front corner of a second trailer (or trailer behind a rigid vehicle) also cannot be seen and could present a risk, particularly to vulnerable road users, who enter the obscured area.

The 16m semi-trailer configuration has a minimal effect on the areas which can be seen through indirect vision when compared with a 13.6m trailer.

On balance, the field of view from the LHV combinations assessed was not found to be a substantial concern and little evidence was found to suggest that they would represent much of an increased risk compared with a standard articulated vehicle. However, if LHVs were to be permitted, it may be appropriate to introduce a requirement for the fitment of collision warning or camera systems to provide the driver with additional information about the areas between vehicle components which cannot be seen by indirect vision.

B.2.5 Collision warning and camera systems

A number of collision warning systems are available on current HGVs, supplied by either vehicle manufacturers or third-party providers. These systems use radar or ultra-sound to determine whether a vehicle is present alongside or behind the HGV in a location that would not be visible to the driver. Warnings can be relayed in audible or visual form. Cameras are also readily utilised to provide information about areas which cannot be seen using direct vision or mirrors.

Consano *et al* (2006) presented the safety and driver support systems developed by truck manufacturer IVECO. One system which was presented was a camera which is mounted below the windscreen which covers the not only the Class VI area but also the area to the side of the cab to provide assistance when changing lanes.

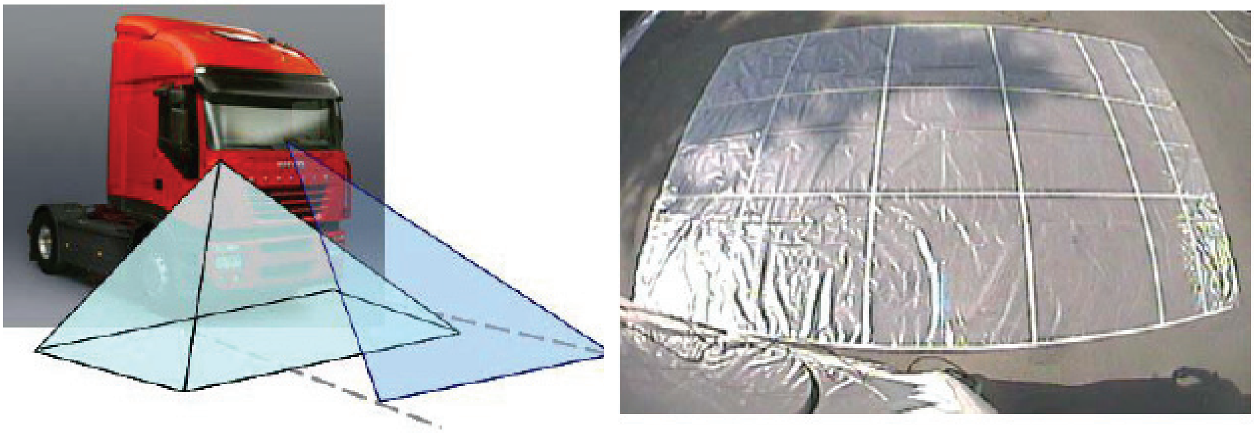


Figure 42: IVECO blind-spot and lane change camera (left) and visible area on ground (right)

Aftermarket camera systems are available from a large number of manufacturers. Cameras designed to meet the requirements for the Class VI area of Directive 2003/97 are readily available. There are also a number of camera systems which can be mounted on the rear of trailers to provide rearward vision directly behind the vehicle. Additionally, Orlaco provide a camera designed for trailers with rear steering which allows the ground plane to the side of the trailer to be viewed during manoeuvres, as shown in Figure 43.

Figure 43: Field of view from camera mounted on the side of trailer (Orlaco, 2007)

Van Uytven (2005) reported that Volvo have conducted research concerned with the optimum position in which to place monitors to provide the driver with enhanced vision but without unnecessary distractions. It was considered most appropriate to place monitors providing front and rear views in the centre of the dashboard and those providing sideward information near the A-pillar on the appropriate side of the cab. It was also noted that to avoid overloading the driver with information it may be advisable to only display the information on the monitors when the driving manoeuvre requires the additional views.

Figure 44 highlights the area between the lead vehicle and the trailer which could be seen using a camera system. This would provide vision of the area that presents the greatest increase in risk to other road users. However, it should be noted that the fitment of cameras at the rear of the lead vehicle in a combination will, to some extent, depend on the body type of the vehicle. It will be relatively straightforward to fit a camera to the top of a box, curtain sided or tank bodies vehicle where it can be fitted high up looking down on the blind spot. It will be more difficult to gain an appropriate field of view from a camera fitted to a skeletal or flat bed trailer where it can only be mounted quite close to the ground.

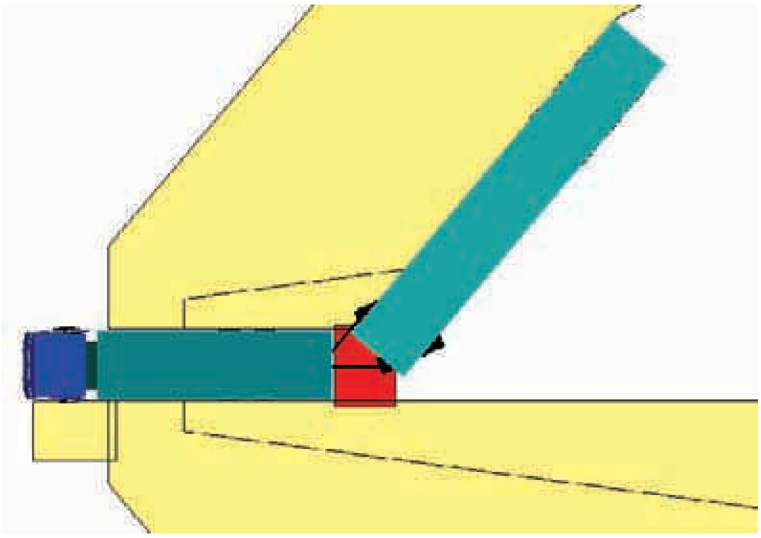


Figure 44: Indication of area which could be covered by camera

B.2.6 Field of view conclusions

- Field of view problems do still exist in relation to the baseline vehicle, in particular the view to the passenger side of the vehicle cab. However, the design of the vehicle cab is expected to remain the same for LHVs so if they were introduced this problem would not be expected to be any worse than for current vehicles.
- During straight ahead manoeuvres LHVs do not present any decrease in field of view compared with the baseline vehicle. LHVs would, therefore, be expected to suffer from similar field of view issues in these manoeuvres.
- The limitations in field of view while cornering for the rigid/A/semi, the C-train, and B-double configurations are all very similar. For each of these combinations the rigid vehicle or front trailer prevents vision of the area in front of the rear trailer during turns. A B-double with fixed trailer axles may be slightly safer than the others because it does not have exposed dolly wheels that cannot be seen by the driver and which could present an increased risk to vulnerable road users. This may not be true if the interlink trailer was equipped with a steering bogie as the vehicle assessed in this research is assumed to be. The risks associated with field of view while cornering are, therefore, slightly higher for LHVs compared with the baseline vehicle.
- The 16m trailer option has minimal impact on the visible ground plane area compared to existing 13.6m trailers. The rear of the trailer would not be visible in the mirrors during tight turns, however this only occurs at angles where the trailer is likely to be visible via direct vision.
- If LHVs were to be permitted, it is recommended that LHVs should be required to have mirrors compliant with Directive 2003/97 in order to prevent “retro-operation” of older vehicles that complied with the previous, less onerous, field of view Directive. The additional

field of view provided by these mirrors and the requirement for a wide-angle mirror on the nearside are necessary to ensure a good view of the combination during manoeuvres.

- Camera technology may be the most suitable method for providing vision to the driver of areas of concern which cannot be seen using mirrors. However, consideration may need to be given to the workload of the driver, which is already high during manoeuvring, because this may limit the effectiveness of the devices. As mentioned previously, the legal ability to require additional safety features such as these on LHVs was considered as part of other work in the project reported in Appendix E.

B.3 Braking

When a vehicle is braking the vehicle should achieve a desirable level of deceleration without losing stability or directional control. Hence, the stability and control of a heavy vehicle combination relies upon avoiding locking any of the wheels because, if the front wheels of the tractor unit lock, the vehicle will not be responsive to steering. If the rear wheels of the tractor unit lock, a semi-trailer combination may jack-knife. If trailer wheels lock, a trailer swing may ensue. All of these conditions are undesirable and each of them could lead to an accident.

B.3.1 Braking efficiency

The braking efficiency is the fraction of the available friction that can be used under braking without locking any wheels. This measure can be used at various levels of deceleration to evaluate the braking capability of a vehicle.

The Turner Truck Study (Fancher et al, 1989) showed that vehicles with a braking efficiency of less than 0.5 were statistically over-represented in accidents involving jack-knife and that vehicles with a braking efficiency greater than 0.7 were under-represented. This suggested that a higher braking efficiency reduced the likelihood of being involved in a jack-knife accident. The study found that many of the trucks with efficiencies below 0.7 were empty. It was suggested that such vehicles would benefit from the fitment of advanced braking systems such as ABS which would help to maintain a higher level of brake efficiency.

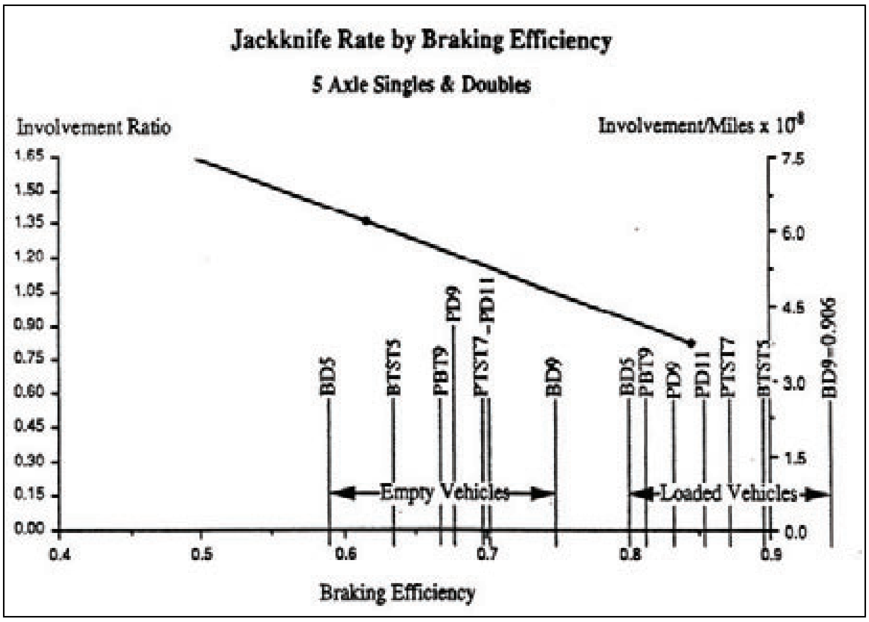


Figure 45: Jack-knife rate by braking efficiency Source: Fig 8.32 (Fancher et al, 1989)

A study by Ervin & Guy (1986) used computer simulations to evaluate the effect of different parameters on the dynamic performance of heavy-duty truck combinations. They assessed 22 vehicle combinations including semi-trailers, A & C-train doubles, B-train doubles, and A & C-train triples.

The study identified that the braking efficiency was mostly affected by the loading of the vehicle. At a low deceleration (0.1g) the range of brake efficiencies for the combinations that were simulated was between 72% and 96%. When the load was carried the efficiencies fell to 56% to 77% mainly because the distribution of the load caused some axles to be under-loaded, and therefore over-braked.

Figure 46 shows that for the semi-trailer combinations tested an increase in the height of the centre of gravity of the payload had a small effect in reducing the brake efficiency.

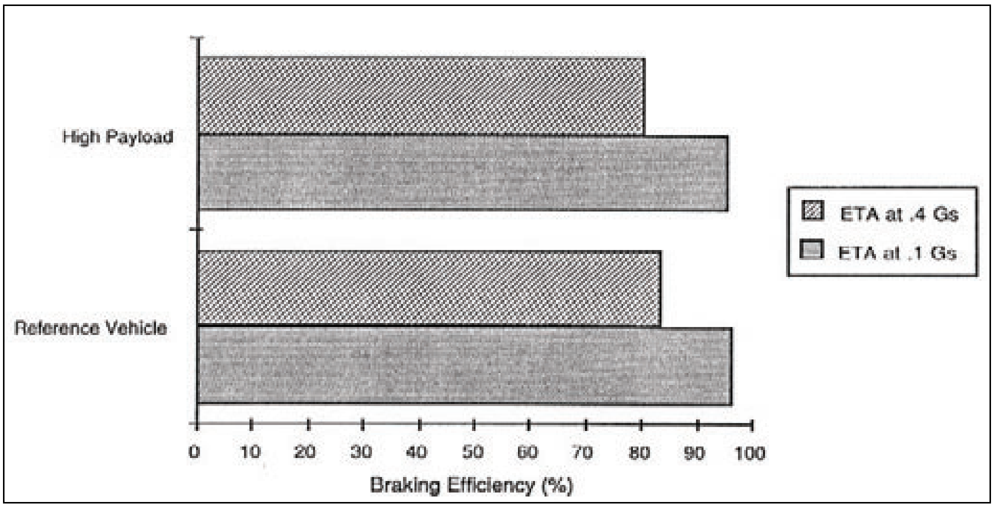


Figure 46: influence of high payload on braking efficiency in tractor/semi-trailer combinations
Source: Fig 3.2.5.d (Ervin & Guy, 1986)

For A & C-train doubles a significant variation in the brake efficiency was evident from changes to the loading of the vehicle. Whilst the reference vehicle could achieve an efficiency of about 70% the efficiencies for the partially or non-balanced loading was less.

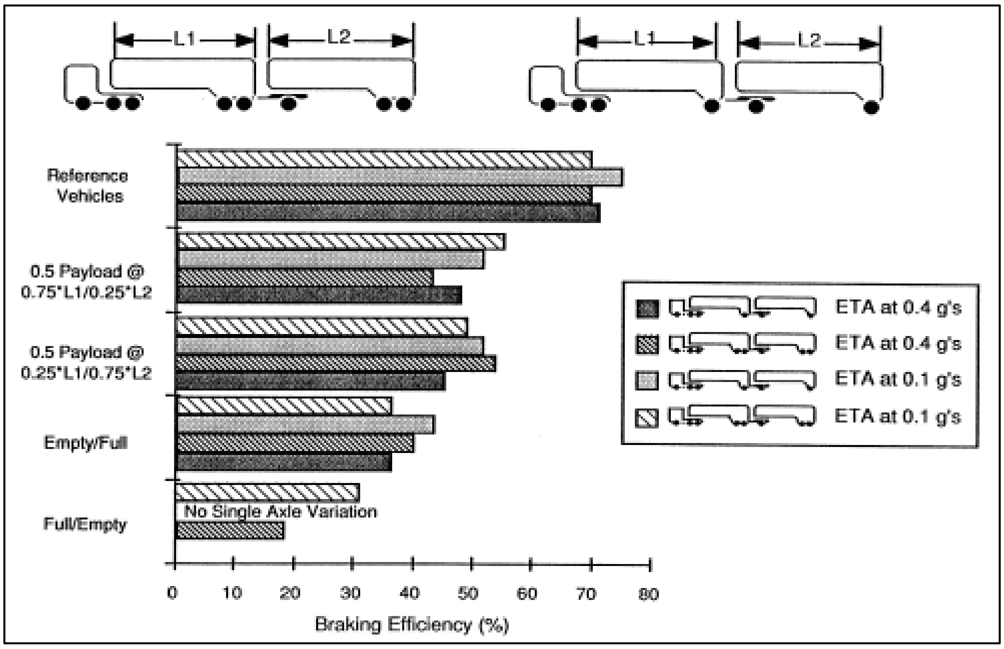
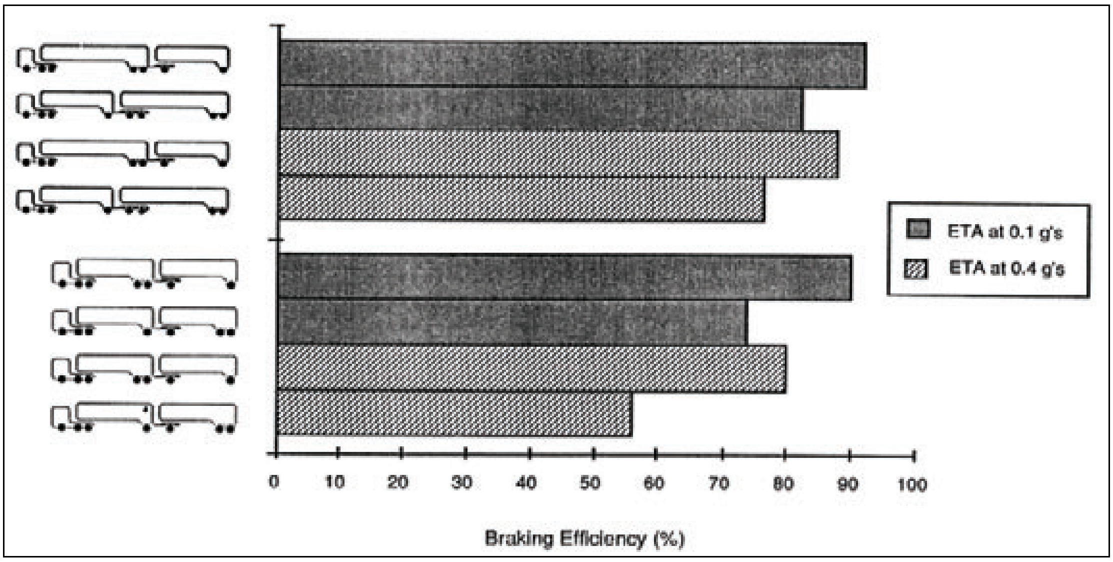


Figure 47: Influence on partial loading on brake efficiency in A & C train doubles **Source: Fig 3.3.3.d (Ervin & Guy, 1986)**

The reason for the drop in efficiency was again reported to be down to the under-loaded, and therefore over-braked, axle(s). Figure 47 shows that when a full trailer was combined with an empty one the efficiencies were even lower. The reason for this was reported to be because the overall mass is still large whilst the axle loads on the empty trailer were so low (20% - 45%) that lock-up occurred at very low decelerations. If the empty trailer were in front of the full trailer then Ervin & Guy (1986) reported that the loss of control mechanism would be jack-knifing. It was not clear in the paper whether there were load sensing valves or ABS fitted. This problem may, therefore, not be relevant to European vehicles meeting the appendix to Annex II of Directive 71/320 and/or Annex X of 71/320. This may require further investigation.

The influence of the changing the order of the trailers is shown in Figure 48. The results showed that with the single-axle trailer in the lead position, the tractor tandem axles became over-braked due to reduced loading, such that braking efficiency was limited. These observations support the general rule that changes in axle load distribution that reduced the degree of uniformity of loading has the effect of lowering the braking efficiency.



Source: Fig 3.3.4.d (Ervin & Guy, 1986)

Figure 48: influence of order of placement of differing configuration trailer on braking efficiency

Figure 49 again shows how the braking efficiency is lower for all configurations when the axles are not loaded in proportion to the brake torque levels being developed. Similar to the A & C-doubles, the poorest levels of brake efficiency were produced when some trailers were empty whilst others were full. Figure 49 shows that for any of the cases in which at least one trailer was empty, the braking efficiency of the combination fell to about 30% when braking at 0.4g.

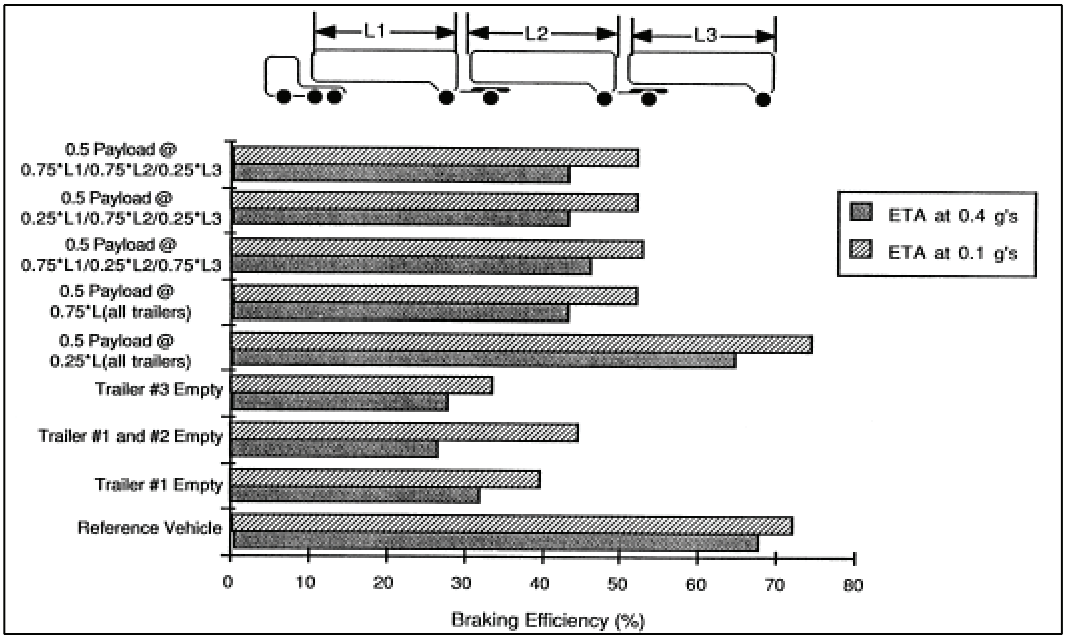


Figure 49: Influence of partial loading on brake efficiency in triples **Source: Fig 3.5.4.c (Ervin & Guy, 1986)**

Ervin and Guy (1986) suggested that given that the carriage of an empty trailer at the rear of a triples combination was a common practice, there was reason for concern that the braking performance of the vehicle in this condition would be 'markedly deficient'.

In theory, this does suggests that the distribution of the load within an LHV could have a substantial impact on the stopping distance and stability of an LHV under braking. However, this research was carried out before 1986 and it is extremely unlikely that the vehicles were fitted with ABS and possible that they were not equipped with load sensing and apportioning valves.

In Europe Directive 71/320 has, for many years, required that the distribution of braking amongst the axles is controlled and related to the weight acting on it. This is known as the adhesion utilisation requirements and acts to minimise the chances of rear wheels locking before the front and creating stability problems. From the early nineties, this has been supplemented by a mandatory requirement to fit ABS to larger goods vehicles and trailers. ABS acts to prevent wheels locking in most circumstances and would be likely to substantially affect the results of tests such as those described above. It is likely that these controls will have minimised the risk of the types of problem described, although further empirical confirmation of this may be required if it is decided that LHVs should be permitted.

B.3.2 Brake system response time

Motor vehicles in the United Kingdom are required to meet or exceed minimum deceleration rates whilst braking, which are specified in United Nations Economic Commission for Europe (UNECE) Regulation 13 or the EC Directive 71/320/EEC. For a passenger car the required deceleration rate is $5.8m/s^2$, whereas for a commercial vehicle it is $5.0m/s^2$.

The brake system on a commercial vehicle is usually a pneumatic system. Air is known to have a relatively low pressure wave propagation rate therefore the increase of air pressure at the foot brake valve will take a finite amount of time to travel to each brake chamber and begin generating brake torque. This is known as the brake response time. The longer the vehicle, the further the air wave must travel and so the longer the response time will be.

In UNECE Regulation 13 the brake response time is controlled such that

“For an actuating time of 0.2 seconds, the time elapsing from the initiation of the braking system control actuation to the moment when the pressure in the brake cylinder reaches 75% of its asymptotic value shall not exceed 0.6 seconds”

The brake response time can have a substantial effect on overall stopping distance, as measured from initiation of the braking system control actuation. However, it should have no effect on the MFDD measured because, by definition, that is the deceleration from 80% of the initial speed to 10%, so the response time should already have elapsed before the calculation is applied.

In Australia, where the use of LHVs is more common, they have additional requirements for the response time of a B-double or a road train. Australian Design Rule (ADR) 35/01 and ADR 38/02 specify the brake response time for tractor units and semi trailers respectively.

ADR 35/01 specifies: *“The pressure at the slowest reacting brake chamber must attain a level not less than 65 percent of the ‘Average Operating Pressure’ within a period not exceeding 600 milliseconds [0.6 seconds] measured from the instant the ‘Control’ leaves the ‘Initial Brake Control Location’.”*

ADR 38/01 specifies: *“The elapsed time[measured from the time when the pressure in the storage reservoir initially drops]…must not exceed in the case of (a) any brake actuator of any ‘Axle Group’ on the trailer, 0.35 seconds; and (b) any trailer or dolly rear service coupling for towed trailers, 0.25 seconds.”*

The additional requirement for LHVs are stated in South Australian Road Traffic (Vehicle Standards) Rules 1999 - Reg 140, where: *“The pressure in the least favoured chamber of the braking system of a B-double or road train with brakes that operate using compressed air must…reach at least 420 kilopascals within (a) for a B-double—1 second after the rapid and complete application of the foot-operated brake control; or (b) for a road train—1.5 seconds after the rapid and complete application of the foot-operated brake control.”*

Increases in weight need to be accompanied with increases in brake torque capacity (Fancher and Campbell, 2002). If it is assumed that a B-double or a road train has the same ultimate braking performance as a standard tractor and semi-trailer combination (for this example a deceleration of 6m/s² has been used) then a longer response time results in a significant increase in stopping distance. Figure 50 shows that if a standard vehicle has a reaction time of 0.6 seconds (i.e. it reached a deceleration of 6m/s² in 0.6seconds) then it would stop (from an initial speed of 50mile/h) in 47.6m. If, due to the longer response time of the B-double and the road-train allowed by Reg140, the deceleration does not reach its peak value until 1.0 and 1.5 seconds respectively, then the stopping distance for these vehicle becomes 51.9m (+9%) and 57.2m (+20%) respectively.

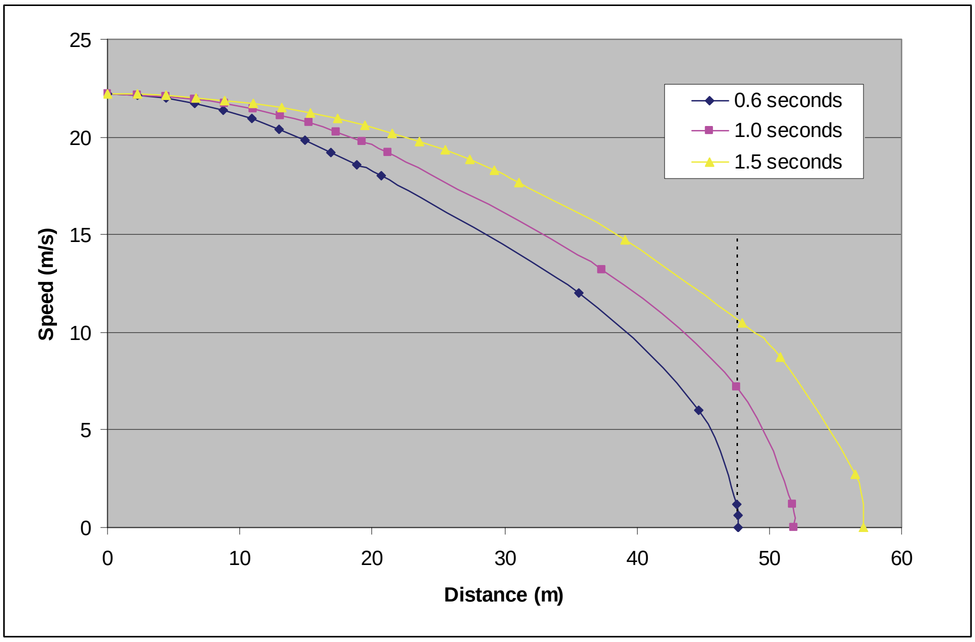


Figure 50: Speed distance comparison for different brake system response times

If it were assumed that the standard vehicle just avoided a collision by stopping in 47.6m, then this means that the B-double and road-train used in the example above would have crashed with an impact speed of 7.2m/s (16mile/h) and 10.5m/s (23mile/h) respectively.

Studying distributions of collision speeds in fatal accidents (Knight, 2000) suggests that very few fatal collisions between cars and trucks occur at closing speeds of less than 23 mile/h such that if the larger vehicle was braking to avoid a stationary car, the reduced brake performance would be unlikely to cause a fatality but it could cause a serious injury. In addition to this, if the car was moving such that the relative collision speed was greater the reduced brake performance could very easily turn a serious injury into a fatal injury. Smith (2006) shows that many fatal accidents between trucks and pedestrians occur at speeds of 23 mile/h or less, such that the reduced brake performance could potentially turn a near miss into a fatal accident.

Tests of LHVs carried out at MIRA (BTAC, 2006) appear to confirm the findings above. A B-double combination achieved a braking efficiency of 73% without stability problems. Research by TRL (Knight *et al*, 2002) found that the best standard HGV tested produced a mean fully developed deceleration of approximately 7.8 m/s^2 (approximately equivalent to an efficiency of 78%). The worst vehicle tested was a 2-axle rigid vehicle that would have failed a type approval test but had no obvious defects likely to fail a roadworthiness test. These results suggest that the B-double tested at MIRA was better than many standard HGVs currently on the road and approached the performance of the best currently on the road.

B.4 Stability

When assessing the stability of a vehicle combination a number of measures can be used. These include:

- Static rollover threshold
- Rearward amplification
- Dynamic load transfer ratio
- High speed off-tracking
- Yaw damping ratio

B.4.1 *Static rollover threshold*

The static rollover threshold (SRT) is the lateral acceleration at which rollover occurs during steady state cornering. This can be calculated using static tilt tests or, using certain assumptions, can be estimated through a simple calculation. A study in New Zealand (de Pont et al, 2000, Mueller et al, 1999) determined relationships between some performance measures and relative crash rates for rollover and loss-of-control crashes involving heavy vehicles in New Zealand. Figure 51 shows the relative crash rate against SRT as determined by this study. From this figure it can be seen that vehicles with poor SRT (less than 0.3g) had a crash rate about four times the average indicating the potential impact on safety from vehicle having a poor static rollover threshold.

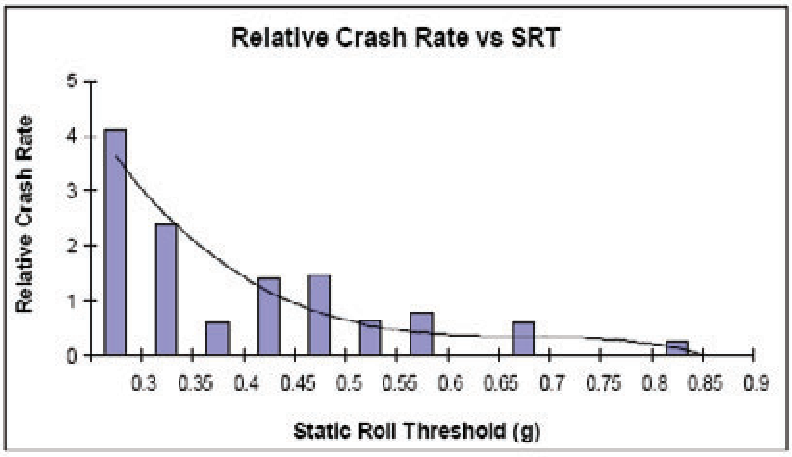


Figure 51: Crash rate against SRT for New Zealand. Source: de Pont et al, 2002

New Zealand authorities carried out a Road User Charges (RUC) Survey to gain information on heavy vehicle stability and compare with crash rates. Rigid vehicles were omitted from the analysis due to an inherent bias in Commercial Vehicle Inspection Unit (CVIU) reporting. A-trains were also omitted from the investigation because they represented a small proportion of the vehicles surveyed. In New Zealand the desirable minimum level of static rollover stability was recommended to be 0.35g, and Figure 52 shows that approximately 15% of the vehicles used in the RUC survey fell below that level.

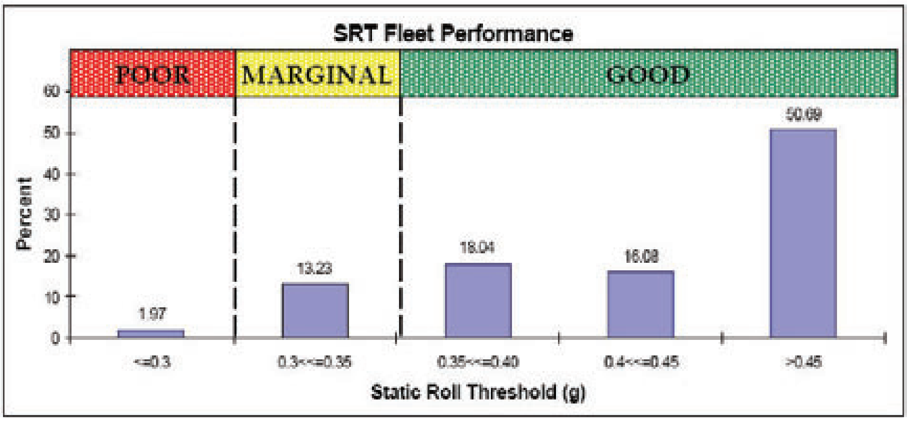


Figure 52: Static Rollover Threshold performance. Source: Mueller et al, 1999

Mueller et al (1999) stated that approximately 40% of commercial vehicles involved in accidents because of instability or rollover had a static rollover threshold of less than 0.35g. Out of those vehicles, eight per-cent had a static rollover threshold of less than 0.3g. This is illustrated in Figure 53.

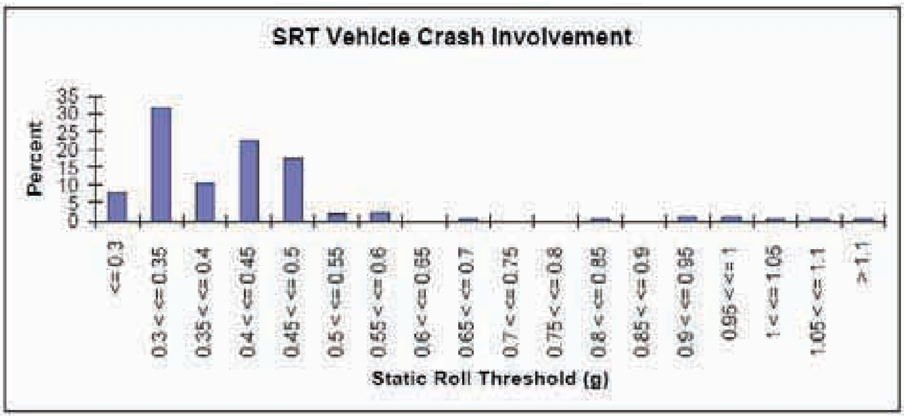


Figure 53: Static Rollover Threshold Crash Involvement Distribution. Source: Mueller et al, 1999

Figure 54, from the USA data report (Clarke et al, 1998), again suggests that as the static rollover threshold decreases then the likelihood of being involved in an accident increases.

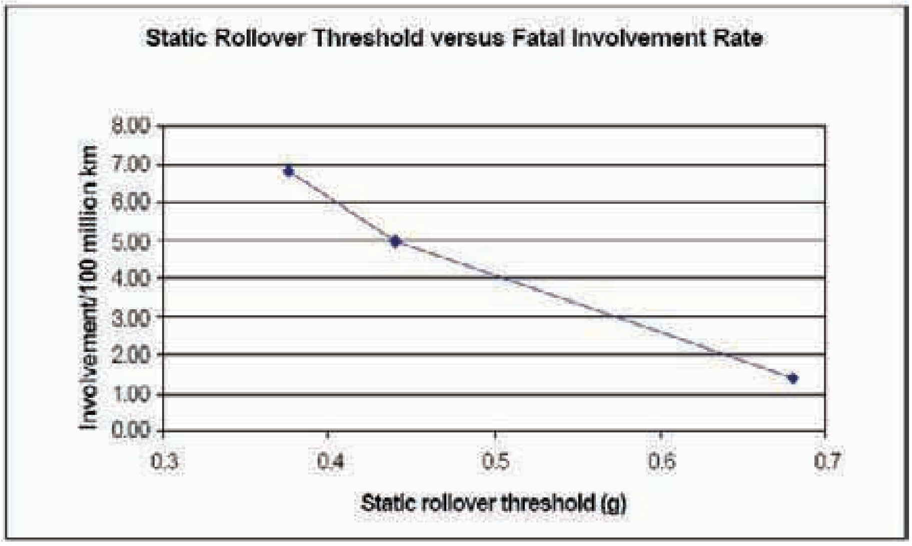


Figure 54: USA semi-trailer static rollover threshold against fatal crash involvement rate. Source: (Clarke et al, 1998)

Commercial vehicles have a low level of basic roll stability compared to light vehicles, which is a significant contributing cause of truck rollover accidents. Most passenger cars have a rollover threshold of greater than 1g, light trucks and vans range from 0.8g to 1.2 g. The rollover threshold of fully laden commercial vehicles often lies well below 0.5g (Chrstos, 1991).

Vehicle combinations rollover when the rollover threshold has been reached. When a vehicle combination is cornering and the trailer axles lift rollover will occur if the axles that are still in contact with the ground cannot provide any further assistance to the increasing roll angle of the trailer. The vehicle combination becomes incredibly unstable and rollover occurs. This is illustrated in Figure 55. However, the vehicle combination will not necessarily rollover if the trailer axles lift during cornering. If the axles of the tractor unit provide a sufficient level of roll resistance then rollover will not occur.

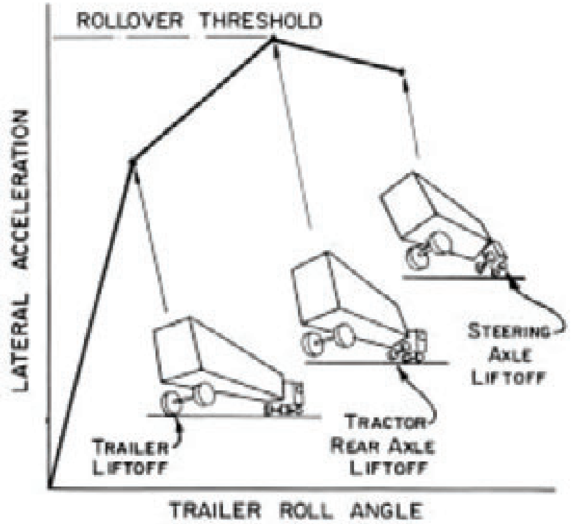


Figure 55: Typical axle lift off sequence and rollover threshold for a tractor unit and semi-trailer. **Source: Ervin et al, 1986**

Rollover in LHV combinations is complex and depends on the type of coupling between each of the trailers. Trailers which are connected via a fifth-wheel coupling will rollover as connected units. However, trailers which are connected via a dolly can rollover independently of each other. This means if the last trailer of the LHV combination reaches its rollover threshold and over turns, other trailers in the vehicle combination do not necessarily reach their rollover stability limit. Figure 56 shows the range of rollover stability performance by vehicle class from an Australian heavy fleet (Prem et al 2002).

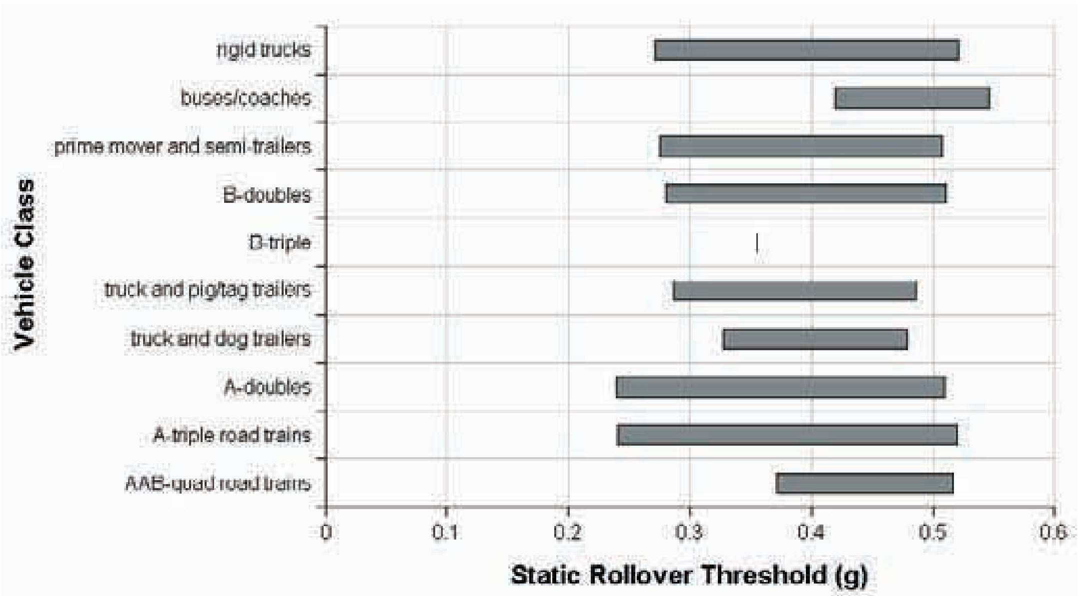


Figure 56: Rollover stability by vehicle class. **Source: Prem et al 2002**

Table 51 shows the performance levels of an Australian heavy vehicle fleet with regards to static rollover threshold. The table shows that there is little difference in SRT between each of the vehicle.

Table 51: Performance levels of an Australian heavy vehicle fleet for Static Rollover Threshold(g) **Source: Appendix G – Table G.3.12 (Prem et al, 2002)**

Vehicle Class	Sample Size	Descriptive Statistic					
		Min	Max	Mean	StdDev	Mode	Median
rigid trucks	17	0.27	0.52	0.41	0.070	0.49	0.43
buses/coaches	6	0.42	0.55	0.48	0.052	0.49	0.49
prime movers and semi-trailers	43	0.28	0.51	0.38	0.053	0.36	0.36
B-doubles	23	0.28	0.51	0.38	0.060	0.35	0.35
B-triple	1	0.36	0.36	0.36	-	-	0.36
truck and pig/tag trailers	9	0.29	0.49	0.37	0.070	0.33	0.37
truck and dog trailers	14	0.33	0.48	0.42	0.055	0.48	0.41
A-doubles	12	0.24	0.51	0.39	0.075	0.35	0.36
A-triple road trains	12	0.24	0.52	0.36	0.071	0.35	0.35
AAB-quad road trains	2	0.37	0.52	0.44	0.103	-	0.44

As mentioned previously in the report, C-trains (C-frame dollies) are not used in Australia, so are not shown in the figure and table above. However, C-trains are virtually indistinguishable from their corresponding version of A-trains in terms of static roll stability (Winkler et al, 1993).

There are a number of consequences associated with a vehicle with a low SRT. These include the safety of the driver and any passengers in the vehicle and the safety of individuals within the immediate vicinity of the vehicle. If the vehicle over turns then it is highly likely that as a consequence there will be injuries to anyone involved and delays to traffic. (Frith et al, 2006), showed that the average duration of accidents involving HGVs was substantially greater than accidents that did not involve an HGV and that this meant that HGV accidents typically caused more congestion than other accidents. Within this group it is likely that HGV rollovers would represent a higher typical duration because of the difficulties involved in recovery compared with, for example, a collision between an HGV and a car.

B.4.2 Rearward amplification

Rearward amplification is the degree to which the trailer(s) amplify or exaggerate the sideways motion of the tractor unit. It is technically defined as the ratio of the lateral acceleration of the rearmost trailer to the lateral acceleration of the tractor.

Reward amplification pertains primarily to vehicle combinations with more than one point of articulation and usually occurs when the vehicle performs a manoeuvre with unusually high frequency content, such as an avoidance manoeuvre. In extreme cases, the sideways movement of the trailer can result in a rollover.

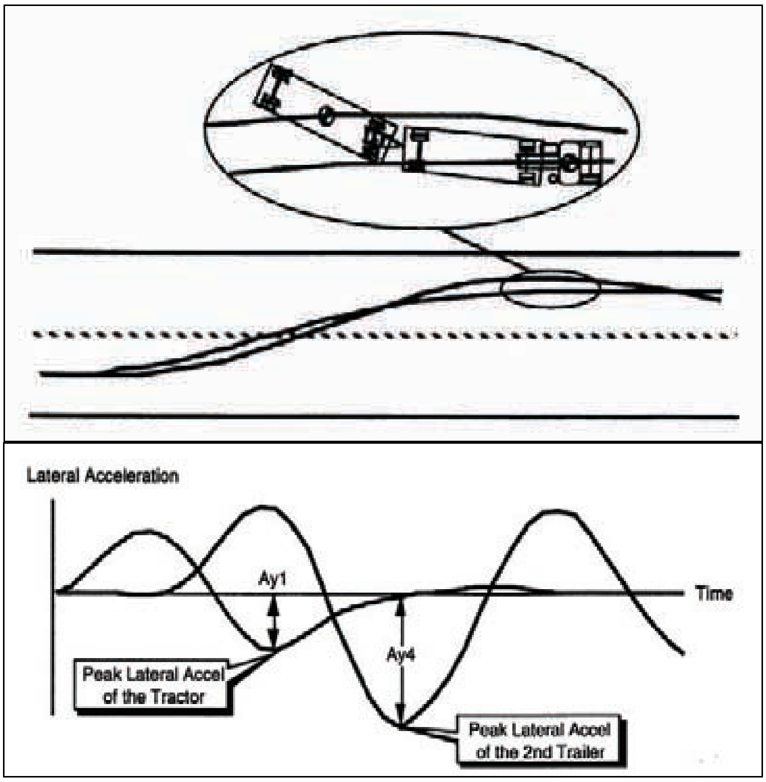


Figure 57: Illustration of rearward amplification **Source: Fig 7, Fancher 7 Campbell (2002)**

A study of the performance levels of the Australian heavy vehicle fleet (Prem at al, 2002) found that the baseline performance for mid-range vehicles varied quite significantly as shown in Table 52. It shows that the standard tractor unit & semi-trailer combinations had the lowest level of rearward amplification with regards to commercial vehicles.

Table 52: Baseline performance of mid-range vehicles **Source: Appendix G – Table G.3.13 (Prem et al, 2002)**

Vehicle Class	Sample Size	Descriptive Statistic					
		Min	Max	Mean	StdDev	Mode	Median
rigid trucks	17	1.11	1.52	1.33	0.12	1.24	1.31
buses/coaches	6	1.01	1.95	1.27	0.34	-	1.17
prime movers and semi-trailers	43	0.97	1.50	1.29	0.09	1.28	1.28
B-doubles	23	1.20	1.74	1.33	0.12	-	1.31
B-triple	1	1.38	1.38	1.38	-	-	1.38
truck and pig/tag trailers	9	1.60	1.97	1.85	0.14	1.97	1.91
truck and dog trailers	14	2.22	2.95	2.52	0.24	-	2.70
A-doubles	12	1.58	2.52	1.99	0.22	-	2.01
A-triple road trains	12	1.86	3.10	2.41	0.33	-	2.39
AAB-quad road trains	2	3.07	3.13	3.10	0.04	-	3.10

Aurell, (2003) also presents information concerning the rearward amplification for vehicle combinations including several vehicle types either used in Europe or proposed for use. The graph presented in Figure 58 was based on the tabular data presented by Aurell (2003) at various points in his report.

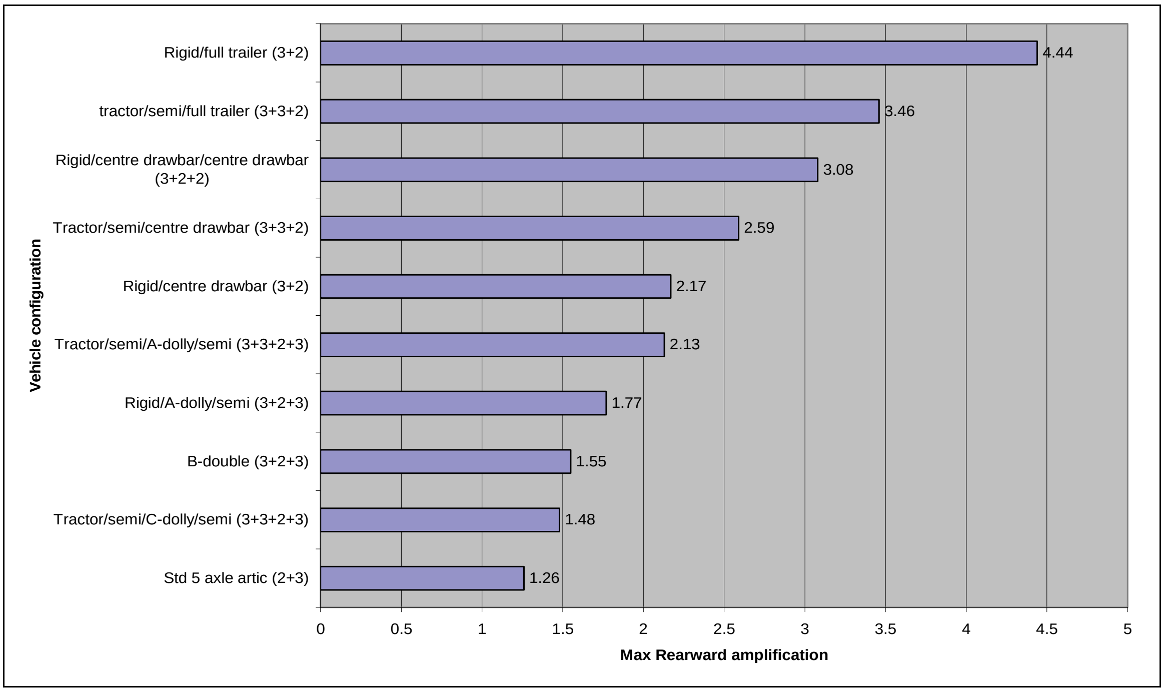


Figure 58. Rearward amplification (Aurell, 2003)

The rigid combination consists of a three axle rigid truck with a 7.82m load unit, plus a two axle A-frame dolly coupled to a 13.6m three axle semi-trailer. This vehicle combination has a total of 8 axles and two points of articulation and is equivalent to the vehicle options 3 or 4, depending on its GVW which was not specified.

The A-train consists of a three axle tractor unit plus a 13.6 m three axle semi-trailer, plus a two axle A-frame dolly coupled to another 13.6m three axle semi-trailer. This vehicle combination has a total of 11 axles and three points of articulation. It is similar to vehicle option 5 in all respects except the use of an A-dolly rather than a C-dolly.

The C-train consists of a three axle tractor unit plus a 13.6 m three axle semi-trailer, plus a two axle C-frame dolly coupled to another 13.6m three axle semi-trailer. Like the A-train, this vehicle combination has 11 axles but only has two points of articulation and this is identical to vehicle option 5.

The B-double combination in the graph is also very similar to vehicle options 6 or 7 as defined in this report, depending on the GVW.

Pilksog et al (2006) also present information on rearward amplification for European vehicles but it should be noted that in their analysis they measure it as the yaw rate gain rather than the lateral acceleration gain. They define a standard tractor/semi, a truck/A/semi equivalent to vehicle option 3/4 and a truck and full trailer (worst case current vehicle in the UK) and show values of approximately 1.1, 1.6 and 3.6 respectively

It can be seen that although estimates of the rearward amplification values vary in different publications, possibly due to subtly different vehicle geometries, loading conditions or test methods, in terms of rank order the conclusions are consistent. In general the traditional articulated vehicle is the least susceptible, the B-double and C-dolly combinations are the best of the LHV types and the worst vehicles are the types of drawbar combination that would already be legal in the UK at lengths of up to 18.75m.

A study by Winkler et al (1993) carried out a study to look at the dynamic performance of different converter dollies and to assess the effect on safety of using a C-dolly rather than an A-dolly. Winkler et al (1993) found that changing from A-dollies to C-dollies produced a fairly reliable and predictable improvement in performance. Figure 59 shows the ratio of A-train to C-train results by vehicle and dolly type. There were four self-steering dollies (2C1, 2C2, 3C1 & 3C2) and two controlled-steering dollies (2C3 & 3C3) tested.

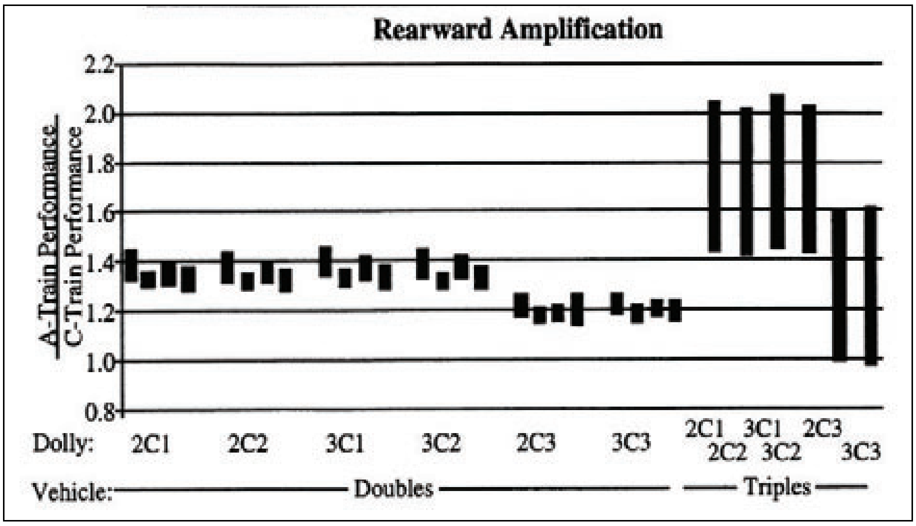


Figure 59: Ratio of rearward amplification performance for A-train and C-train

The results showed that, when applied to doubles, the self steering C-dollies improved (reduced) the rearward amplification by a factor of approximately 1.35. A similar result was seen for the controlled steering C-dollies, although with a slightly lower factor of 1.2.

For the triples, the improvement seemed to be higher, but a greater degree of scattering was evident from the results, therefore it was concluded that predicting an improvement factor was most appropriate for doubles.

Winkler et al (1993) also carried out an economic analysis to estimate the benefits gained from fitting C-dollies rather than A-dollies. They compared the effect of reducing traffic accidents with the extra cost associated with the purchase and operation of such equipment.

The analysis was based on the assumption that the additional rollover resistance provided by C-dollies was roughly equivalent to the constraints from a fifth wheel coupling between a tractor and semi-trailer. Therefore, since it was assumed that C-dolly equipped doubles would exhibit an accident rate similar to that of a tractor semi-trailer.

The analysis showed that the fatal rollover rate for doubles was significantly higher than for singles, 1.20 compared with 0.99, as shown in Table 53.

Table 53: Travel, rollover fatal involvements, and involvement rates by road type for singles and doubles. **Source: Table 14 (Winkler et al, 1993)**

Road Type	*Miles (10^8)*	*Percent*	*Fatal Involvement*	*Percent*	*Involvement Rate*
Singles					
Limited Access	193.97	55.20	1,239	33.6	0.61
Other	138.30	39.30	2,200	59.7	1.52
Single Subtotal	332.28	94.50	3,439	93.4	0.99
Doubles					
Limited Access	13.96	4.00	103	2.8	0.70
Other	5.40	1.50	141	3.8	2.49
Double Subtotal	19.35	5.50	244	6.6	1.20
Grand Total	351.63	100.00	22,063	100.0	1.00

The number of property damage-only (PDO) accidents was also assessed. Using the US General Estimates Systems (GES) data it was found that the proportion of PDO accidents with a rollover involving doubles was higher at 8% compared with 3.7% for singles. Using Truck in Fatal Accidents (TIFA) data to more accurately represent the true number of singles and doubles accidents per year it was estimated that there were 305 PDO rollovers accidents annually (3695 x 8.2%)

Table 54: Number of involvements by combination type and accident severity 1986-1988 (TIFA data). **Source: Table G-2. Winkler et al, 1993**

	Single	*Doubles*
PDO	126,942	3,695
Injury	43,685	2,278
Fatal	3,317	232
Total	173,944	6,205

It was found that if doubles rolled over at the same rate as singles, there would be 137 PDO rollovers, a saving of 168 rollovers (55%) of this type.

B.4.3 Dynamic load transfer

The dynamic load transfer ratio is a measure of the dynamic roll stability of a vehicle. It measures the proportion of a vehicle's total axle load that is carried on one side of the vehicle relative to the other. A perfectly balanced vehicle would have a load transfer ratio of 0, whilst a vehicle with all of its weight on one side (and the other side in the air) would have a load transfer ratio of 1.0. The majority of researches recommend a load transfer ratio of no greater than 0.6. For load transfer ratios above 0.6 the majority of heavy vehicles are highly susceptible to rolling over (Clarke et al, 1998). This means if 60% of the gross vehicle weight or more is carried by axles on one side of the vehicle combination then the probability of rollover is increased.

The dynamic load transfer ratio is linked with both static rollover threshold and rearward amplification and is another measure of a vehicle combinations ability to perform turning and avoidance manoeuvres safely.

The dynamic load transfer ratio can be applied to various aspects of a vehicle combination. These include; individual axles, axle groups, separate units (semi-trailer and supporting dolly) or the vehicle as a whole i.e. tractor unit and trailer(s). Below is the calculation for the dynamic load transfer ratio for a vehicle combination. Any steered axles are not included in the calculation due to their negligible influence on load transfer.

$$\text{dynamic load transfer ratio} = \frac{\left|\Sigma(F_L - F_R)\right|}{\Sigma(F_L + F_R)}$$

Where:

F_L = vertical load on tyres on the left side of the vehicle

F_R = vertical load transfer on the right side of the vehicle

As gross mass and overall vehicle length increases the dynamic load transfer ratio decreases, as shown in Figure 60. However, A-trains are generally confined to values above 0.6 (Prem et al 2002).

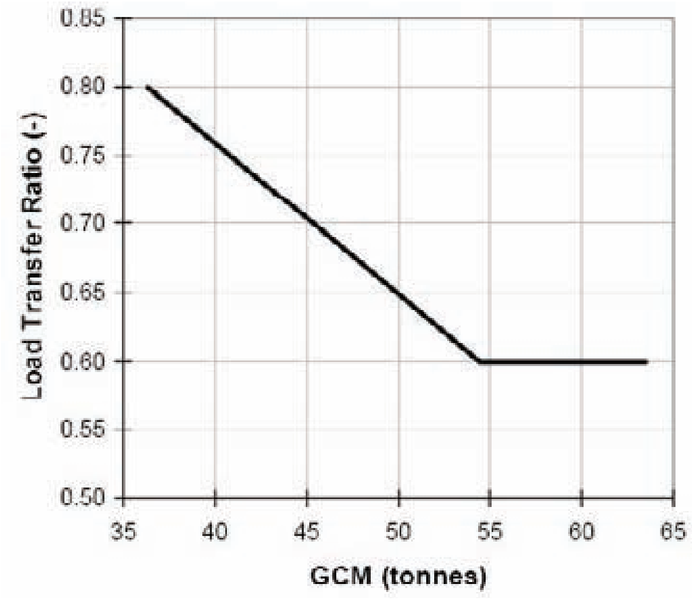


Figure 60: Recommended minimum load transfer ratio performance versus Gross Combined Mass (GCM). **Source: Sweatman et al 1998**

The dynamic load transfer ratio is also extremely sensitive to small changes in speed as shown in Figure 61.

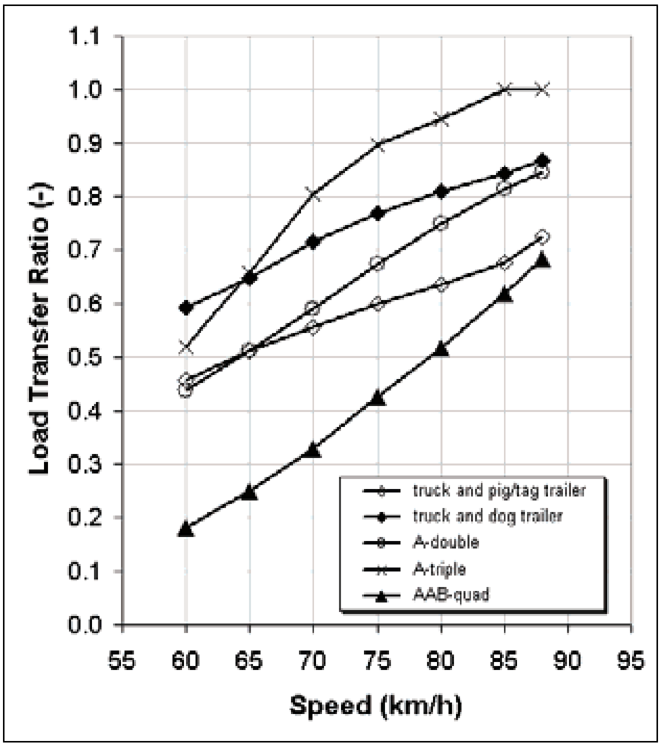


Figure 61: Influence of speed on load transfer ratio. Source: Prem et al 2002

B.4.4 High speed transient off-tracking

The tracking of a vehicle combination describes the ability of the rear trailer(s) to follow the path of the tractor unit. When an LHV travels in a straight line, the trailers do not necessarily follow exactly the same path as the tractor unit. A report by Australia's National Road Transport Commission

(NRTC, 2001) suggested that in practice each trailer undergoes small lateral deviations from the path of its tractor unit as it responds to steering actions, road surface unevenness, and other external disturbances.

When an LHV combination is travelling in a steady turn, the tractor unit is steered to follow the required path and the trailer(s) is expected to follow the path of the tractor unit. As the speed increases the low speed off-tracking (as mentioned previously) begins to diminish and at some speeds reduces to zero. At higher speeds the rear trailer(s) may track to the outside path of the towing unit and this is known as high speed off-tracking. High speed off-tracking can be influenced by turn radius and speed. High speed off-tracking can be unnoticed by drivers until it is too late. This is particularly prevalent in articulated vehicles and should be eliminated wherever possible.

A vehicles' tracking ability is measured by the lateral displacement between the centre of the tractor unit and the rear of any trailer during travel. It is important to ensure that any LHV remains within it's lane because any vehicle that does not presents a risk to safety. If the vehicle crossed the centreline of the road then there is a risk of a collision with oncoming or overtaking traffic. An LHV combination that crosses the edge of the road may cause damage to the edge of the road, or worse, instigate a rollover.

High speed off-tracking increases with both gross mass and overall vehicle length. B-trains and C-trains only have negligible effect on high speed off-tracking compared to an A-train (Fancher et al 1986).

B.4.5 Yaw damping ratio

Yaw damping ratio quantifies how quickly yaw oscillations (sway) of the rear of the trailer take to settle after a rapid steering manoeuvre. Trailers where the yaw oscillations take a long time to settle represent a higher safety risk. The worst situation is vehicles with a value of 0, which suggests that there is no damping present in the yaw response. In this situation if there was no corrective steering input by the driver, the oscillations would continue indefinitely. The best situation would give a value of 1, which indicates that damping occurs instantaneously.

Yaw damping tends to decrease with speed, so at higher speeds the oscillations may take longer to decay, which results in the potential for rollovers in extreme cases. When a system is over-damped the vehicle would become extremely slow when responding to steering, hence the vehicle response would be generally quite slow.

To evaluate the yaw damping ratio of a vehicle, a steering is applied rapidly over a very short time period in one direction and then rapidly applied again to the original driving direction and no attempt is made to correct the vehicle's course after the steering has been applied. Initially when the steering is applied the trailer(s) will follow the direction of the tractor unit, but when the vehicle is steered back in the original direction the yaw oscillations of the trailer(s) will diminish.

Yaw damping generally decreases with vehicle gross mass and overall length, this can be seen in Table 55, where the rigid vehicle, which has the least gross mass and overall length has the greatest yaw damping.

Table 55: Performance levels of an Australian heavy vehicle fleet yaw damping. **Source: Appendix G – Table G.3.15 (Prem et al, 2002)**

Vehicle Class	Sample Size	Descriptive Statistic					
		Min	Max	Mean	StdDev	Mode	Median
rigid trucks	17	0.68	1.00	0.98	0.08	1.00	1.00
buses/coaches	6	0.23	1.00	0.81	0.32	1.00	1.00
prime movers and semi-trailers	43	0.55	1.00	0.76	0.19	1.00	0.65
B-doubles	23	0.39	0.81	0.49	0.09	-	0.48
B-triple	1	0.35	0.35	0.35	-	-	0.35
truck and pig/tag trailers	9	0.23	1.00	0.61	0.33	1.00	0.46
truck and dog trailers	14	0.13	0.32	0.22	0.07	-	0.19
A-doubles	12	0.25	0.40	0.34	0.05	0.39	0.35
A-triple road trains	12	0.14	0.29	0.21	0.05	-	0.22
AAB-quad road trains	2	0.18	0.20	0.19	0.01	-	0.19

The influence of C-dollies on the yaw damping ratio are shown in Figure 62. The graph illustrates that C dollies improve the yaw damping ratio for doubles because most of the bars are centred below a value of unity. However, the graph shows that the tendency is neither strong nor consistent (Winkler et al, 1993). In this case, the average A-frame to C-frame ratio is 0.62 (inverting this value implies an improvement factor of 1.61.).

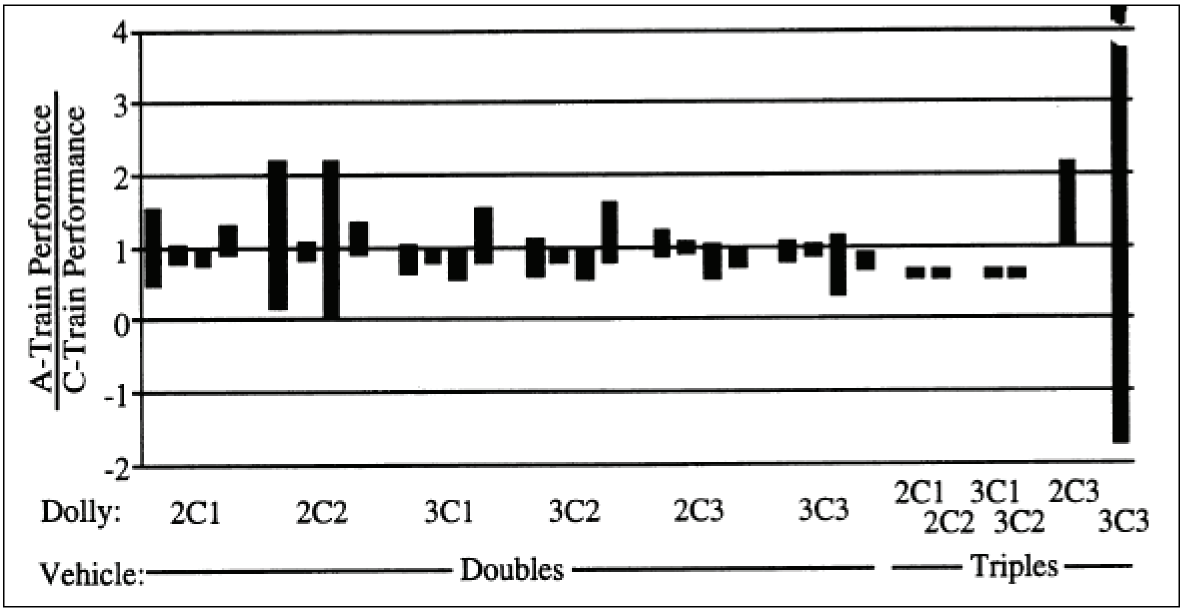


Figure 62. Ratio of A/C dolly performance in terms of yaw damping

B.4.6 Influence of basic design parameters on key stability parameters

Table 56 shows the effect that various vehicle configurations have on the static rollover threshold, reward amplification and high speed off-tracking. The information in this table has been synthesised from a number of studies and reports.

Table 56: Relationship between design parameters and stability/safety factors

Vehicle Configuration	Static Rollover Threshold	Rearward Amplification	High Speed Off-Tracking
Increasing gross vehicle weight	1	1	2
Increasing n^o of articulation points	3	1	2
Increasing trailer length	3	3	1
Longer wheelbase	3	5	4
Longer overhangs to rear hitches	3	1	2
Increasing n^o of axles	5	1	2
Increasing axle spreads	3	1	2

Where:

1. Significantly degrades the level of fundamental safety
2. Moderately degrades the level of fundamental safety
3. Not applicable or only a small effect
4. Moderately improves the level of fundamental safety
5. Significantly improves the level of fundamental safety

The type of dolly used in an LHV combination also has a significant effect on the stability of the vehicle. The number of articulation points does not have much affect on the static rollover threshold, so the type of dolly used will also have little effect on the static rollover threshold. The number of articulation point has a moderate affect on the high speed off-tracking. As Table 56 shows increasing the number of articulation points moderately degrades the level of fundamental safety, therefore, ideally the C-frame dolly or B-double set up should be used to reduce or eliminate high speed off-tracking as they remove a point of articulation compared to the A-frame dolly. Rearward amplification is affected the most by increasing the number of articulation points, significantly degrading the level of fundamental safety. So to limit the number of points of articulation and reduce or eliminate rearward amplification the C-frame dolly or B-double configuration is preferable to A-dolly type couplings.

Steering axles on trailers have been suggested as a solution to the low speed off-tracking problem. There has been relatively little research into the safety effects of trailer steering axles. However, Junjovich and Cebon (2002), carried out computer simulations of the performance of different types of steering axles on a tractor-semi trailer combination in the tests proposed at the time for the Australian Performance Based Standards. They defined three types of trailer steering axle:

- Self steering systems: These are typically the simplest and lowest cost form of axle and typically consist of a hub mounted on a trailing arm with a preloaded spring and damper such that the tyre forces generated during cornering induce the steering axle but the spring ensures that substantial forces have to be generated to induce the steering effect, thus helping to centre the axle, offset the effects of unbalanced braking and to provide lateral forces at low angles of steer to prevent instability. A self steer angle is, therefore, relatively stiff in yaw at low angles of steering but becomes relatively compliant at larger steering angles. Typically only the rear axle of a tri-axle group is steered and has the effect of reducing the wheelbase.

- Command steer: These systems act in a similar manner to normal steer axles and steer in response to the articulation angle between tractor and trailer, which is sensed either electronically or mechanically. The steering forces are transmitted to the axles either electronically, mechanically or hydraulically. Typically the two rearmost axles of a tri-axle group will be steered. A command steer axle also has the effect of reducing the wheelbase.
- Pivotal Bogie: In a pivotal bogie system the whole of a tandem or triaxle group is mounted on a ball race such that the bogie can pivot relatively freely in relation to the trailer body. The rearmost two axles of the bogie also steer in relation to the angle between the bogie and the trailer body such that as the bogie angle increases the axles steer in a way that tends to bring the bogie back into line with the trailer. In a pivotal bogie system the effective wheelbase can be dramatically reduced and can be half that of an equivalent fixed axle trailer.

Overall it was found that steering axles improved the low speed performance of articulated vehicles, reducing the swept path width and the lateral tyre forces such that vehicle were more manoeuvrable and caused less damage to tyres and roads during slow speed cornering. The only disadvantage at low speeds was an increased outswing.

However, these advantages were found to be partially offset by poorer high speed performance, with an increase in the rearward amplification and the transient high speed off-tracking. However, it was noted that these problems could be improved by simply locking the steering mechanisms at high speeds.

B.5 Impact Severity Assessment

It is generally recognised that accidents involving heavy good vehicles (HGVs) have more severe consequences on average than those involving only smaller vehicle. HGVs account for approximately 5.8% of all vehicle traffic (distance travelled), yet 18.3% of all road accident fatalities occur in accidents involving at least one HGV. There is concern that allowing even heavier goods vehicles might increase the proportion of truck crashes that result in fatalities.

A breakdown of accidents involving HGVs by road user (Knight, 2000) revealed that the majority of fatalities are car occupants. If un-protected road users are excluded (the consequences of a conflict with a heavier goods vehicle are unlikely to change significantly for those within this group) car users represent 80% of all fatalities. In these impacts, the primary determinants of whether a fatality results are the speed at which they collide, their mass and the impact configuration.

The relative closing speed (essentially the sum of the two vehicles' speeds) at impact is the single largest predictor of the likelihood that a given crash will have a fatal outcome. In car-truck impacts, higher closing speeds result in higher changes in velocity for the car involved in the conflict. The probability that an occupant of a car involved in a crash with a truck will be killed can be correlated with the change in velocity of the car during the crash (Figure 63).

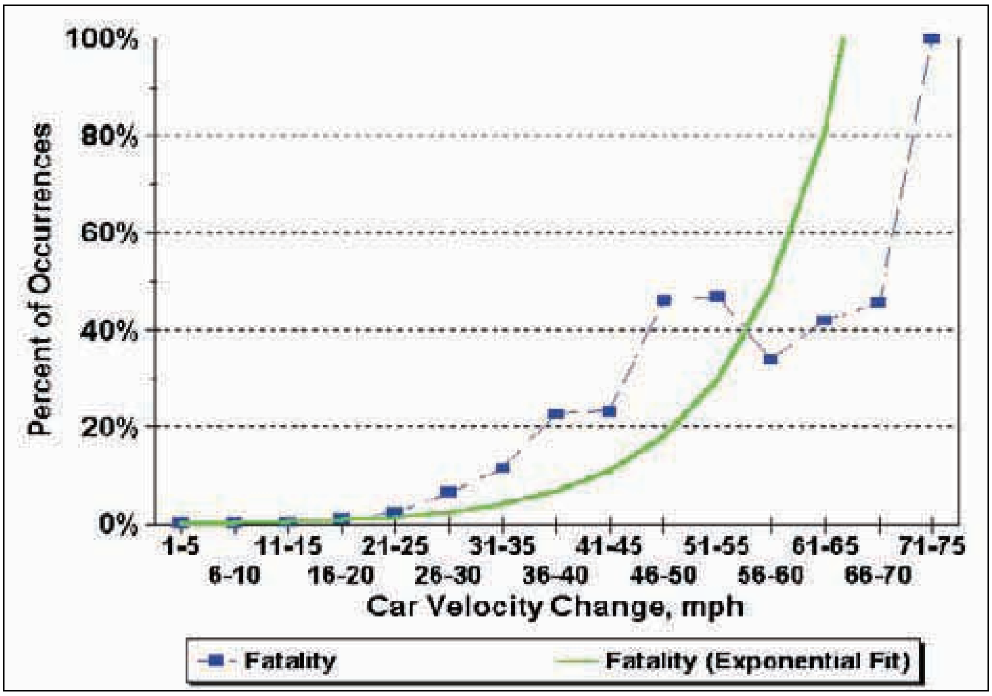


Figure 63: Fatality occurrence in car-truck collisions as a function of the change in car velocity (FHWA, 2000)

As the mass ratio increases, the change in velocity sustained by the smaller vehicle as a fraction of the closing velocity quickly rises (Figure 64). In car-truck impacts where the mass ratio is sufficiently large, physics dictates that the energy dissipated in a collision becomes insensitive to the mass of the truck – at mass ratios around 10:1 the smaller of the two vehicles sustains virtually all the change of velocity resulting from the collision. Current mass ratios in car-truck collisions are sufficiently large – mass ratios of up to 50:1 are possible – that there would be no perceptible increase in impact severity for the passenger car were heavier goods vehicle allowed.

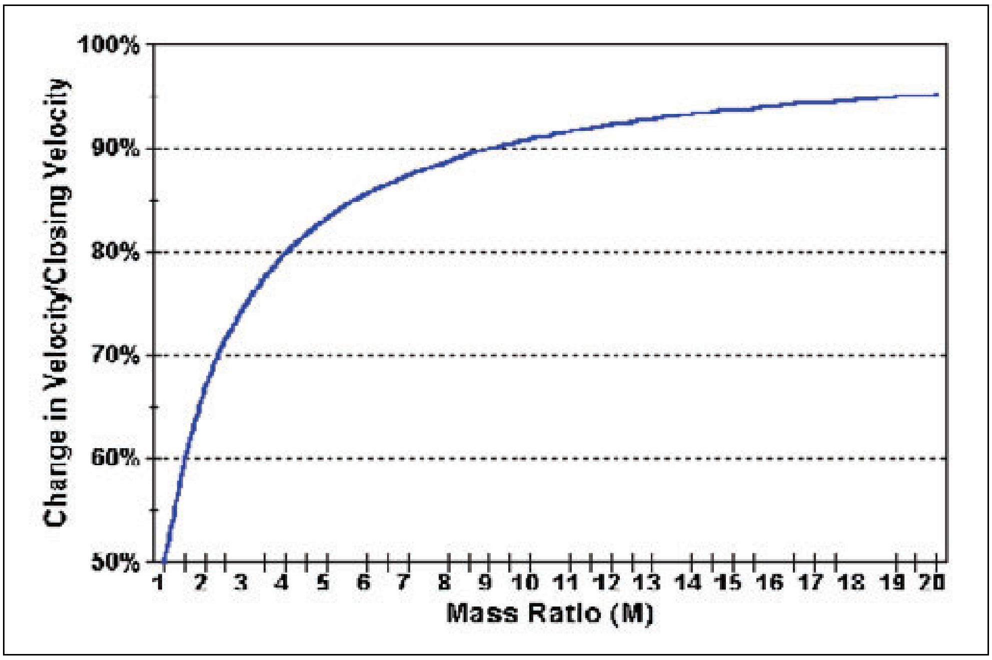


Figure 64: Relationship between the difference in weight of two vehicles involved in collision (mass ratio) and the relative change in velocity sustained by the smaller vehicle (FHWA, 2000).

Riebeck (2006) supports the views expressed above that increasing the weight of a truck will have negligible effect on the injury outcome for occupants of light vehicles in a primary collision. However, he does state that if other obstacles are also in the path of the post primary collision vehicles then the severity could be increased in line with the increased energy. Collisions between the front of a truck and the rear of a car where the car may have other vehicles stationary ahead is quoted as the most relevant example.

Truck occupants account for a much smaller proportion of the fatalities from accidents involving trucks (9% in Knight, 2000). Increasing the maximum mass would place a greater demand on the crashworthiness of the truck. Higher vehicle mass increases impact severity and places greater demand on the crashworthiness of the truck. Survivability is dependent on the ability of the vehicle to maintain a survival space in a crash and the ability of the vehicle to absorb some of the energy from a crash (eg by crumpling). The structure of current truck cabins is only capable of meeting these criteria at relatively low closing speeds when the collision partner is another heavy vehicle or a rigid fixed object. Increasing the mass of the truck is likely to exacerbate this problem and could lead to an increase in the risk of an occupant fatality.

B.6 Junctions, crossing and overtaking

The recent German study (Glaeser *et* al, 2006) of the impact of LHVs did not find that there were any increased safety risks on motorways. However, on non-motorway roads the researchers expected to find negative safety and performance impacts resulting from the use of LHVs at junctions, railway crossings and more generally on single carriageway rural roads. This was considered to be mainly due to the increased time that a longer vehicle would take to clear a junction, execute a manoeuvre or to be overtaken.

Ramsay (undated) assessed the interaction of multi-combination vehicles with the urban traffic environment and found that longer vehicles did take longer to clear intersections and railway crossings. One hazard that was highlighted was how this was related to the “inter-green” time at traffic light controlled junctions (that is the time between when the green light for one direction is extinguished and the green in another direction is illuminated). It was noted that typically inter-green times were less than would be required for a 25m vehicle, thus increasing the safety risk. Increasing the inter-green time would eliminate this risk but would reduce the traffic flow capacity of the junction. It was suggested that this problem could be overcome if signals were “intelligent” and recognised the approach of a longer vehicle.

These problems could be exacerbated where, due to traffic conditions, an LHV began accelerating from rest to cross a junction when a light was green because of the time taken to accelerate. Similar concerns were cited for railway level crossings.

One of the commonly cited risks that could potentially be associated with LHVs is the risk associated with requiring a longer time to overtake them. A study of this phenomenon was carried out in Sweden (VTI, 1976) by operating vehicles of 18m and 24m in length in ordinary traffic on predefined test sections. In total, the vehicles covered more than 13,000 km during the tests. The amount of time between the completion of an overtake and the arrival of oncoming traffic was used as an indicator of accident risk and was recorded by cameras mounted on the test vehicles. The difference in this mean time value between the 18m and 24m vehicles were very small. The data suggested that the longer vehicle did tend to induce a greater number of overtaking manoeuvres defined as “hazardous” but that this suggestion was not statistically significant.

Ramsay (undated), cited research by Troutbeck (1980) also showing that overtaking times increased only slightly with vehicle length, because the typical overtaking manoeuvre takes place over a much greater length than the vehicle length alone.

Hanley and Forkenbrock (2005) attempted to quantify the problem of overtaking LHVs on two-lane highways using a Monte-Carlo computer simulation technique. They found that the odds of a failure to successfully overtake did increase with increasing vehicle length and estimated that the odds of failure to overtake a 120 foot (36.6metre) vehicle in the presence of moderate oncoming traffic was about 2-6 times greater than for a 65 foot (19.8metre) vehicle.

B.7 Stakeholder concerns

Concerns related to safety were expressed at focus groups for infrastructure owners and enforcement agencies and for representatives of other road users. In particular, the manoeuvrability and field of view issues were considered to be a concern for vulnerable road users, there were concerns about making collisions with other vehicles more severe and concerns that modal shift and traffic generation effects would mean that the total level of heavy vehicle traffic would actually increase, thus increasing accidents and casualties. Many of these concerns related to operation in urban environments but it was stated that cyclists did also use rural “A” roads and even dual carriageways to some extent. The analysis described in preceding sections of this appendix has attempted to quantify these concerns. It has found that some of the concerns are valid when considering standard current HGVs but would not be expected to be substantially exacerbated by increased length or weight. However, other aspects are expected to be worse for LHVs than for current vehicles and subsequent sections of this appendix attempt to quantify these in terms of a predicted accident rate per vehicle km, which is later embodied in the analysis of costs and benefits (Appendix H).

There was some support within the focus groups for the concept that many of the safety risks could be controlled by the use of vehicle technology such as electronic stability controls, collision mitigation braking systems etc. although others questioned whether it would be possible to mandate such systems for part of the vehicle fleet but not all of it.

Considerable concern was expressed by stakeholders about the ability to enforce safety standards. Many of these concerns related to access limitations both in terms of enforcing compliance with any permitted road sub-network and in terms of access to enforcement sites and weighbridge facilities. These concerns have been discussed in more detail in the infrastructure section (Appendix D). In addition to this there was concern about the effects of trailer defects. It was stated that a much higher proportion of trailers suffer serious brake defects compared with tractive units. It was considered that if a vehicle combination included two trailers a higher proportion of the complete braking system could be defective, thus increasing the consequences of any problems.

In general, there were greater safety and enforcement concerns in relation to vehicles visiting the UK from other countries. Targeted enforcement campaigns had suggested that more visiting vehicles were defective than UK vehicles and that it was more difficult to enforce compliance on these vehicles. It was considered that allowing visiting LHVs would exacerbate this problem.

Reversing of LHVs with more than one articulation point was raised as a concern by several stakeholders. This was in the area of general manoeuvring but also in relation to the fact that occasionally the vehicle combination may need to be reversed in the event of an emergency, for example, if a tunnel was blocked by an accident. The addition of an extra articulation point will undoubtedly make reversing more difficult. However, it is worth noting that vehicles with two articulation points are already permitted on UK roads in the form of drawbar combinations using full trailers. These are used without major reported problems although there is anecdotal evidence to suggest drivers do find them more difficult. There are also ways of improving the ability to reverse such vehicles, at least in a straight line or gentle curve, by mechanically locking one articulation point during reversing. Some stakeholders reported witnessing skilled drivers reverse 25.25m LHVs through 90 degree turn manoeuvres without apparent difficulty.

The issue of the skill of the driver, driver fatigue and training was raised. Several stakeholders were concerned that driving LHVs may be more tiring than driving standard HGVs. This is consistent with the research presented in section 5.6 of the main report and some stakeholders questioned whether driver’s hours should be reduced to reflect this finding. There was also a general concensus that some form of additional training, experience and/or qualifications should be required before people were permitted to drive LHVs. It was also suggested that other road users would need to be educated about the characteristics of LHVs, possibly through revisions to the Highway Code.

The perception of other road users was also raised as a concern, with several stakeholders suggesting that the general public would be opposed to introducing larger vehicles. While it was acknowledged by the majority at the meetings that this was likely to be true, it was pointed out that such views were not restricted to large goods vehicles. One stakeholder pointed out that their organisation received a large quantity of complaints about light commercial vehicles of less than 3.5 tonnes GVW.

Subsequent to the focus group meetings one stakeholder has published the results of an NOP survey of public opinion, which found that 75% of the public was opposed to the introduction of LHVs. However, several claims made in this publication were factually incorrect and/or misleading. The survey appeared to only consider 25.25m 60 tonne vehicles and appeared to ask two simple questions:

- The Government is considering legislation that will allow 60-tonne lorries, which are more than a third longer and heavier than the present legal limit, onto our roads. Would you be likely to support this or not?
- A possible alternative to allowing 60 tonne lorries onto our roads could be for the Government, through planning policy and funding, to encourage more freight to go by rail. Would you be likely to support this as an alternative or not?

The limited data available to the project team suggests that the sample was of adequate size and was balanced in terms of age, sex, social class and region. However, it was not apparent from this data whether any supporting information had been provided to respondents. If the questions above were the only supporting information then the results are likely to reflect an uneducated view of what is a complex matter and it may be that educating respondants about the relative advantages and disadvantages of each approach may have changed the results to some degree (in either direction).

The leaflet accompanying the publication of the results of this survey stated, incorrectly, that current HGVs were involved in twice as many fatal accidents as cars. In fact, it is the rate of involvement per vehicle km of HGVs that is twice that of cars but cars are involved in 6 times as many fatal accidents as HGVs. If such misleading information was presented to respondents it could substantially bias the results.

Although views in other countries may very well be quite different to the UK, it is worth noting that the Dutch trial of LHVs carried out a public opinion survey with a sample size of approximately 1,000 people. They found that although a large proportion of people reported feeling either unsafe or neither safe nor unsafe when interacting with current HGVs, there appeared to be no significant difference when considering interaction with an LHV. There appeared to be *"substantial"* support for the concept of introducing LHVs and respondants were able to cite *"sufficient advantages"* although there were concerns over the safety of right turn manoeuvres (equivalent to left turns in the UK).

B.8 Accident risk

B.8.1 Statistics from literature

Very few studies were found that could quantify the accident risk in terms of accident statistics in a scientifically robust manner. One recently published paper (Nagl, 2007) on the subject states that, so far, no empirical evidence has been found that suggests that LHVs are significantly more dangerous than standard goods vehicles. This lack of statistical evidence has led many researchers to take a risk based approach to assessing the influence of LHVs on accidents and accident rates.

The recent trial of LHVs in the Netherlands (Arcadis, 2006) found that there was no reason to assume that the larger vehicles would carry an increased safety risk and that there could be a 4% to 7% reduction in the number of fatal accidents involving trucks (>3.5 tonnes maximum weight). However, this prediction relied on an assumption that the accident rate per unit of distance travelled would be the same for LHVs as it was for ordinary trucks and that there would be a net reduction in the total distance travelled by all trucks, thus generating the benefit. It was not actually based on accidents recorded in the trial or the risk assessment approach taken to assess safety risks.

It was acknowledged by the authors that the trial was too small to enable a meaningful accident analysis with just one accident occurring with a relevant vehicle. In this case it was considered that the accident was unrelated to any specific feature associated with longer heavier vehicles. It was also acknowledged that strict pre-conditions had been imposed for the trial, which may have limited the accident potential. These included requirements that:

- There would be a maximum of 300 LHVs
- They would be restricted to appropriate routes
- Vehicles must have a range of safety features including an ABS operational on all axles and mirrors providing 5m width of view on the right of the vehicle
- Drivers must be experienced and gain a special certificate to show suitability for LHV driving.

For this reason, the authors carried out a risk assessment when developing recommendations for the future safe running of LHVs and identified that:

- The safety of using LHVs on roads other than those permitted in the trial remained a risk
- The trial requirements relating to driver experience and suitability should be maintained
- There was a risk in terms of there being sufficient “line up space” for the length of an LHV at intersections.
- The signs warning other road users of the length of the combination during the trial were difficult to understand.

Although the above studies have found little empirical evidence with relation to accident statistics and LHVs, more is available from the USA. The road network and operating conditions are very different in the USA compared with the UK so simply transferring results to a UK context can be misleading. However, as reported earlier in this section, Winkler *et al* (1993) found that if the property damage only rollover rate for double trailer vehicles could be reduced to that of single trailer vehicles then the total number of rollovers would more than halve. This research also suggested that doubles were statistically over involved in rollover accidents.

Carston (1987) found that overall there was no conclusive evidence of an overall difference in injury and fatal accident involvement rates of doubles and singles. However, he stated that this lack of difference in the overall statistics could possibly be hiding a genuine difference because doubles were more likely to be travelling on a safer road network (e.g. not in urban areas). He also found that there were strong indications that doubles had problems in property damage rollover accidents.

Fancher (1989) stated that most studies that had attempted to compare the involvement rates of single and double vehicles were based on limited data but cited research by the University of Michigan that had controlled for the different use of each vehicle type in terms of time of day and road type used. This research was said to have found a modest increase of 5%-10% in the involvement rate of double vehicles compared with singles.

The physical research described earlier in this appendix showed that some vehicle combinations exhibited greater levels of rearward amplification. Fancher and Campell (2002) linked rearward amplification to the statistical risk of involvement in different types of accident as shown below.

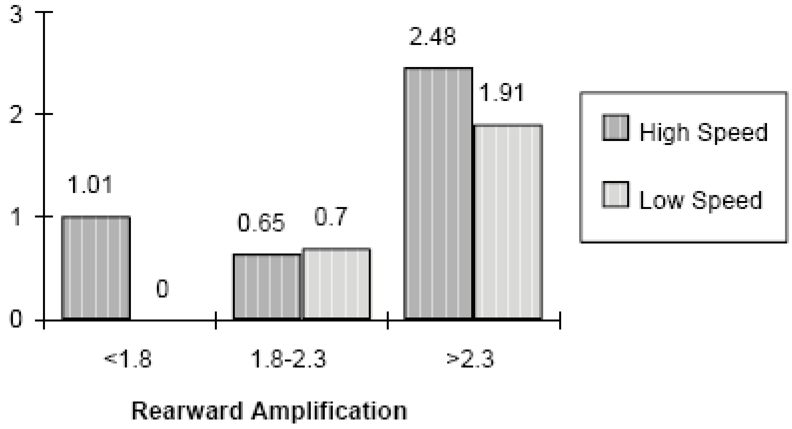


Figure 65. Relative risk of fatal single vehicle crash involvement by rearward amplification factor (5-axle double combination) (Fancher and Campbell, 2002)

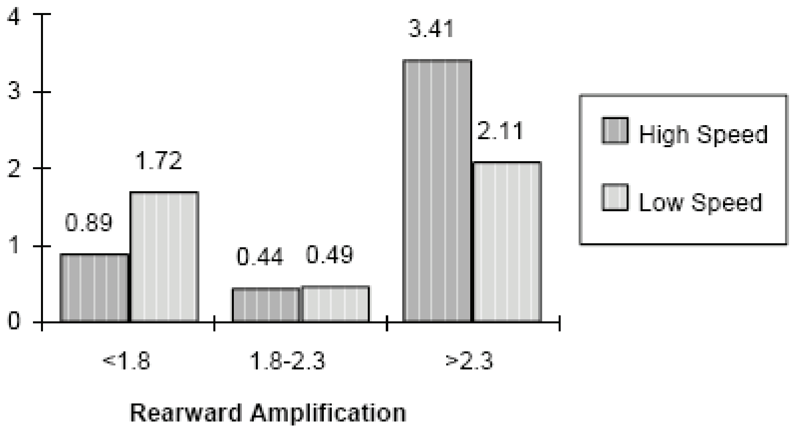


Figure 66. Relative risk of fatal rollover involvement by rearward amplification factor (5-axle double combination) (Fancher and Campbell, 2002)

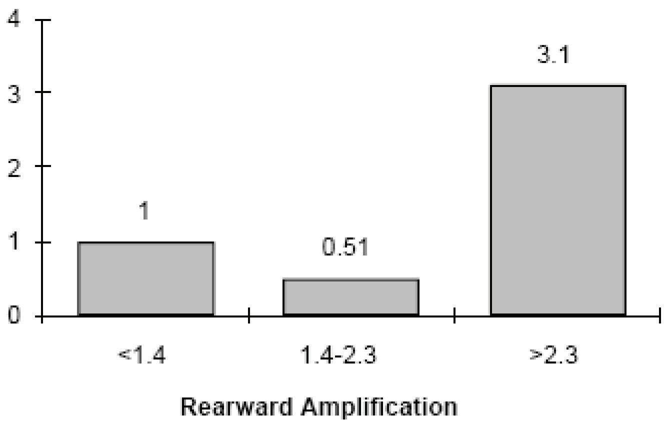


Figure 67. Relative risk of steering related (side swipe ramp or curve) involvement by rearward amplification factor (5-axle double combination) (Fancher and Campbell, 2002)

It can be seen that in all three accident types identified, all involving cornering of some sort, vehicles with a rearward amplification factor greater than 2.3 carried a substantially higher risk of involvement in fatal accidents than vehicles with a lower factor. Vehicles with higher rearward amplification could have a relative risk as much as three times higher.

Craft (1999) showed data on longer combination vehicles involved in fatal crashes in the USA. It was shown that during the period studied only 1.3% of the fatal crashes where a large truck (standard articulated tractor and trailer and bigger) actually involved a longer combination vehicle. This represented between 24 and 50 LHVs involved in fatal crashes per year compared with between 2,478 and 2,943 tractor semi-trailers. The report stated that LHVs accounted for approximately 2% of all "combination vehicle" traffic, (not defined more rigorously but could be assumed to mean articulated vehicles). Unfortunately, more detailed travel data was not available to produce an accident rate but the authors concluded that based on existing LHVs did not appear any more or less safe than other combination trucks but that more definitive conclusions would require additional data.

B.8.2 In-depth review of multi-fatal LHV accident in Finland

Throughout the literature and internet search, only one in-depth review of a specific accident involving an LHV was found. This was a multi-factor accident and many of the factors were not specific to the fact that it was an LHB but it was very severe and contained several elements strongly related to the LHV safety issues discussed elsewhere in this report so it was considered worthy of inclusion. In particular, the accident represents a graphic worst case illustration of the potential consequences of trailer instability and rearward amplification. This section of the report is based entirely on a published accident investigation report from this accident (Accident Investigation Board Finland, 2006).

The accident involved an LHV combination becoming unstable and the trailer stepping out of line with the truck towing it and entering the lane for oncoming traffic. The front of the trailer then collided head-on with an oncoming coach, killing 23 of the 37 people on board the coach.

The LHV involved in the accident consisted of a three axle rigid vehicle and a four axle "full" trailer. The trailer had fixed front and rear bogies, as shown in Figure 68 below. A full trailer of this type is effectively a semi-trailer being towed by a dolly, the main difference being that the dolly is permanently attached to the semi-trailer part such that it becomes one vehicle. The vehicle combination was, therefore, of an equivalent type to some 18.75m drawbar combinations in the UK where "full trailers" are used. However, the "full" trailer was considerably longer (13.6m) than would be permitted in the UK. The vehicle had a combined length of 24.98 m and a gross combined weight (GCW) of 64,105 kg. In Finland, the maximum permissible length for the combination is 25.25 m and the maximum permissible GCW for a LHV combination is 60,000 kg, therefore, the vehicle exceeded the GCW limit by 4,105 kg. The vehicle involved in the accident does not, therefore, match exactly any of the LHV options defined by this report but does approximate quite closely to option 3, the rigid A-dolly and semi-trailer combination at 60 tonnes.

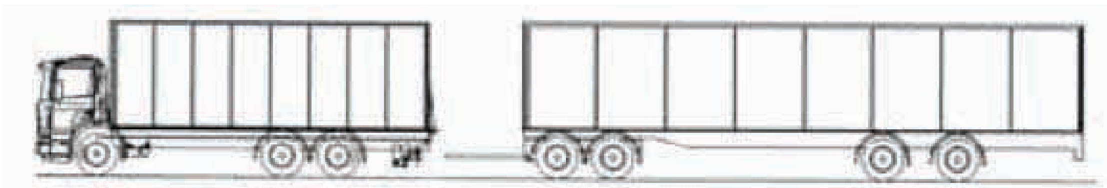


Figure 68. The type of vehicle involved in the accident.

The gross vehicle weight (GVW) of the coach involved in the accident was 18,000 kg and the permissible axle loads were 7,500 kg for the first axle and 11,500kg for the second axle. Neither the GVW nor the permissible axle loads were exceeded.

Moments before the accident occurred the driver of the LHV lost control and the rear trailer began to fishtail on the apex of a hill. As the LHV came down the hill, the rear end of the trailer veered onto the verge. The trailer then went back onto the road and the whole LHV combination drifted to the left. The driver tried to steer the vehicle back to the right, but the trailer continued to travel in the left hand lane. At the same time a coach was travelling in the opposite direction and the collision occurred between the rear trailer of the LHV and the coach (as shown in Figure 69). The evidence suggested that at the point of contact both vehicles were travelling at about 70 km/h.

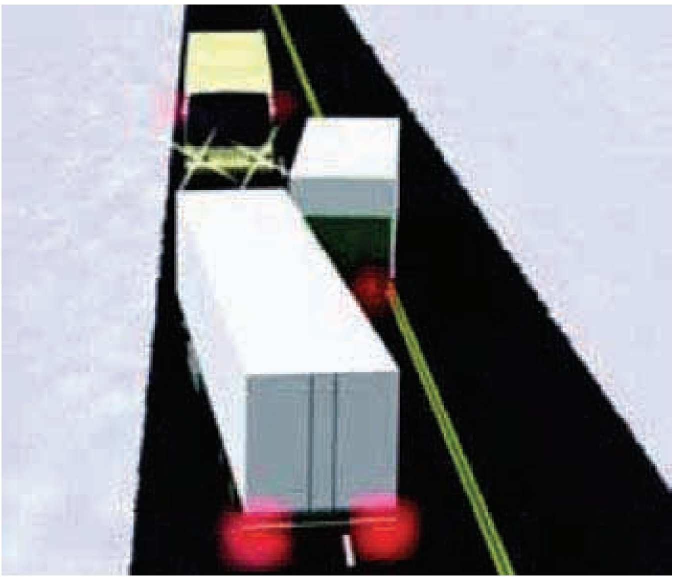


Figure 69. Simulated vehicle positions just prior to the point of collision.

The report states that the two key events that caused the collision between the LHV and the coach were the loss of control of the LHV when the trailer started fishtailing and the coach driver not noticing that the trailer of the oncoming LHV was fishtailing.

The accident investigation report indicated that the accident involved a range of contributory factors including

- An unexpectedly slippery road
- Exceeding the speed limits
- Exceeding drivers hours
- Overloaded vehicle

A simulation of the accident was carried out and demonstrated that the excessive load at the time of the collision destabilised the rear trailer compared to that of a load within the legal weight limits. During the simulation the rearward amplification of a legally loaded LHV combination was compared against one that had been loaded similarly to the LHV involved in the collision as well as to a standard tractor semi-trailer combination. It is shown in Figure 70 that the rearward amplification was higher in the LHV that was overloaded, thus offering lower stability compared to the same vehicle within the legal weight limits. However, it was also shown that the rearward amplification was much lower for a semi-trailer combination and that the difference between that and the legally loaded LHV was much greater than the difference as a result of the 7% overload.

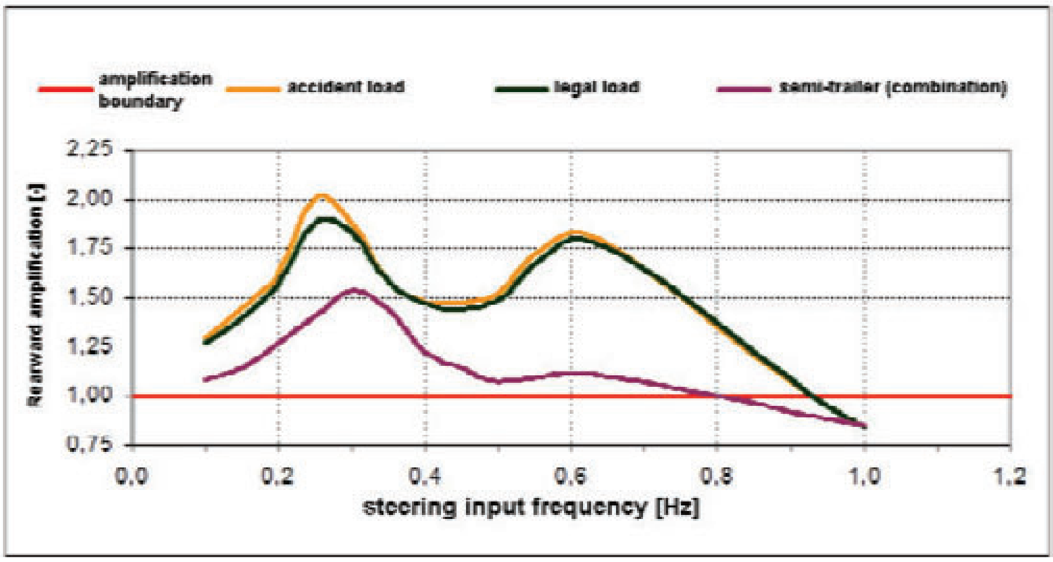


Figure 70- Effect of load on reward amplification.

At a steering input frequency of 0.25 Hz the maximum rearward amplification increased by 6.5% and at a steering input frequency of 0.6 Hz the maximum rearward amplification increased by 2.0%. The report states that such an increase in rearward amplification alone would not result in an accident. But the vehicle's rearward amplification would strengthen resulting in an increased risk of the driver losing control in unfavourable driving conditions, such as the day the collision occurred. It should be noted that some of the LHV options assessed in this report as well as some standard length drawbar combinations may well be expected to have substantially higher rearward amplification factors than that predicted for the combination involved in the Finnish accident.

Although rearward amplification and the presence of two points of articulation was clearly found to be a feature of the accident there was no conclusions in the report relating to whether the accident would still have occurred, or been as severe, if the truck involved conformed to the standard requirements of 96/53/EC. It seems unlikely that the same accident could have occurred with a standard 16.5m articulated vehicle but it is quite possible that a very similar accident could occur with an 18.75m drawbar combination using a "full" trailer. It is difficult to draw any firm conclusions from this single accident but it provides an indication that some of the features discussed earlier in this appendix can and do contribute to serious accidents with LHVs but that in fact some of these potential problems already exist within the current UK vehicle fleet.

B.8.3 Predictions of future accident involvement rates

In order to account for changes in the accident risks associated with the different vehicle options assessed in this report, while also considering the change in exposure to risk (vehicle kms driven), it was necessary to estimate accident rates per unit of distance driven for each of the vehicle types. This information was then combined with the estimates of distances driven by each vehicle option and information on the value of injury prevention included in the combined cost model in order to estimate the overall effects of potentially changed accident risk and changed exposure.

However, it is apparent that while there has been a great deal of research into the physical risks that might arise from the use of LHVs, if permitted, recent information on their involvement in accidents is scarce overall and almost non-existent in Europe. This limits the reliability of the analysis such that the figures provided represent the best estimate of the accident rate that is allowed within the current limitations of the data. In order to try to reflect this uncertainty in the estimates a range of methods were used.

B.8.3.1 Top down approach

The top down approach was to take data from existing accidents and to study the patterns at a high level and extrapolate them to estimate what they may be for LHVs. This involved linking the STATS 19 database to the enhanced data set available from the DVLA database. This process is not 100% reliable and a number of accidents do not have a corresponding enhanced data set. In addition to this, there are some issues of inaccurate data where a vehicle is recorded in one way in STATS 19 but in another way in the enhanced data such that there is a conflict and it is not known which classification is correct. This means that there was a relatively high number of "unknowns" in the data, which were accounted for by assuming that the distribution of accidents in the "unknown" data set was the same for the known data. In addition to this, dividing the numbers of casualties by the type of HGV involved in the accident means that adding the different numbers is no longer entirely valid because accidents where more than one HGV was involved will be counted more than once.

Data regarding the annual distance travelled by different vehicles was taken from two different sources. The first was from traffic census data, which allows a breakdown by road class, articulation and number of axles on the vehicle. This estimate includes the activity of foreign vehicles on UK roads but also includes the activity of large vehicles that do not carry goods (e.g. recovery vehicles, refuse collectors etc.) and is reported to include a degree of misclassification of goods vehicles of less than 3.5 tonnes GVW. The second source was the CSRGT, which collects information directly from a representative sample of UK hauliers. This information allows a breakdown by vehicle class and gross vehicle weight and also allows drawbar vehicle combinations to be separately identified (drawbars are included in "articulated" in the traffic census data). The CSRGT data produces a lower estimate of total distance than the traffic census, because it does not allow for the activity of foreign HGVs and does not suffer from the inclusion of light goods vehicles or heavy vehicles that are not goods vehicles.

The accident data was disaggregated to match the categories permitted by the exposure data and casualty rates per billion vehicle kms were derived. It should be noted that the various limitations discussed above do mean that several important assumptions had to be made and the analysis must be treated with a certain amount of caution. The CSRGT accident rates derived during this analysis produced estimates that were approximately 75% of those derived based on simple totals for STATS 19 without the link to the enhanced data and the detailed breakdowns of type. Where traffic census data was used the estimates were approximately 95% of the simple total. Accident data was also disaggregated into specific accident types to match some of the risks described by other research but the casualty numbers were divided by accident type, vehicle characteristics and road type they became too small for meaningful analysis.

Figure 71, below, shows the casualty rate per Billion Vehicle Kilometres (BVK) for different classes of vehicle, based on the CSRGT exposure data.

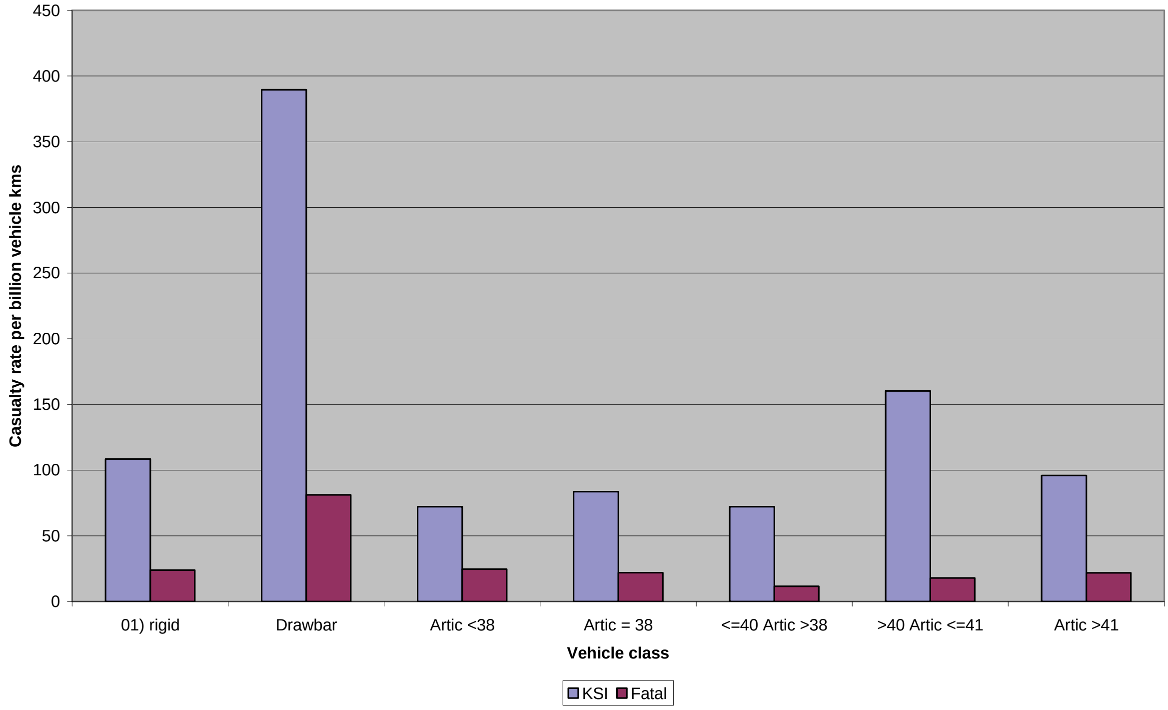


Figure 71. Casualty rates by vehicle and weight class (all roads)

Firstly, it can be seen that the casualty rate in accidents involving drawbar combinations for both fatal and Killed and Seriously Injured (KSI) casualties is more than three times that of most other vehicle categories. Some additional caution must be applied to results for drawbar combinations because both the accident and exposure samples are based on small data sets (30 fatalities, 144 KSI and 0.48 billion vehicle km compared with 107 fatalities, 470 KSI and 6.21 billion vehicle kms for articulated vehicles >41 tonnes), thus meaning increased error is possible. Despite this concern, the data clearly suggest that drawbar combinations are less safe than either rigid vehicles or tractor semi-trailer combinations and this is consistent with the other research citing existing drawbar combinations as some of the least stable in terms of rearward amplification. There is some variation in the rates for other vehicle categories, particularly those such as the 40/41 tonne articulated vehicles that also have low numbers, but no strong overall trend with respect to weight was found. This trend is studied in more detail, for articulated vehicles, in Figure 72, below.

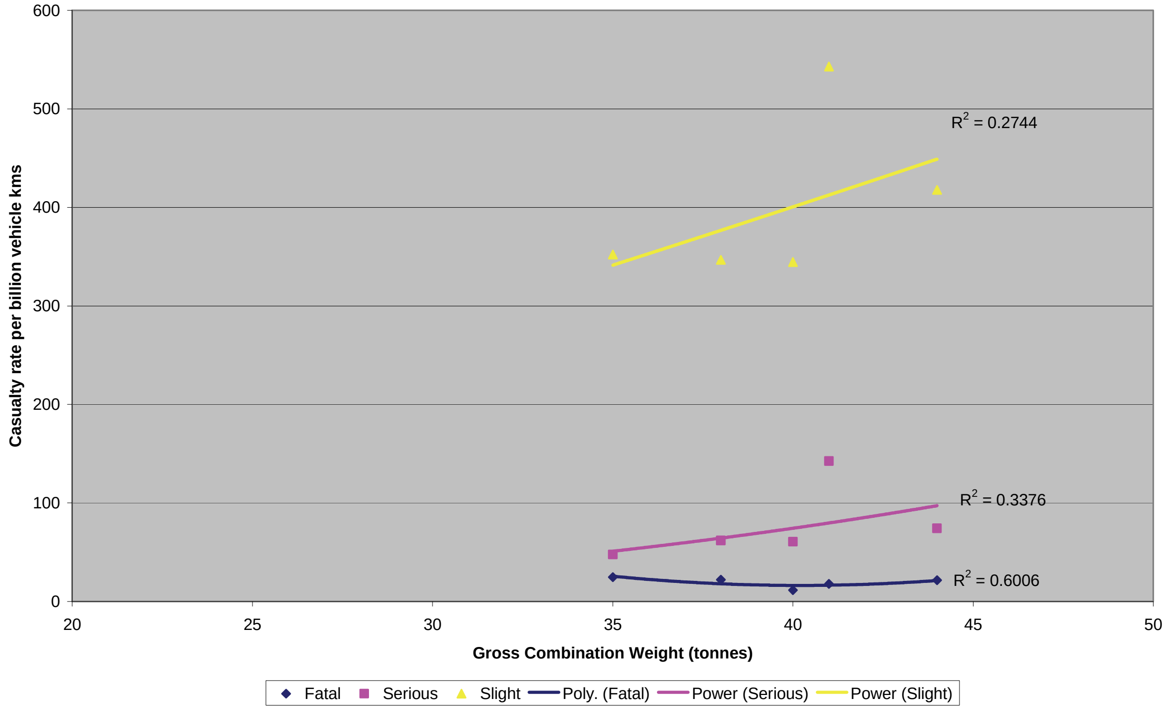


Figure 72. Articulated vehicle accident rate by severity and GVW

The trend line for fatality rate shows almost no dependence on GVW but there is a trend for serious and slight casualty rate to increase with GVW. However, the mathematical correlation for this relationship is weak.

The casualty rates from the traffic census data can be broken down by road class as well as type of vehicle and this is shown in Figure 73, below. Note that the exposure data for articulated vehicles with three or four axles is grouped together and cannot be separated. The accident data has been grouped the same way and the casualty rate has been expressed as single point for a vehicle with 3.5 axles.

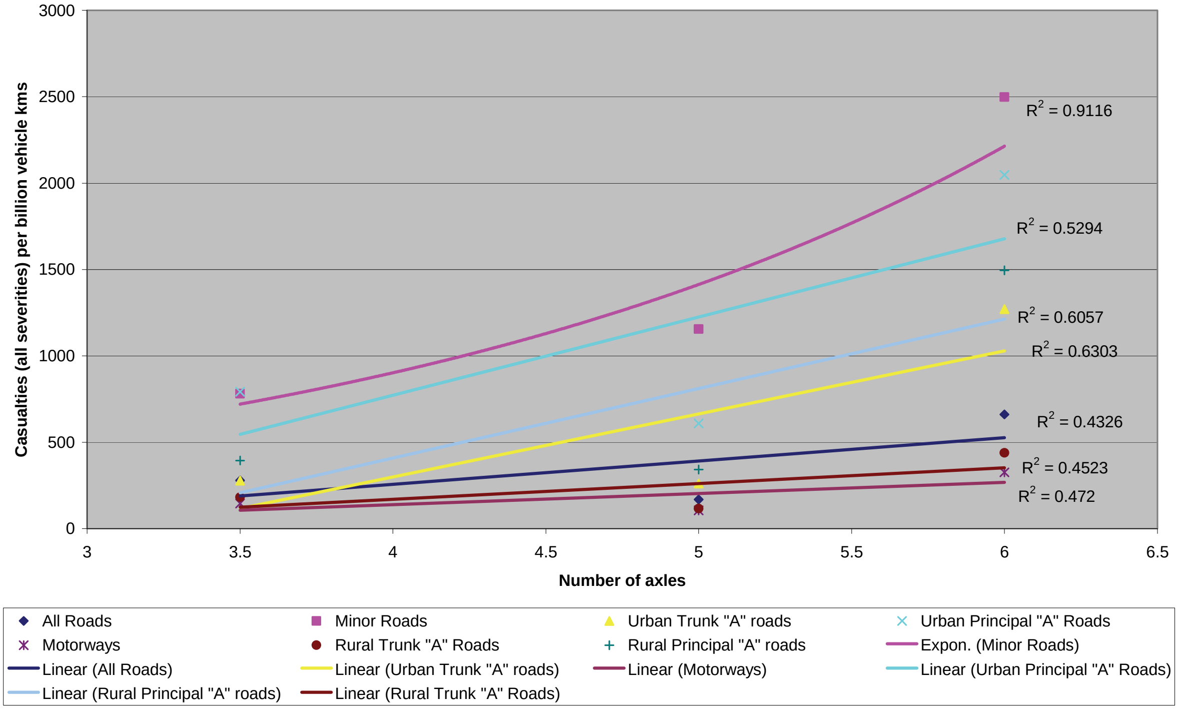


Figure 73. Casualty rates for articulated vehicles by number of axles and road class

It should be noted that dividing the data by road class does mean that for some classes of road the size of the sample is very small and not, therefore, likely to be statistically significant. For example, 6 axle articulated vehicles (where linked STATS 19 data was available) were involved in accidents resulting in just 102 casualties while travelling on urban trunk “A” roads and travelled just 0.08 billion vehicle kms on such roads. In addition to this, statistical correlations should be based on more than 3 data points in order to provide reliable conclusions, but these are the only data points available.

A number of very important conclusions could potentially be drawn from Figure 73. Firstly, the accident rate for goods vehicles generally varies considerably according to road class. Perhaps unsurprisingly, motorways have been shown to be the safest roads and minor roads have the highest casualty rate per billion vehicle km. By comparison, national statistics for accidents involving all types of vehicle (i.e. car, bus, goods etc.) show that urban “A” roads have a higher overall accident rate than minor roads, thus suggesting that some characteristic of HGVs separates the risk by type of road from that for other vehicles.

Another conclusion from this graph is that there is at least some correlation between accident rate and number of axles on all types of roads, casualty rate increasing with increased number of axles. It can also be seen that the rate of increase and the strength of the correlation is greater on the more dangerous roads. However, it is understood that the traffic census data is collected on the basis that vehicles are categorised according to the number of axles in use at the time the vehicle is observed. This means that a 6 axle articulated vehicle travelling with a light load with one retractable axle lifted from the ground will be classified as a 5 axle vehicle. In the DVLA data set used to link the accident data to vehicle characteristics the same vehicle would be classified as a 6 axle vehicle. This discrepancy means that the accident rate per vehicle km will be overestimated for vehicles with higher numbers of axles. This will at least partially explain the trend observed. It is not possible to quantify how much of the trend can be attributed to this phenomenon. However, not all HGVs are equipped with retractable axles and they should only be in the lifted position when the vehicle is unladen or very lightly laden so this may not explain all of the increase observed for 6 axle vehicles.

If these limitation are ignored then these trends can be extrapolated to estimate the rates expected for LHVs, assuming that no other feature other than number of axles influences the difference (see Figure

74). It should be noted that there were only three data points for each trend. A second order polynomial trend line did, therefore, always give a perfect correlation of one but did not really represent a realistic trend accounting for other variations in the data. The trend lines were, therefore, based on a linear relationship.

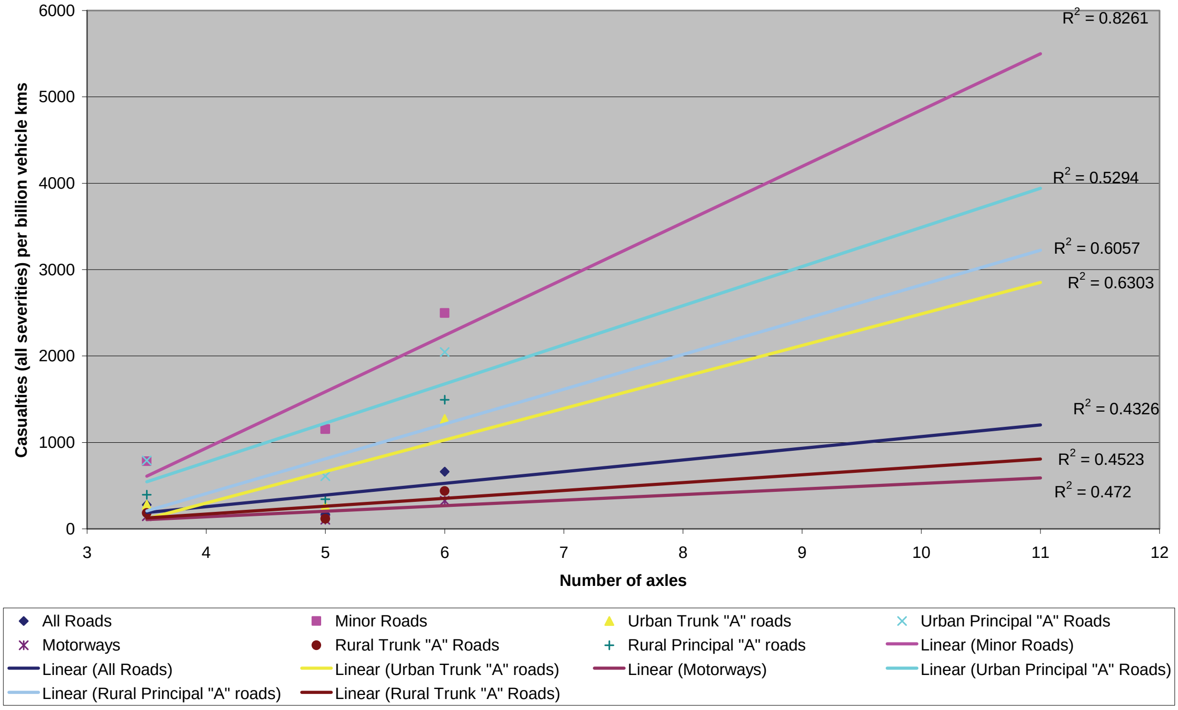


Figure 74. Extrapolated casualty rates for articulated vehicles by number of axles and road class

These graphs clearly suggest that there are three groups of roads that could be considered in terms of risks. Motorways and rural trunk “A” roads can be considered relatively low risk and the analysis suggests that the risk would approximately double for an 11 axle vehicle compared with a six axle vehicle. The results suggest that the risk for an eight axle vehicle would be approximately 1.35 times that for a six axle vehicle.

Urban trunk “A” roads and all principal “A” roads (urban and rural) could be considered to form a medium risk group. On these roads the increase in risk compared with a 6 axle vehicle would appear from this analysis to be a factor of between 2.3 and 2.8 for 11 axle vehicles and between 1.5 and 1.8 for eight axle vehicles.

Minor roads, defined as all “B”, “C” and unclassified roads whether rural or urban, can be considered a high risk group. Even if only the linear extrapolation is considered, the predicted increase in risk for an 11 axle vehicle is a factor of 2.5. If the exponential fit, with a higher correlation value, is considered then the risk for an 11 axle vehicle is increased by a factor of almost ten.

However, there is a strong risk that these increases are substantial over-estimates because of the limitation in the data with respect to retractable axles. Despite the limitations of the data and the caution with which the results must, therefore, be considered, the analysis does provide some consistent conclusions. Physical research has shown that current drawbar vehicles can have a higher rearward amplification factor than any of the potential LHV combinations being assessed. The accident statistics have suggested that the casualty rate per BVK for drawbars is approximately three times that of articulated vehicles and predictions based on number of axles have suggested that articulated vehicles with more axles will have casualty rates 1.35 to 2.8 times higher than standard articulated vehicles. Thus, if these predictions were correct then the casualty rates for standard articulated vehicles, LHVs and drawbars would quite closely follow their rearward amplification factors.

Although severely limited by the inconsistencies in the data sources and the low numbers, this analysis does clearly suggest that, if permitted at all, LHVs should not be allowed onto all areas of the road network. Ideally, from a safety point of view, their use would be restricted to motorways and rural trunk "A" roads.

B.8.3.2 Bottom up approach

The research literature identified four main risk areas where it might be expected that LHVs would present a higher accident risk than standard 6-axle articulated vehicles:

- Rollover and directional instability
- Manoeuvring
- Collisions with other heavy vehicles
- Braking

The bottom up approach was to calculate casualty rates for standard HGVs in accidents relevant to these specific circumstances and then to estimate an increase in that rate for each LHV type and recalculate an overall accident rate for the LHV given the specific increases. It should be noted that accidents relevant to the above issues form only a small proportion of all accidents and thus, the numbers quoted below are correspondingly small.

Based on a 2003 to 2005 average, 9 HGV occupants are killed in accidents involving articulated vehicle rollover each year, 73 are seriously injured and 312 are slightly injured. This translates to a casualty rate per billion vehicle kms of 0.65, 5.25 and 22.4 respectively.

A variety of American research reviewed in preceding sections suggested that double trailer combinations were at increased risk of involvement in rollover accidents and the physical research suggested that this was because of rearward amplification and related stability problems. Overall, Winkler *et al* (1993) estimated that the risk of rollover was approximately 80% higher with a double (predominantly "A" double combinations) than with a single. The analysis reported in B.8.3.1 suggested that drawbar combinations had an overall casualty rate of 300% of standard artics. If this relative accident rate is plotted against rearward amplification factors for standard articulated vehicles, "A" trains, and 18.75m drawbars then Figure 75 shows that there is a very strong linear correlation. It should be noted that the rearward amplification for drawbar combinations was calculated as a simple mean of the values quoted by Aurell (2003) for rigid towing full trailer and rigid towing centre axle trailer.

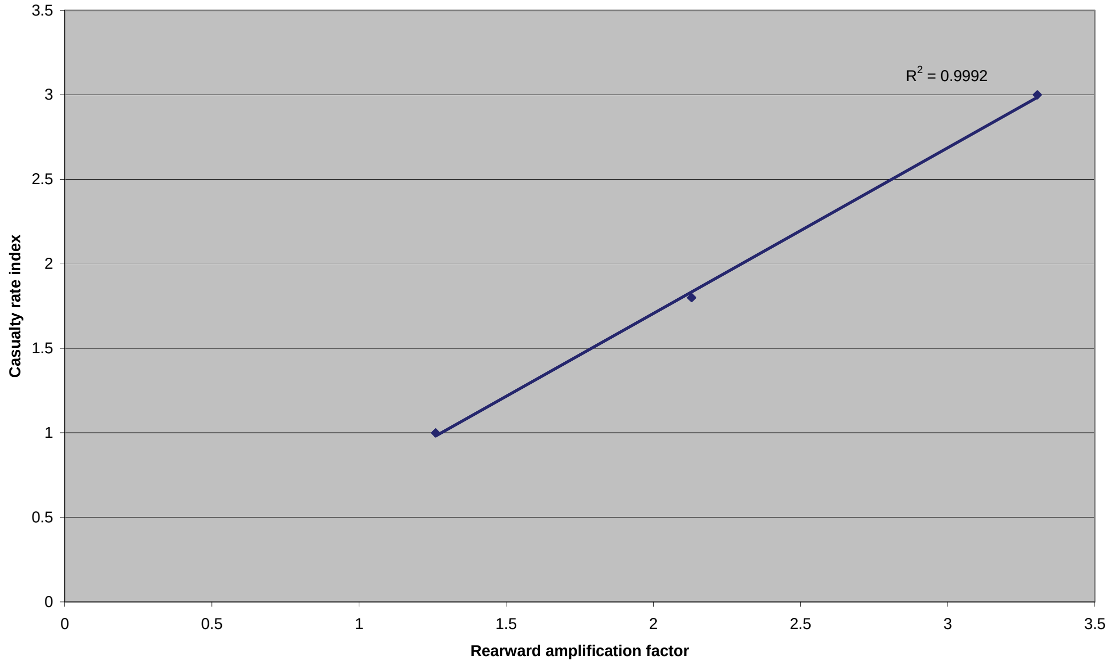


Figure 75. Correlation of rearward amplification and casualty rate

It does, therefore, seem reasonable to use interpolation of this data to produce the estimates of rollover rates shown in Table 57, below. However, rearward amplification is not the only factor influencing the likelihood of rollover. Static stability factors have also been shown to have a strong relationship to the frequency of rollover. Each of the LHV options was assumed to be limited to a height of 4m in line with Directive 96/53 with the exception of the double decked vehicle. Double decked vehicles are relatively unique to the UK and can have heights of up to approximately 4.9 metres and do, therefore, tend to have a considerably higher centre of gravity than single deck vehicles carrying the same density of product. If all other parameters remain the same then this means that they will have a lower static stability factor. It has been assumed that this reduction will lead to an increase in the casualty rate for this vehicle type only of 10%. If the centre of gravity of a vehicle and the height it is loaded to stay the same but the total mass of the load carried increases, this will also reduce the static stability factor of a vehicle. Therefore, the casualty rate index for LHVs with two weight options has been adjusted to account for the variations in static stability such that their rate is ±5% of the rate predicted by the rearward amplification value.

Table 57. Estimated rollover rate based on rearward amplification, static stability factor and accident rates

Vehicle option	Approx RA factor	Casualty rate index	Casualty rate per BVK		
			Fatal	Serious	Slight
Candidate vehicles					
Standard articulated	1.26	1.00	0.65	5.25	22.40
Double decked	1.26	1.10	0.72	5.78	24.64
Rigid/A/Semi 44	1.77	1.35	0.88	7.09	30.24
Rigid/A/Semi 60	1.77	1.45	0.94	7.61	32.48
Tractor/Semi/C/Semi	1.48	1.17	0.76	6.17	26.31
B-Double 44	1.55	1.18	0.77	6.20	26.43
B-Double 60	1.55	1.28	0.83	6.72	28.67
Longer semi	1.26	1.00	0.65	5.25	22.40
Reference vehicles					
Tractor/Semi/A/Semi	2.13	1.80	1.17	9.45	40.32
18.75m drawbar	3.31	3.00	1.95	15.75	67.20

Note: White fields are real data or assumptions described above. Shaded cells are calculated from white cells.

The values used in Table 57 are based on travel on all road categories. However, a large number of rollovers are known to occur at medium to large roundabouts on main routes and on motorway slip roads. For this reason, it has been assumed that these estimates will be valid regardless of road access restrictions.

STATS 19 data also records information on “contributory factors” and one such factor is “loss of control”. This field is subjectively coded in the STATS 19 database by the attending Police officer and it is not known in exactly what circumstances it is coded. However, it is likely to include cases of rollover and directional instability and may well include some cases of skidding in a straight line. According to the data, articulated vehicles were associated with a loss of control in accidents resulting in 35 fatalities, 80 serious injuries, and 350 slight injuries. If the definition includes rollover accidents then it seems likely that rollover accounts for the majority of these cases. Although it is possible that rearward amplification and/or braking issues could result in a further increase in casualty rate in this category the data is not sufficiently well defined to produce additional estimates with confidence and the effect is likely to be very small.

Based on STATS 19 data for 2005 it has been possible to define a total scope of accidents that could potentially be related to vehicle manoeuvring and field of view. This has involved selecting accidents on certain types of road in conjunction with certain kinds of pre-impact manoeuvre. These have been defined as accidents where the pre-impact manoeuvre was changing lane, turning left or right, starting or reversing. In total it was estimated that articulated vehicles were involved in accidents resulting in 12 fatalities, 62 serious injuries, and 556 slight injuries. This translates to casualty rates of 0.86, 4.46, and 40 respectively.

TRL is not aware of any research that has quantified the number of accidents caused by HGV manoeuvrability problems and, in particular, none that has assessed the effects of manoeuvrability that falls outside of the current minimum standards and turning circles. Smith *et al* (2003) assessed the effect of increased rear outswing of longer 15 metre buses on the likely risk of accidents and concluded that there would be a small overall increase in risk as a result of a relatively large increase in risk in a very narrow and specific set of circumstances. Overall it was suggested that the number of fatalities per year would increase by approximately 0.5 to 5.5 per year. DfT publications show that buses were involved in 108 fatal accidents in 2005 so the increase would be approximately 0.5% to 5%.

The analysis of HGV manoeuvrability reported earlier suggests that rear outswing is less likely to be a problem for LHVs and it is an increase in the off-tracking that will be important. The increases discussed result in a greater increase in the swept path of the vehicle than considered by Smith *et al* (2003) so it seems likely that the effects may be greater.

In the absence of any firm data on this risk, the following assumptions have been made:

- Vehicle combinations capable of meeting the turning circles in 96/53/EC and 97/27/EC will not suffer an increased risk in relation to manoeuvring
- The use of steering axles on B Doubles and longer semi-trailers will not introduce new adverse risks (i.e. it is assumed that potential high speed stability problems will be eliminated by locking the steering mechanisms at higher speed)
- Field of view issues identified with respect to blind spots at the coupling points for the second trailer will result in a very small increase in overall risk of accidents of 0.1%.
- Longer semi-trailer options will not suffer from these field of view problems.
- Vehicle combinations found to have manoeuvrability falling outside of the turning circles have been assumed to have an increased risk of 1% to 10% (double that found for buses by Smith *et al*, 2003), assuming that they are permitted to travel on all roads. The mean figure of 5.5% will be used in the analysis
- If road access is restricted to motorways only the increase in risk will be reduced by a factor of ten. If restricted to motorways and rural trunk “A” roads it will be reduced by a factor of

eight, all rural “A” roads a factor of 5 and all “A” roads, it will be reduced by a factor of two.

These assumptions have been combined with the data on casualty rates from accidents deemed to be potentially affected by manoeuvrability and field of view issues and result in the predicted casualty rates shown in Table 58.

Table 58. Predicted manoeuvrability and field of view casualty rates

Road Access Restriction	Casualty Severity	Standard articulated	Double decked	Longer semi		Rigid/A/Semi 44	B-Double 44		Rigid/A/Semi 60	B-Double 60		Tractor/Semi/C/Semi
				Non-steered axles	Steered axles		Non-steered axles	Steered axles		Non-steered axles	Steered axles	
Motorways only	Fatal	0.127	0.127	0.128	0.127	0.128	0.128	0.127	0.128	0.128	0.127	0.128
	Serious	0.635	0.635	0.638	0.635	0.639	0.639	0.636	0.639	0.639	0.636	0.639
	Slight	19.568	19.568	19.676	19.568	19.695	19.695	19.588	19.695	19.695	19.588	19.695
Motorways and Rural trunk "A"	Fatal	0.181	0.181	0.182	0.181	0.182	0.182	0.181	0.182	0.182	0.181	0.182
	Serious	1.629	1.629	1.638	1.629	1.640	1.640	1.631	1.640	1.640	1.631	1.640
	Slight	20.540	20.540	20.653	20.540	20.684	20.684	20.561	20.684	20.684	20.561	20.684
Motorways and any rural "A"	Fatal	0.316	0.316	0.317	0.316	0.319	0.319	0.316	0.319	0.319	0.316	0.319
	Serious	2.762	2.762	2.777	2.762	2.793	2.793	2.765	2.793	2.793	2.765	2.793
	Slight	26.000	26.000	26.143	26.000	26.291	26.291	26.026	26.291	26.291	26.026	26.291
Motorways and any "A" road	Fatal	0.520	0.520	0.534	0.520	0.534	0.534	0.520	0.534	0.534	0.520	0.534
	Serious	3.341	3.341	3.433	3.341	3.434	3.434	3.344	3.434	3.434	3.344	3.434
	Slight	35.338	35.338	36.310	35.338	36.327	36.327	35.373	36.327	36.327	35.373	36.327
Any road	Fatal	0.886	0.886	0.935	0.886	0.936	0.936	0.887	0.936	0.936	0.887	0.936
	Serious	4.460	4.460	4.706	4.460	4.710	4.710	4.465	4.710	4.710	4.465	4.710
	Slight	40.000	40.000	42.200	40.000	42.240	42.240	40.040	42.240	42.240	40.040	42.240

The research reported earlier did not consider that increased mass of a HGV would have an effect on the severity of collisions between the goods vehicle and cars, motorcycles, bicycles and pedestrians. However, it was highlighted that where a heavier goods vehicle collided with another heavy vehicle or a rigid fixed object, the increased mass would mean increased energy and would place greater demands on the structural crashworthiness of the cab, thus increasing the risk of injury for the cab occupant(s).

Analysis of STATS 19 data (2005) relating to articulated vehicle occupants injured in collisions with other HGVs, rigid fixed objects and buses suggests that 27 (12%) were killed, 120 (52%) were seriously injured and 84 (36%) were slightly injured. This produces casualty rates per BVK of 1.94, 8.63 and 6.04 respectively. The additional weight has been assumed not to affect accident frequency only injury severity, such that its affect would be to change the distribution of fatal, serious and slight casualties but not affect the total number of all casualties. If the risk of being killed is assumed to be directly proportional to the increased energy associated with a heavier vehicle then for a 60 tonne vehicle the rates would become 2.65 fatalities per BVK, 8.63 serious injuries per BVK and 5.38 slight injuries per BVK. The equivalent for an 82 tonne vehicle would be 3.53, 8.63 and 3.32 respectively. Again, a large proportion of this type of accident does occur on motorways and major roads so the accident rates have not been divided by road type

One potential risk highlighted during discussions with stakeholders was that of increased time to overtake. However, the research reviewed on this was not conclusive, although there was suggestions that the time was increased, and no data quantifying the effect on accident statistics could be found. The same was true of the risks associated with longer vehicles obstructing junctions. These can only be considered as unquantified risks during the final analysis and would need to be considered as part of further research if it is decided that there is sufficient evidence to take the possibility of permitting LHVs further.

Combining the changes in risks for those situations highlighted by the research that could be quantified produces the estimates of risk shown in Table 59, below.

Table 59. Bottom up estimates of casualty rates for each vehicle type (access to all roads)

Vehicle Option	New predicted total casualty rates (All Roads)			Percentage increase (All roads)		
	Fatal	Serious	Slight	Fatal	Serious	Slight
All current articulated vehicles	17.63	53.68	308.94	0.00%	0.00%	0.00%
Double decked	17.70	54.21	311.18	0.37%	0.98%	0.73%
Longer semi steer	17.63	53.68	308.94	0.00%	0.00%	0.00%
Longer semi non steer	17.68	53.93	311.14	0.28%	0.46%	0.71%
Rigid/A/Semi 44	17.91	55.77	319.02	1.57%	3.89%	3.26%
B-double 44 steer	17.75	54.63	313.01	0.67%	1.77%	1.32%
B-double 44 non steer	17.80	54.87	315.21	0.95%	2.23%	2.03%
B-double 60 non steer	18.57	55.40	314.59	5.34%	3.20%	1.83%
B-double 60 steer	18.52	55.15	314.59	5.06%	2.75%	1.83%
Rigid/A/Semi 60	18.68	56.29	320.60	5.97%	4.87%	3.77%
Tractor/Semi/C/Semi	19.38	54.85	312.37	9.94%	2.17%	1.11%

The following tables show the same predictions based on restriction to different groups of roads.

Table 60. Casualty rate predictions for motorway only

Vehicle Option	New predicted total casualty rates (Motorways only)			Percentage increase (Motorways only)		
	Fatal	Serious	Slight	Fatal	Serious	Slight
All current articulated vehicles	9.551	23.347	161.309	0.000%	0.000%	0.000%
Double decked	9.616	23.872	163.549	0.681%	2.249%	1.389%
Longer semi steer	9.551	23.347	161.309	0.000%	0.000%	0.000%
Longer semi non steer	9.552	23.351	161.417	0.007%	0.015%	0.067%
Rigid/A/Semi 44	9.780	25.189	169.276	2.391%	7.888%	4.939%
B-double 44 steer	9.668	24.293	165.361	1.226%	4.050%	2.512%
B-double 44 non steer	9.669	24.297	165.468	1.234%	4.065%	2.578%
B-double 60 non steer	10.444	24.822	167.048	9.348%	6.314%	3.558%
B-double 60 steer	10.443	24.818	166.941	9.340%	6.299%	3.491%
Rigid/A/Semi 60	10.555	25.714	170.856	10.505%	10.137%	5.919%
Tractor/Semi/C/Semi	11.256	24.268	162.628	17.844%	3.944%	0.817%

Table 61. Casualty rate predictions for motorway and rural trunk "A" roads

Vehicle Option	New predicted total casualty rates (Motorways and rural trunk "A" roads)			Percentage increase (Motorways and rural trunk "A" roads)		
	Fatal	Serious	Slight	Fatal	Serious	Slight
All current articulated vehicles	11.338	28.092	174.598	0.000%	0.000%	0.000%
Double decked	11.403	28.617	176.838	0.573%	1.869%	1.283%
Longer semi steer	11.338	28.092	174.598	0.000%	0.000%	0.000%
Longer semi non steer	11.339	28.101	174.711	0.009%	0.032%	0.065%
Rigid/A/Semi 44	11.566	29.941	182.582	2.018%	6.582%	4.573%
B-double 44 steer	11.455	29.039	178.651	1.034%	3.370%	2.321%
B-double 44 non steer	11.456	29.048	178.774	1.043%	3.405%	2.392%
B-double 60 non steer	12.231	29.573	180.354	7.879%	5.273%	3.297%
B-double 60 steer	12.230	29.564	180.231	7.869%	5.239%	3.226%
Rigid/A/Semi 60	12.341	30.466	184.162	8.853%	8.450%	5.478%
Tractor/Semi/C/Semi	13.042	29.020	175.933	15.036%	3.304%	0.765%

Table 62. Casualty rate predictions for motorways and all rural "A" roads

Vehicle Option	New predicted total casualty rates (Motorways and all rural "A" roads)			Percentage increase (Motorways and all rural "A" roads)		
	Fatal	Serious	Slight	Fatal	Serious	Slight
All current articulated vehicles	14.612	43.836	233.355	0.000%	0.000%	0.000%
Double decked	14.677	44.361	235.595	0.445%	1.198%	0.960%
Longer semi steer	14.612	43.836	233.355	0.000%	0.000%	0.000%
Longer semi non steer	14.614	43.852	233.498	0.012%	0.035%	0.061%
Rigid/A/Semi 44	14.843	45.705	241.486	1.581%	4.262%	3.484%
B-double 44 steer	14.729	44.784	237.413	0.803%	2.162%	1.739%
B-double 44 non steer	14.733	44.812	237.678	0.825%	2.226%	1.853%
B-double 60 non steer	15.508	45.337	239.258	6.129%	3.424%	2.530%
B-double 60 steer	15.504	45.309	238.993	6.107%	3.360%	2.416%
Rigid/A/Semi 60	15.618	46.230	243.066	6.885%	5.460%	4.162%
Tractor/Semi/C/Semi	16.319	44.784	234.837	11.682%	2.162%	0.635%

Table 63. Casualty rates for motorways and all "A" roads

Vehicle Option	New predicted total casualty rates (Motorways and all "A" roads)			Percentage increase (Motorways and all "A" roads)		
	Fatal	Serious	Slight	Fatal	Serious	Slight
All current articulated vehicles	15.294	47.743	276.127	0.00%	0.00%	0.00%
Double decked	15.359	48.268	278.367	0.42%	1.10%	0.81%
Longer semi steer	15.294	47.743	276.127	0.00%	0.00%	0.00%
Longer semi non steer	15.309	47.835	277.098	0.09%	0.19%	0.35%
Rigid/A/Semi 44	15.536	49.674	284.956	1.58%	4.04%	3.20%
B-double 44 steer	15.412	48.692	280.194	0.77%	1.99%	1.47%
B-double 44 non steer	15.426	48.782	281.148	0.86%	2.18%	1.82%
B-double 60 non steer	16.201	49.307	282.728	5.93%	3.27%	2.39%
B-double 60 steer	16.187	49.217	281.774	5.84%	3.09%	2.05%
Rigid/A/Semi 60	16.311	50.199	286.536	6.65%	5.14%	3.77%
Tractor/Semi/C/Semi	17.012	48.754	278.307	11.23%	2.12%	0.79%

B.8.4 Potential safety countermeasures

The preceding analysis has shown that there is evidence to suggest that LHVs can have higher casualty rates per unit of distance driven than conventional articulated vehicles. However, it is important to note that it is possible to control and reduce the risks through safety interventions or countermeasures. Figure 76 shows the trend in the killed and seriously injured accident rate for HGVs, buses and coaches and light commercial vehicles (LCVs).

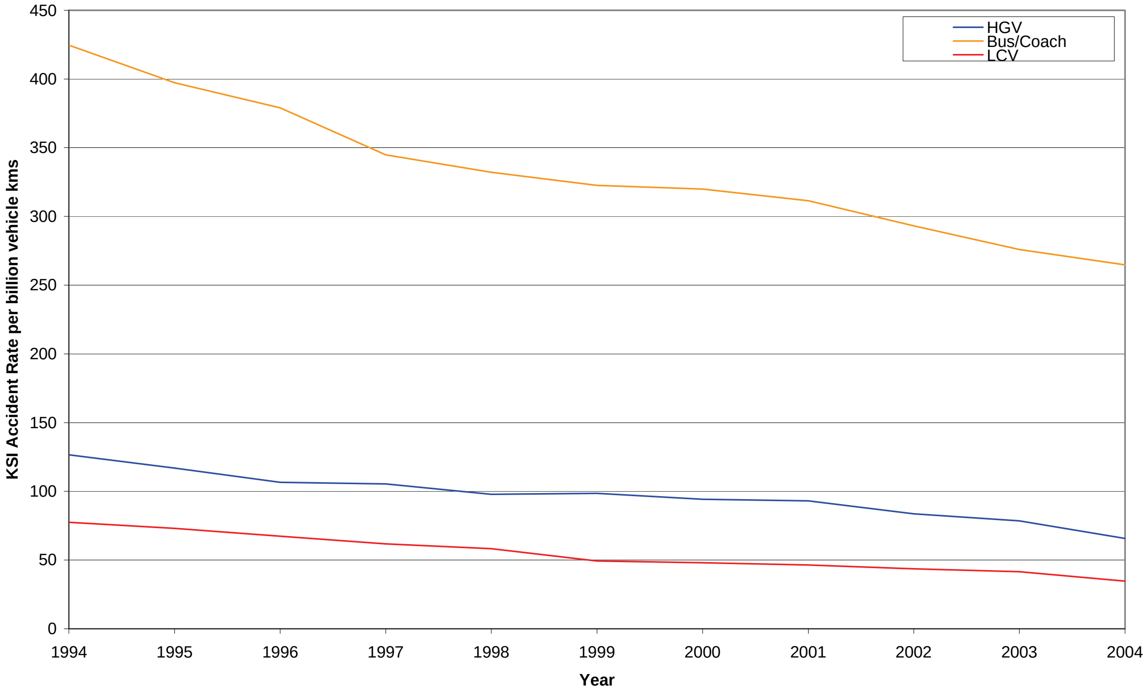


Figure 76. Trend for KSI accident rate

It can be seen that the accident rate per billion vehicle km for HGVs has been reducing steadily over the ten year period studied and this is despite the increase in maximum weights that took place between 1999 and 2001. The same is true for buses and coaches where the accident rate continues to decline despite the increase to a maximum length of 15 metres. This strongly suggests that at least some of the many safety initiatives that were introduced in this time period , for example reduced drink driving, introduction of ABS, seat belts, EBS, stability controls etc, have been effective and can have a greater effect than increases to the size and weight of vehicles.

The research literature identified three main risk areas where it might be expected that LHVs would present a higher accident risk than standard 6-axle articulated vehicles:

- Rollover and directional instability
- Manoeuvring
- Collisions with other heavy vehicles
- Braking

In terms of measures to prevent rollover and directional instability there has been considerable research to show that Electronic Stability Controls can be very effective. These stability controls can fall into two categories:

- Roll stability control
- Directional stability controls.

The current state of the art suggests that for articulated vehicles, roll stability control may be more effective when it is fitted to the trailer because that is where rollover is almost always initiated. For ordinary articulated vehicles directional stability control would only be of use in preventing trailer swing and this is a rare phenomenon in the UK. Directional stability control fitted to the towing vehicle of an articulated combination will help to prevent both jacknife and simple understeer problems. The UNECE Group of Rapporteurs on running gear and brakes (GRRF) are currently debating amendments to Regulation 13 to define technical provisions for both rollover and directional stability controls. There has also been a proposal to make such controls mandatory for all heavy vehicles (M2, M3, N2, N3, O3 and O4) (GRRF, 2007) although no decision has been taken on this at the time of writing.

Electronic stability controls do, therefore, have considerable potential to limit the additional rollover problems expected if LHVs were to be permitted. However, it is important to note that the proposal to mandate stability controls on heavy vehicles aims to mandate both rollover and directional stability control for towing vehicles but only rollover control for trailers. This is because the current technological state of the art means that directional stability control for trailers is not yet available. The main reason for this is likely to be that its function requires an accurate assessment of the path that the driver intends to take. For tow vehicles this is taken from a sensor on the steering wheel but it is much more difficult to measure this parameter on a trailer because there is no driver or steering wheel. This means that current generation stability controls cannot prevent the directional instability suffered by “full” trailers in particular as exemplified by the very severe fatal accident suffered in Finland and reported in section B.8.2 above. The increased risk associated with instability and rollover of LHVs can, therefore, be substantially reduced by the use of this technology but cannot be eliminated. However, it is also important to note that short wheelbase “full” trailers are already permitted and in use in the UK and the difficulties with directional control apply at least equally to these.

As shown by the analysis in the preceding section, there are two key measures to reduce the risk associated with manoeuvring. These are to limit the class of road on which LHVs would be permitted to travel if they were introduced and to use steering axles to improve the off-tracking and limit the swept path. The only additional (i.e. over and above those suffered by standard articulated vehicles) field of view issues identified by the research related to the blind spots in the areas around the articulation points of LHV combinations. These could potentially be resolved by the use of cameras strategically placed at the rear of the tow vehicle or first trailer. However, two concerns remain. Firstly, there has been little research to quantify the in-service effectiveness of cameras as a field of view aid for anything other than reversing and the driver already has to monitor as many as six mirrors while manoeuvring. Secondly, there may be practical constraints on the location at which cameras can be mounted. On a standard box bodied or curtainsided vehicle it will be relatively straightforward to mount a camera high up that can view the area around the axles. However, on a flat bed vehicle or a skeletal trailer for carrying ISO containers the potential mounting points and resultant field of view from the camera may be much more limited. It may be that advanced vulnerable road user sensors that are under development and in early production could be used more effectively than cameras to help solve this potential problem.

Providing additional countermeasures to protect LHV occupants when they collide with other heavy vehicles is more difficult. There are currently no compulsory EC requirements for cab strength or crashworthiness of trucks. There is a voluntary UNECE regulation and a Swedish national regulation but these will have been designed with current weights in mind and some commentators claim that the standards are not adequate for current vehicles. However, a first step might be to require that only trucks meeting one of these regulations could be used in an LHV combination.

One of the major factors involved in truck occupant fatalities remains the fact that seat belt wearing rates are still relatively low overall despite the fact that some haulage companies have policies that make failure to wear a seat belt a dismissable offence. It is possible that using a system whereby only companies demonstrating best practice with excellent safety records and procedures such as this can operate LHV combinations (although from a regulatory point of view this could be difficult to implement, as discussed in Appendix E) would have the effect that belt wearing rates were higher in LHVs than in other HGV types. This would substantially help to reduce the risk to occupants. In addition to this, seat belt warnings and/or interlocks could be fitted to vehicles to encourage greater seat belt use. In theory, the interlock would prevent the vehicle from driving away if the seatbelt was not fastened. In practice it has been found that persistent offenders can get around the system by fastening the seatbelt permanently and then sitting on top of the belt or by obtaining a spare belt buckle and clipping it into the fastener permanently, so it would not be expected to be 100% effective.

Potentially, the most substantial measure to protect the LHV occupants and the occupants of other vehicles they may be in collision with would be to require that only tow vehicles equipped with a Collision Mitigation Braking System (CMBS) could be used in an LHV combination. These systems have only recently become available and remain available on only a few truck models, usually as an optional extra. They employ forward looking sensors based on those for adaptive cruise control to track other vehicles and obstacles and to calculate the probability of a collision. When the system considers that the probability of a collision is getting high it takes action to warn the driver. When the collision has become inevitable hard braking is automatically applied to reduce the collision speed. Research by Grover *et al* (2007) has suggested that between 25% and 75% of all fatalities from front to rear shunt accidents involving an impact to a heavy vehicle front could be prevented by such a system. Riebeck (2006) states that a distance radar must be a compulsory feature of “innovative” trucks in order to avoid or mitigate this type of collision.

There would be a substantial difficulty with requiring LHVs to be fitted with CMBS. This is because it is such a new system that very few vehicles in the current fleet will be fitted with it such that, if LHVs were to be permitted in the immediate future, the availability of CMBS would substantially limit the potential take up of vehicles. In addition to this, there are not yet many formal definitions of what constitutes a CMBS and no technical requirements or minimum standards for them. A Japanese guideline is in existence and an ISO standard is expected soon.

Many of the research papers considering the performance of braking systems were written in the 1980’s. This research related, or was considered likely to relate, to vehicles that were not fitted with ABS and possibly not fitted with load sensing and brake apportioning valves. It is likely, therefore, that those risks are no longer relevant to modern vehicles capable of use in an LHV combination because these have been fitted with ABS as standard since 1991. Despite this, a requirement that all individual units forming part of an LHV combination must have ABS should be maintained. Some heavy vehicles, particularly trailers, have a very long lifespan so it is highly likely that a number of vehicles not equipped with ABS are still in circulation and it would be undesirable to use these as part of an LHV.

One of the more relevent research concerns was with the reaction time of the brake system. Pneumatic braking systems rely on air pressure waves travelling the length of the vehicle in order to apply the brakes. Even with current articulated vehicles a substantial amount of time can pass before full braking is available at the axle furthest from the driver. The research suggested that with a longer vehicle this time would inevitably increase with a consequence of extended stopping distances, although mean fully developed deceleration should not be affected. However, systems have been developed to try to counter this problem with current vehicles. Electronically controlled braking systems (EBS) carry the signal from the brake pedal to the pneumatic distribution valve electronically and thus, almost instantaneously. Air pressure is still used to physically apply the brake force but because this air is stored relatively locally to the axle, the overall reaction time is considerably reduced. These conclusions were supported by testing carried out by Knight *et al* (2002). With this type of system it is considered that an increased vehicle length would have a negligible affect on the reaction time of the brakes. In addition to this, EBS can offer additional functionality in terms of ensuring balanced braking between tractors and trailer and in terms of fault warnings and diagnostics.

In countries such as Australia, specific safety systems have not been prescribed. However, performance based standards have been introduced and adding safety systems such as ESC would be expected to help vehicles to meet some of those standards. If the performance levels required do not change as safety technology develops this may help to make less stable vehicles meet the tighter requirements for access to lesser roads rather than to increase the level of safety. Provided the new technology was still fitted to all vehicles this would still be likely to represent an improvement in the level of safety.

In the Netherlands trials of LHVs, vehicles were required to be equipped with special markings to highlight risks of overtaking and were also required to be fitted with a variety of vehicle equipment, including that listed below:

- ABS braking system operating on all axles of the combination
- Spray suppression on all axles
- Enclosed panel sideguards
- The tow vehicle is equipped with front underrun protection

Most of these requirements are now compulsory for new standard vehicles but may be required to ensure older vehicles do not get coupled in an LHV combination.

No material was identified that suggested that Finland or Sweden required any specific vehicle safety features over and above the requirements for the component vehicles, although road access restrictions do exist as well as winter speed limits.

B.9 Discussion

A range of views have been identified in the research, including some that conclude longer heavier vehicle combinations have no inherent increase in safety risk and will, therefore, reduce the number of accidents through improved efficiency and reduced exposure to risk (fewer vehicle kms travelled in total). However, most of the research would support the view that longer, heavier combinations will present a higher risk per unit of distance travelled and that the magnitude of the increase will depend strongly on on the characteristics of the particular vehicle combinations in question, such as weight, wheelbase, number of axles/articulation points etc. as well as the types of roads on which they are driven. This may still represent either an increase or decrease in the total number of accidents depending on the relative magnitudes of the increase in risk and the change in vehicle kms travelled. This section has focussed on only the risk part of that equation. This will be combined with the other work described elsewhere in this report to estimate overall changes in the number of casualties annually (see Appendix H).

The research suggests that current articulated vehicles have much higher involvement in casualty accidents per unit of distance travelled on minor roads and much lower involvement on motorways and rural trunk “A” roads. There is also some evidence to suggest that this involvement increases with the size of the vehicle and that the increase is greater on the more minor roads, although this evidence is somewhat contradictory; evidence based on number of axles suggests an increase over-estimates the trend due to inconsistencies in collection methods in different sources of data, evidence based on gross vehicle weight shows no strong conclusions. Despite the limitations in the evidence there is, therefore, justification on safety grounds for limiting road network access for LHVs if they were permitted. Ideally this would be to motorways and rural trunk “A” roads where the casualty rate for an eight axle vehicle would be expected to be comparable to the overall casualty rate for current articulated vehicles averaged across all road types. This would be consistent with research in the USA (Carston, 1987) which showed that overall there was little difference between the accident rates of single and double vehicles but concluded this may be because they were travelling on safer roads.

Risks have been identified in specific circumstances. These are:

- Rollover
- Directional stability
- Manoeuvrability and field of view
- Collisions with other heavy vehicles and rigid fixed objects
- Braking

Most of the evidence reviewed leads to the conclusion that it is reasonable to assume that there will be an increase in the accident and casualty risk per unit of distance travelled by LHVs when compared directly to current articulated vehicles in the same circumstances and with no additional controlling factors. However, the research has also identified that it is reasonable to assume that there is an increase in risk associated with alternative types of vehicle that can be used to increase freight efficiency and that these types of vehicle are legal and in use now, albeit in relatively small numbers at this time. There is likely to be a moderately higher risk of rollover in a double decked vehicle compared with a standard articulated vehicle. Compared with the LHV types assessed (i.e. single decked) the standard double decked artic is likely to have a moderately higher risk of rolling over in steady state cornering manoeuvres but a lower risk in transient cornering manoeuvres (e.g. swerving). Of more concern was the finding (although not statistically robust) that current drawbar vehicles could potentially have a casualty rate up to three or four times greater than current articulated vehicles. This is a greater increase in risk than predicted for any of the LHV combinations assessed.

Not all of the potential risks could be quantified. In particular, there was insufficient evidence available either in the literature or in the accident data to be able to quantify any potential risk associated with overtaking an LHV or with the possibility of an LHV obstructing a junction or railway crossing because of limited road space and a longer vehicle. These will need to be considered further on a risk assessment basis if it is decided to progress further towards allowing this type of vehicle.

All of the predictions in this section have referred to casualty risk per unit of distance travelled. In order to convert this risk to a prediction of changes in casualty numbers it is necessary to combine the findings with those relating to the changes in the quantity of freight carried nationally and the amount of that freight carried by rail, water, standard HGVs and LHVs. To achieve this, the various estimates made in this appendix must be combined into overall estimates of the increase in risk. This was carried out in the parametric cost modelling described in Appendix H.

The analyses carried out so far in this section are severely limited by the capabilities and quality of the data sources. These data sources are not perfect for this type of analysis but represent the best data available for an estimate of the likely accident effects of LHVs, given the lack of real empirical data on LHV performance in the UK. The predictions must, therefore, be treated with caution and can only be considered as an estimate. As a result, the range of potential effects will, in some cases, be quite wide. In order to combine the estimates the following assumptions have been made:

- The extrapolations of current accident data based on road class and number of axles will represent an upper boundary because of the inconsistencies in the data regarding retractable axles and the same size effect was not found when studying accident rates by maximum permitted weight. It is included only to ensure that the predictions are very cautious, reflecting the concerns of a variety of stakeholders.
- The estimates derived from analyses of specific risks will form a lower boundary because not all risks could be quantified in this way.
- Current vehicles for which actual data is available will not have upper and lower boundaries with the exception of drawbar combinations. The uncertainty because of low numbers and potential recording errors associated with drawbar combinations means that the actual data will be treated as an upper estimate and a lower estimate will be based on half the recorded total.
- In line with the original assumptions about the vehicle types to be evaluated, it has been assumed that the B-double and the longer semi-trailer will be equipped with steering axles whereas the rigid vehicle towing a semi-trailer on an “A” dolly and the “C” train will not.
- Information for current drawbar combinations and double decked vehicles is only available for “all roads” so it has been assumed that the distribution of accident rate is proportional to that for all articulated vehicles.

These assumptions result in the following overall predictions of potential casualty rate ranges.

Table 64. Overall ranges of predicted casualty rates assuming no additional countermeasures

Vehicle Option	Casualty severity	All roads		Motorway only		Motorway and rural trunk "A" roads		Motorway and all rural "A" roads		Motorway and all "A" roads	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
All current rigid vehicles	Fatal	21.499	21.499	13.392	13.392	12.100	12.100	21.150	21.150	21.110	21.110
	Serious	76.550	76.550	38.438	38.438	42.478	42.478	61.486	61.486	67.927	67.927
	Slight	569.175	569.175	274.444	274.444	271.997	271.997	399.137	399.137	494.403	494.403
All current articulated vehicles	Fatal	17.625	17.625	9.551	9.551	11.338	11.338	14.612	14.612	15.294	15.294
	Serious	53.677	53.677	23.347	23.347	28.092	28.092	43.836	43.836	47.743	47.743
	Slight	308.944	308.944	161.309	161.309	174.598	174.598	233.355	233.355	276.127	276.127
Double decked	Fatal	17.700	17.700	9.616	9.616	11.403	11.403	14.677	14.677	15.359	15.359
	Serious	54.210	54.210	23.872	23.872	28.617	28.617	44.361	44.361	48.268	48.268
	Slight	311.180	311.180	163.549	163.549	176.838	176.838	235.595	235.595	278.367	278.367
Drawbar	Fatal	40.582	81.165	21.992	43.983	26.106	52.212	33.644	67.289	35.216	70.431
	Serious	154.213	308.427	67.077	134.153	80.708	161.415	125.941	251.883	137.166	274.332
	Slight	1,024.031	2,048.063	534.679	1,069.358	578.727	1,157.454	773.483	1,546.966	915.254	1,830.508
Longer semi	Fatal	17.630	17.630	9.551	9.551	11.338	11.338	14.612	14.612	15.294	15.294
	Serious	53.680	53.680	23.347	23.347	28.092	28.092	43.836	43.836	47.743	47.743
	Slight	308.940	308.940	161.309	161.309	174.598	174.598	233.355	233.355	276.127	276.127
Rigid/A/Semi 44	Fatal	17.910	33.635	9.112	9.780	11.566	17.097	14.843	26.416	15.536	30.778
	Serious	55.770	107.146	25.189	50.506	29.941	57.860	45.705	89.260	49.674	99.614
	Slight	319.020	656.523	169.276	336.476	182.582	364.564	241.486	517.403	284.956	590.785
B-double 44	Fatal	17.750	33.635	9.112	9.668	11.455	17.097	14.729	26.416	15.412	30.778
	Serious	54.630	107.146	24.293	50.506	29.039	57.860	44.784	89.260	48.692	99.614
	Slight	313.010	656.523	165.361	336.476	178.651	364.564	237.413	517.403	280.194	590.785
Rigid/A/Semi 60	Fatal	18.680	33.635	9.112	10.555	12.341	17.097	15.618	26.416	16.311	30.778
	Serious	56.290	107.146	25.714	50.506	30.466	57.860	46.230	89.260	50.199	99.614
	Slight	320.600	656.523	170.856	336.476	184.162	364.564	243.066	517.403	286.536	590.785
B-double 60	Fatal	18.520	33.635	9.112	10.443	12.230	17.097	15.504	26.416	16.187	30.778
	Serious	55.150	107.146	24.818	50.506	29.564	57.860	45.309	89.260	49.217	99.614
	Slight	314.590	656.523	166.941	336.476	180.231	364.564	238.993	517.403	281.774	590.785
Tractor/Semi/C/Semi	Fatal	19.380	49.469	8.081	11.256	13.042	22.316	16.319	37.900	17.012	46.052
	Serious	54.850	158.675	24.268	76.717	29.020	86.799	44.784	133.182	48.754	150.005
	Slight	312.370	994.127	162.628	503.856	175.933	548.630	234.837	794.522	278.307	895.876

It can be seen that in many cases the estimates produced in the two different ways span a very wide range. In order to develop a central “best” estimate of what the national effects would be if this type of vehicle were adopted, it is necessary to estimate where in this range the true answer is most likely to fall. To this end, it is worth considering all of the sources of accident data and what conclusions can be drawn from them:

- Extrapolation of actual UK data on casualty rate by number of axles shows a strong increase in rates with greater number of axles. This dependency increases on roads with a higher overall casualty rate. This method predicts large percentage increases in casualty rates but is an acknowledged over-estimate because of the inconsistent data recording with respect to retractable axles.
- Extrapolation of actual UK data on casualty rate by gross vehicle weight shows some variation in rates for different weight groups but no clear consistent trend linking increased weight to increased casualty rate and certainly no large effects of the type seen when comparing by number of axles. It should be noted that the data on vehicle travel by gross vehicle weight comes from the CSRGT and cannot be divided by type of road so it is not possible to assess accident rate trends by gross vehicle weight on different road types.
- A risk based approach assessing the casualty rates for specific groups of accidents that physical testing and scientific theory suggests may be a problem for larger vehicles has suggested more moderate increases in casualty rate up to approximately 10% dependant on vehicle option and road restrictions selected.
- The literature reviewed has shown that very severe accidents can and do happen with larger vehicles but that in general accident rates are comparable with smaller vehicles, although this is likely to hide an increase because they travel on safer roads. Few specific figures were available but Fancher (1989) cited research that suggested the involvement rate of double trailer combinations was a modest 5% to 10% greater than for singles, once the different patterns of road use were controlled for.
- The Dutch trial found no reason to suggest an increased accident rate, although it was acknowledged that the trial was too small for statistically meaningful results.

It can be seen that four of the five sources of estimates suggest a modest, single figure percentage increase in casualty rate while the other approach predicts potentially very large increases. Given the relative scarcity of data none of these sources can be ignored but the limited body of evidence does suggest that the true answer will lie closer to the lower estimates presented. It has, therefore, been assumed that the central estimate of affect will be the simple weighted mean of the maximum and minimum values where the minimum is weighted at 0.8 and the maximum is weighted at 0.2 to reflect the 80% of research sources suggesting a lower change. This produces the following central estimates.

Table 65. Central estimates of casualty rates assuming no additional safety features.

Vehicle Option	Casualty severity	All roads		Motorway only		Motorway and rural trunk "A" roads		Motorway and all rural "A" roads		Motorway and all "A" roads	
		Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic
All current rigid vehicles	Fatal	21.499	1.220	13.392	1.402	12.100	1.067	21.150	1.447	21.110	1.380
	Serious	76.550	1.426	38.438	1.646	42.478	1.512	61.486	1.403	67.927	1.423
	Slight	569.175	1.842	274.444	1.701	271.997	1.558	399.137	1.710	494.403	1.790
All current articulated vehicles	Fatal	17.625	1.000	9.551	1.000	11.338	1.000	14.612	1.000	15.294	1.000
	Serious	53.677	1.000	23.347	1.000	28.092	1.000	43.836	1.000	47.743	1.000
	Slight	308.944	1.000	161.309	1.000	174.598	1.000	233.355	1.000	276.127	1.000
Double decked	Fatal	17.700	1.004	9.616	1.007	11.403	1.006	14.677	1.004	15.359	1.004
	Serious	54.210	1.010	23.872	1.022	28.617	1.019	44.361	1.012	48.268	1.011
	Slight	311.180	1.007	163.549	1.014	176.838	1.013	235.595	1.010	278.367	1.008
Drawbar	Fatal	48.699	2.763	26.390	2.763	31.327	2.763	40.373	2.763	42.259	2.763
	Serious	185.056	3.448	80.492	3.448	96.849	3.448	151.130	3.448	164.599	3.448
	Slight	1,228.838	3.978	641.615	3.978	694.472	3.978	928.180	3.978	1,098.305	3.978
Longer semi	Fatal	17.630	1.000	9.551	1.000	11.338	1.000	14.612	1.000	15.294	1.000
	Serious	53.680	1.000	23.347	1.000	28.092	1.000	43.836	1.000	47.743	1.000
	Slight	308.940	1.000	161.309	1.000	174.598	1.000	233.355	1.000	276.127	1.000
Rigid/A/Semi 44	Fatal	21.055	1.195	9.246	0.968	12.672	1.118	17.158	1.174	18.584	1.215
	Serious	66.045	1.230	30.252	1.296	35.525	1.265	54.416	1.241	59.662	1.250
	Slight	386.521	1.251	202.716	1.257	218.978	1.254	296.669	1.271	346.122	1.253
B-double 44	Fatal	20.927	1.187	9.223	0.966	12.583	1.110	17.066	1.168	18.485	1.209
	Serious	65.133	1.213	29.536	1.265	34.803	1.239	53.679	1.225	58.876	1.233
	Slight	381.713	1.236	199.584	1.237	215.834	1.236	293.411	1.257	342.312	1.240
Rigid/A/Semi 60	Fatal	21.671	1.230	9.401	0.984	13.292	1.172	17.778	1.217	19.204	1.256
	Serious	66.461	1.238	30.672	1.314	35.945	1.280	54.836	1.251	60.082	1.258
	Slight	387.785	1.255	203.980	1.265	220.242	1.261	297.933	1.277	347.386	1.258
B-double 60	Fatal	21.543	1.222	9.378	0.982	13.203	1.165	17.686	1.210	19.105	1.249
	Serious	65.549	1.221	29.956	1.283	35.223	1.254	54.099	1.234	59.296	1.242
	Slight	382.977	1.240	200.848	1.245	217.098	1.243	294.675	1.263	343.576	1.244
Tractor/Semi/C/Semi	Fatal	25.398	1.441	8.716	0.913	14.897	1.314	20.635	1.412	22.820	1.492
	Serious	75.615	1.409	34.758	1.489	40.576	1.444	62.464	1.425	69.004	1.445
	Slight	448.721	1.452	230.874	1.431	250.472	1.435	346.774	1.486	401.821	1.455

It should be noted that at the very end of the project, after the above analyses had taken place, Australian research (Moore, 2007) was published which suggested that B-double vehicles had substantially lower casualty rates per tonne-km although it did not state the same comparison in terms of vehicle kms or differentiate between accident rates on different classes of road. The same research also cited Canadian research that stated that:

Turnpike Doubles [a Turnpike Double is a prime mover with two trailers, each 14.65 or 16.15 metres in length] are in the order of two to three times safer than the overall tractor-trailer population currently operating on Ontario's multi-lane highways on a per vehicle-kilometre basis. (L-P Tardif et al, 2006)"

In addition to this, Vierth *et al* (2008) carried out analysis of the likely effects of ending the use of LHVs in Sweden. As part of this analysis, the researchers compared the numbers of accidents with small and large trucks and the different accident rates and assigned casualty valuations to these to produce a cost. The results are shown in the form of accident costs per vehicle km in Table 66, below.

Table 66. Swedish average accident cost per km (SEK/km) by size of truck (Vierth *et al*, 2008)

Gross weight / Number axles	2	3	4	5	6	7	8	9	Total
Truck 3.5–7.5 tonnes	-								-
Truck 7.5–12 tonnes	0.53								0.53
Truck 12–14 tonnes	1.47								1.47
Truck 14–20 tonnes	0.71	0.00							0.71
Truck 20–26 tonnes	0.46	2.06							1.34
Truck 26–28 tonnes		1.52							1.52
Truck 28–32 tonnes		3.10	5.12						3.36
Truck above 32 tonnes		39.05	2.09						3.03
Total Trucks	0.70	1.89	3.15						1.18
Truck below 28 tonnes		0.00	0.00						0.00
Truck with trailer 28–34		0.21	0.66						0.58
Truck with trailer 34–40		3.28	0.83	0.02	0.00				0.67
Truck with trailer 40–50		0.11	0.40	0.55	2.65				0.63
Truck with trailer 50–60 tonnes			0.32	0.20	0.55	0.50	1.04	2.19	0.47
Total Trucks with trailers		0.36	0.54	0.27	0.58	0.50	1.04	2.19	0.48

Note: The proportion of unknown trucks is 0.37, by which all costs for trucks alone are adjusted upwards. The equivalent proportion for truck + trailer is 0.77, which has been used to adjust the cost for this category upwards.

It can be seen that the Swedish data suggest that the largest trucks actually present a lower risk per km than the smaller trucks. However, the authors note that this is likely to be strongly influenced by the type of roads that each truck travels on with smaller trucks likely to travel in urban areas much more frequently. In their prediction of the effects of prohibiting trucks in excess of the European standard they actually assume that the smaller trucks replacing the LHVs would have the same casualty rate as an LHV. This assumption leads to a prediction that the increased truck traffic would increase the number of fatalities each year from an average of 67 to between 74 and 79, depending on how much mode shift from road to rail could be produced.

There is therefore, evidence to strongly suggest that the estimate made above for the UK is likely to be a cautious estimate that may actually predict higher accident rates than would in reality occur if LHVs were to be permitted.

The research has suggested that a number of safety technologies are available that are not yet mandatory on current vehicles but could have the potential to mitigate or eliminate some of the additional risks identified for LHVs. For example, stability control could mitigate some of the problems caused by rearward amplification and CMBS could substantially reduce the risk in forward collisions with other heavy vehicles and rigid fixed objects. However, the research identified could not quantify a percentage reduction in risk. For the purposes of this analysis it has been assumed that the change in risk relative to the current fleet of articulated vehicles will be halved if these technologies are made compulsory for vehicles used in an LHV combination. This is consistent with the view that EBS would eliminate braking delay time and the increased risk due to increased stopping distance, CMBS was estimated to be 25% to 75% effective and that ESC and field of view technologies would have an effectiveness of less than 50%. This assumption makes the following changes to the predicted accident rates, as shown in the table overleaf. As noted previously, this assessment does not take into consideration the ability of UK authorities to impose additional safety features on vehicle operators, and in particular foreign operators. This is currently being considered as part of other work within the project. It is important to note however, that accident rates representing both cases (with and without additional safety features) were considered in the final cost analysis.

Table 67. Central estimates of LHV casualty rates assuming additional countermeasures are mandatory and halve the increase in risk

Vehicle Option	Casualty severity	All roads		Motorway only		Motorway and rural trunk "A" roads		Motorway and all rural "A" roads		Motorway and all "A" roads	
		Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic	Casualty rate	Indexed to baseline artic
Longer semi	Fatal	17.628	1.000	9.551	1.000	11.338	1.000	14.612	1.000	15.294	1.000
	Serious	53.679	1.000	23.347	1.000	28.092	1.000	43.836	1.000	47.743	1.000
	Slight	308.942	1.000	161.309	1.000	174.598	1.000	233.355	1.000	276.127	1.000
Rigid/A/Semi 44	Fatal	19.340	1.097	9.398	0.984	12.005	1.059	15.885	1.087	16.939	1.108
	Serious	59.861	1.115	26.800	1.148	31.808	1.132	49.126	1.121	53.703	1.125
	Slight	347.732	1.126	182.013	1.128	196.788	1.127	265.012	1.136	311.124	1.127
B-double 44	Fatal	19.276	1.094	9.387	0.983	11.961	1.055	15.839	1.084	16.890	1.104
	Serious	59.405	1.107	26.441	1.133	31.448	1.119	48.758	1.112	53.310	1.117
	Slight	345.328	1.118	180.447	1.119	195.216	1.118	263.383	1.129	309.219	1.120
Rigid/A/Semi 60	Fatal	19.648	1.115	9.476	0.992	12.315	1.086	16.195	1.108	17.249	1.128
	Serious	60.069	1.119	27.010	1.157	32.018	1.140	49.336	1.125	53.913	1.129
	Slight	348.364	1.128	182.645	1.132	197.420	1.131	265.644	1.138	311.756	1.129
B-double 60	Fatal	19.584	1.111	9.465	0.991	12.271	1.082	16.149	1.105	17.200	1.125
	Serious	59.613	1.111	26.651	1.142	31.658	1.127	48.968	1.117	53.520	1.121
	Slight	345.960	1.120	181.079	1.123	195.848	1.122	264.015	1.131	309.851	1.122
Tractor/Semi/C/Semi	Fatal	21.512	1.220	9.134	0.956	13.117	1.157	17.624	1.206	19.057	1.246
	Serious	64.646	1.204	29.053	1.244	34.334	1.222	53.150	1.212	58.374	1.223
	Slight	378.833	1.226	196.091	1.216	212.535	1.217	290.065	1.243	338.974	1.228

The above analysis has only considered the effect of fitting the countermeasures to LHVs. The additional economic benefits of operating an LHV will substantially alter the benefit to cost ratio of any particular safety countermeasure if it is considered an essential part of permitting their introduction. It is, therefore, likely to be much easier, from a cost benefit point of view, to introduce new safety technologies on LHVs (bearing in mind that the legal issues discussed previously, particularly in relation to foreign operators, have not been considered at this point). However, most of the countermeasures identified also have benefits for standard HGVs and are voluntarily fitted to some standard vehicles and are likely to become mandatory for standard vehicles at some stage in the future. It can, therefore, be argued that the analysis above over-emphasises the effect that the countermeasures will have in the safety differential between standard vehicles and LHVs. However, it is also likely to be the case that the increased risks associated with LHVs will mean that the countermeasure is proportionally more effective when fitted to an LHV than when fitted to a standard vehicle, which acts to mitigate the mis-representation. It is also likely that mandatory fitment of a measure to an LHV will increase the number of vehicles used in standard combinations that are voluntarily equipped with systems, thus acting to improve the overall level of safety of the fleet. It is not possible to quantify these effects with any degree of confidence and, thus, the assessments of wider effects will use the figures based on the simpler assumptions as shown in Table 67.

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Appendix C. Analysis of impacts on Emissions

C.1 Introduction

The proponents of LHVs argue that introducing LHVs would have the effect of reducing the total impact of freight transport on the environment by reducing the total quantity of CO_2 and other pollutants by goods vehicles. Opponents argue that emissions will be increased because of higher tail-pipe emissions per km combined with modal shift and traffic generation effects. The rigorous assessment of the likely emissions from different vehicle types is therefore of critical importance. This section of the report describes the work undertaken to assess the likely tail-pipe emissions per km under different loading conditions and defines the values that were used as inputs to the final analysis of costs and benefits where the effects of take-up rate, modal shift and traffic generation were combined with the emissions per km and the financial valuation of those emissions to estimate the total net effect on the environment.

C.2 Methods

Whilst the assessment of fuel consumption changes may be measured under controlled laboratory conditions, the limited availability of the full range of LHV configurations and the relatively short duration of this project prohibited this approach. Therefore the derivation of the emissions and fuel consumption associated with an existing and standard 44 tonne, 6-axle articulated HGV was compared with an option for improving the capacity of a vehicle within current weight and dimensional limits, and six different types of LHVs. The vehicle types considered are described in more detail in Appendix A. For each of these eight vehicle types, emissions and fuel consumption were assessed using a state-of-the-art modelling approach.

The EU fifth framework ARTEMIS[5] project and the COST Action 346[6] provided new insight into the emission behaviour of modern vehicles. One of the main outputs of these projects was the development of a model capable of accurately simulating emission factors for all types of vehicles over any driving cycle and for various vehicle loads and gradients. The resulting tool – PHEM (**P**assenger car and **H**eavy-duty **E**mission **M**odel) - estimates fuel consumption (FC) and the emissions of carbon monoxide (CO), total hydrocarbons (THC), oxides of nitrogen (NO_X) and particulate matter (PM) based on the instantaneous engine power demand and engine speed during a driving cycle specified by the user. The model combines steady-state engine maps with correction functions for transient operation (Rexeis *et al*., 2005). Within PHEM, for a given driving cycle and road gradient, the required engine power is calculated each second, based on the driving resistance and losses in the transmission system. Engine speed is calculated from the transmission ratios and a gear-shift model. To allow for the effects of transient vehicle operation on emissions, the results from the steady-state maps are altered using transient correction functions.

PHEM takes the form of a computer-executable program with a user-friendly interface. It is optimised for simulating fuel consumption and emissions from Heavy Duty Vehicle (HDV) fleets, but can also be used for simulations of single vehicles as well as passenger cars. Figure 77 illustrates the structure of the model.

[5] http://trl.co.uk/artemis
[6] http://www.cordis.lu/cost-transport/src/cost-346.htm

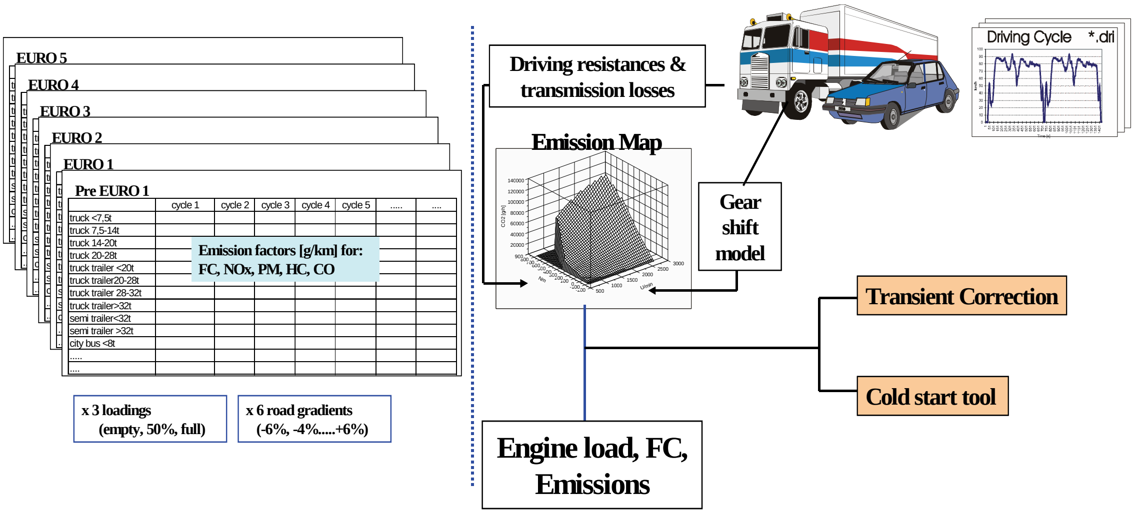

Figure 77: Structure of PHEM (Rexeis *et al*., 2005).

PHEM has some special features which were developed to enable the straightforward simulation of average HDV classes. For example, the input data are modular, with different files being used to describe the vehicle characterisation, the driving cycle, the engine emission map and the full-load curve. This enables a rapid simulation of various vehicle and driving cycle combinations. In the input file for the driving cycle, the measured engine speed or the gear position can be given as an optional model input. If neither the engine speed nor the gear position is given in the input file, PHEM uses a gear-shift model to simulate engine speed.

TRL holds a database of in-service driving characteristics, measured over a range of road types and vehicle classes. One hundred and twenty typical HGV driving cycles were selected to represent a range of average speed driving conditions between 5 and 90 km/h. These cycles were previously collected during various studies including the DfT TRAMAQ UG214 project (Green and Barlow, 2002) and the HA project on the assessment of the M42 active traffic management regimes (McCrae and Barlow, 2005). Emission and fuel consumption estimates were derived using PHEM over each of these selected cycles, for each of the 8 vehicle configurations and for Euro 3, 4 and 5 emission classes, introduced into the UK fleet in 2000/01, 2005/06 and 2008/09 respectively. This included simulations of these vehicles operating part laden and fully-laden. The part laden condition was defined as the average load assuming that the average percentage of maximum payload was the same as that currently recorded by CSRGT for 44 tonne vehicles (excluding empty running). The vehicle weights used in the analysis are summarised in Table 68.

Table 68: Vehicle mass specifications used in the PHEM model.

Vehicle type reference	1	2	3	4	5	6	7	8
Vehicle description	Baseline - 6 axle articulated vehicle	Improved inside current limits (baseline + double deck)	Tractor, 16 m semi-trailer	Rigid truck, converter dolly (A), semi-trailer (25.25m, 44t)	Tractor, 'interlink' semi-trailer with fifth-wheel coupling, semi-trailer (25.25m, 44t)	Rigid truck, converter dolly (A), semi-trailer (25.25m, 60t)	Tractor, 'interlink' semi-trailer with fifth-wheel coupling, semi-trailer (25.25m, 60t)	C-train (34m, 82t)
Fully-laden								
Unladen weight	14,891	15,782	15,869	20,349	20,651	20,349	20,651	23,620
Max payload	29,109	28,218	28,131	23,651	23,349	39,651	39,349	60,380
Gross weight	44,000	44,000	44,000	44,000	44,000	60,000	60,000	84,000
Part-laden								
Unladen weight	14,891	15,782	15,869	20,349	20,651	20,349	20,651	23,620
Typical payload	17,600	17,600	17,009	14,301	13,866	23,977	19,528	36,506
Gross weight	32,491	33,382	32,878	34,650	34,517	44,326	40,179	60,126

The application of the PHEM model to the 8 vehicle types, the two levels of loading, combined with the 120 vehicle operating cycles and the three Euro emission classes resulted in the generation of 5,760 data points for each of the 5 emission parameters, as indicated in Table 69.

Table 69: PHEM model input and output parameters.

Vehicle scenario	Laden condition	Drive cycle	Euro class	Emission parameter (FC, CO, THC, NO_X, PM)
Inputs				**Output**
8	2	120	3	5760

For each of the vehicle scenarios, 120 data points were thus derived which related average cycle speed to a pollutant emission, expressed in g/km. For each combination of vehicle scenario, laden condition, Euro-emission standard and pollutant, average speed emission functions were derived. Although carbon dioxide (CO_2) is not calculated directly, it can be derived from the standard carbon balance equation, as specified in the Commission Directive 93/116/EC. Total CO_2 emissions were calculated by summing the fractional contributions of each carbon-containing exhaust pollutant. These fractional contributions were calculated using the relative atomic and molecular weights of each of the elements forming part of each pollutant. For total hydrocarbons, an empirical formula of CH_2 was assumed. Half of the mass of emitted particulate matter was assumed to be carbon. Given that the vast majority of carbon is directly emitted in the form of CO_2, the assumptions regarding THC and PM do not significantly affect the result of the calculation.

For each of the 8 vehicle types, and for the Euro 3, 4 and 5 emission legislation classes, the PHEM model was used to estimate the emission of CO, HC, NO_X, PM, CO_2 and fuel consumption (FC). Detailed results of the analysis can be presented in terms of vehicle specific emission plots and speed related emission functions. These functions were derived using simple power curves, with the following form:

$$E = a.v^b$$

Where:

v is speed in km/h

a & b are the coefficients contained in the tables below

E is the emissions in g/km

C.3 Results

Table 70 to Table 75 provide the estimated emissions for each of the 8 vehicle types, expressed in terms of g/km of pollutant, and in terms of per tonne of payload. These emissions are estimated with an average associated vehicle speed of 86.9 km/h. This average speed is typical of existing 4 axle and 5+ axle articulated HGVs in operation on the existing high speed road network (DfT, 2006). The following definitions apply to all tables:

CO Carbon Monoxide

HC Hydrocarbons

NO_x Nitrous oxide

PM Particulate Matter

CO_2 Carbon Dioxide

FC Fuel Consumption

Table 70: Emission rates for Euro 3 vehicles with typical laden weight

	Emission rates						
	CO (g/km)	**HC (g/km)**	**NOx (g/km)**	**PM (g/km)**	**CO_2 (g/km)**	**FC (g/km)**	**Payload (kg)**
Veh 1	2.584	0.258	8.021	0.195	969.833	307.321	17,600
Veh 2	2.625	0.258	8.511	0.203	1042.397	330.148	17,600
Veh 3	2.591	0.258	8.084	0.196	977.194	309.52	17,009
Veh 4	2.646	0.26	8.77	0.207	1082.978	342.888	14,301
Veh 5	2.644	0.261	8.755	0.207	1081.645	342.465	13,866
Veh 6	3.322	0.33	10.652	0.256	1303.409	412.706	23,977
Veh 7	3.266	0.326	10.08	0.247	1218.223	386.032	19,528
Veh 8	3.283	0.356	12.469	0.272	1585.633	502.006	36,506

Table 71: Emission rates for Euro 4 vehicles with typical laden weight

	Emission rates						
	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	CO_2 (g/km)	FC (g/km)	Payload (kg)
Veh 1	0.103	0.013	5.024	0.022	878.314	276.994	17,600
Veh 2	0.105	0.013	5.402	0.022	944.175	297.78	17,600
Veh 3	0.103	0.013	5.065	0.022	885.358	279.223	17,009
Veh 4	0.106	0.013	5.592	0.023	981.489	309.536	14,301
Veh 5	0.106	0.013	5.583	0.023	980.633	309.276	13,866
Veh 6	0.132	0.017	6.722	0.029	1181.001	372.458	23,977
Veh 7	0.13	0.017	6.313	0.028	1102.917	347.84	19,528
Veh 8	0.14	0.017	8.036	0.03	1449.871	457.218	36,506

Table 72: Emission rates for Euro 5 vehicles with typical laden weight

	Emission rates						
	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	CO_2 (g/km)	FC (g/km)	Payload (kg)
Veh 1	0.103	0.013	2.858	0.022	892.348	281.419	17,600
Veh 2	0.105	0.013	3.051	0.022	959.256	302.528	17,600
Veh 3	0.103	0.013	2.88	0.022	899.485	283.67	17,009
Veh 4	0.106	0.013	3.147	0.023	997.162	314.476	14,301
Veh 5	0.106	0.013	3.141	0.023	996.296	314.213	13,866
Veh 6	0.132	0.017	3.8	0.029	1199.874	378.397	23,977
Veh 7	0.13	0.017	3.595	0.028	1120.525	353.381	19,528
Veh 8	0.14	0.017	4.46	0.03	1473.093	464.515	36,506

Table 73: Emission rates for Euro 3 vehicles with maximum laden weight

	Emission rates						
	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	CO_2 (g/km)	FC (g/km)	Payload (kg)
Veh 1	2.618	0.274	9.398	0.213	1186.673	375.672	29,109
Veh 2	2.611	0.278	9.672	0.214	1232.191	389.999	28,218
Veh 3	2.616	0.274	9.398	0.213	1186.45	375.601	28,131
Veh 4	2.616	0.28	9.784	0.215	1248.881	395.309	23,651
Veh 5	2.615	0.28	9.794	0.215	1250.082	395.688	23,349
Veh 6	3.28	0.356	12.431	0.272	1581.393	500.448	39,651
Veh 7	3.28	0.356	12.432	0.272	1581.393	500.448	39,349
Veh 8	3.059	0.398	14.893	0.268	1898.878	600.271	60,380

Table 74: Emission rates for Euro 4 vehicles with maximum laden weight

	Emission rates						
	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	CO_2 (g/km)	FC (g/km)	Payload (kg)
Veh 1	0.109	0.013	6.031	0.023	1081.297	340.989	29,109
Veh 2	0.11	0.013	6.237	0.023	1124.248	354.543	28,218
Veh 3	0.109	0.013	6.031	0.023	1081.495	341.055	28,131
Veh 4	0.111	0.013	6.317	0.024	1139.771	359.443	23,651
Veh 5	0.111	0.013	6.325	0.024	1140.834	359.775	23,349
Veh 6	0.14	0.017	8.014	0.03	1445.172	455.759	39,651
Veh 7	0.14	0.017	8.011	0.03	1445.306	455.759	39,349
Veh 8	0.174	0.018	9.752	0.034	1758.198	554.614	60,380

Table 75: Emission rates for Euro 5 vehicles with maximum laden weight

	Emission rates						
	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	CO_2 (g/km)	FC (g/km)	Payload (kg)
Veh 1	0.109	0.013	3.356	0.023	1098.57	346.446	29,109
Veh 2	0.11	0.013	3.47	0.023	1141.705	360.204	28,218
Veh 3	0.109	0.013	3.357	0.023	1098.781	346.498	28,131
Veh 4	0.111	0.013	3.513	0.024	1157.959	365.179	23,651
Veh 5	0.111	0.013	3.519	0.024	1159.061	365.518	23,349
Veh 6	0.14	0.017	4.449	0.03	1468.333	463.038	39,651
Veh 7	0.14	0.017	4.449	0.03	1468.333	463.038	39,349
Veh 8	0.174	0.018	5.458	0.034	1786.178	563.464	60,380

Rail freight emissions were not modelled explicitly but an average value was taken from an unpublished report for EWS (2007). The values are shown in Table 76, below.

Table 76. Rail emissions

Emission	grams per tonne-km
CO_2	18.769
Methane	0.00078
Carbon Monoxide	0.02921
Nitrous Oxide	0.00718
Nitrogen Oxides	0.10177
Sulphur Dioxide	0.01580
Non-methane VOC	0.02143
Benzene	0.00004
1,3-butadiene	0.00186
PM_{10}	0.00485

C.4 Discussion

The tables show the emission rates for the different vehicle combinations as the actual tailpipe emission rate (grams per kilometre). It can be seen that in terms of emissions per vehicle km travelled, all of the vehicle options produce higher values than the reference baseline vehicle. However, the emissions can also be expressed in terms of the weight of the goods carried (grams per kilometre per tonne of payload). Generally, the heavier the vehicle, the greater the exhaust emissions and fuel consumption. There is also generally a decrease in the emissions with advances in the Euro standards.

Vehicle scenario 8 (84 tonne GVW) produces generally the highest tailpipe emissions and has the greatest fuel consumption. This is followed by vehicles 4 and 7 (both 60 tonne GVW). However, when considering the emissions rates per tonne of payload carried, these heavier vehicles produce similar or lower relative emissions than the current 44 tonne articulated HGV. When fully-laden, Vehicle 8 produces significantly lower relative emissions than a current HGV together with lower fuel consumption.

The average loads used in the analysis were assumed to be equivalent, in percentage terms, to the average load when laden of current 44 tonne vehicles based on recent CSRGT data. However, in the detailed cost analysis, described in Appendix H, it was found to be desirable to test a range of loading conditions, including one based on the average load including empty running for existing vehicles and one based on increasing the average loads by 10% in accordance with the findings of the information gathering exercise.

Analysis showed that the relationship between load and emissions for heavy vehicles was relatively linear and, therefore, that a good approximation of the emissions at any level of load could be made by interpolating or extrapolating between the two conditions modelled in detail above. An example of this analysis is shown in Table 77, below for Euro5 emissions standard at a load equivalent to current average loads including empty running.

Table 77: Extrapolated results per vehicle km and per tonne km at loading equivalent to current average loads including empty running

	Emission rates (Euro 5)						
	CO (g/km)	HC (g/km)	NOx (g/km)	PM (g/km)	CO2 (g/km)	FC (g/km)	Payload (kg)
Vehicle 1	0.099	0.013	2.558	0.021	768.313	242.308	10,678
Vehicle 2	0.101	0.013	2.675	0.021	795.680	250.818	9,952
Vehicle 3	0.099	0.013	2.567	0.021	768.726	242.448	10,243
Vehicle 4	0.103	0.013	2.953	0.022	911.995	287.621	9,349
Vehicle 5	0.104	0.013	2.960	0.023	918.169	289.587	9,314
Vehicle 6	0.129	0.017	3.524	0.029	1,085.784	342.426	17,316
Vehicle 7	0.129	0.017	3.497	0.028	1,080.619	340.800	17,254
Vehicle 8	0.123	0.016	3.958	0.028	1,315.490	414.705	25,495

	Emission rates (Euro 5)					
	CO (g/tkm)	HC (g/tkm)	NOx (g/tkm)	PM (g/tkm)	CO2 (g/tkm)	FC (g/tkm)
Vehicle 1	0.009	0.001	0.240	0.002	71.955	22.693
Vehicle 2	0.010	0.001	0.269	0.002	79.949	25.202
Vehicle 3	0.010	0.001	0.251	0.002	75.052	23.671
Vehicle 4	0.011	0.001	0.316	0.002	97.553	30.766
Vehicle 5	0.011	0.001	0.318	0.002	98.578	31.091
Vehicle 6	0.007	0.001	0.204	0.002	62.705	19.775
Vehicle 7	0.007	0.001	0.203	0.002	62.631	19.752
Vehicle 8	0.005	0.001	0.155	0.001	51.598	16.266

The financial value of emissions was taken from figures derived by other research. Values for SO_2, NOx, and PM were taken from a study for DEFRA (2006) and values for carbon were taken from the Department for Transport's website for guidance on the conduct of transport studies (http://www.webtag.org.uk/index.htm). Valuations are shown in Table 78, below. Standard values could not be found for all pollutants so the external costs will be under-estimated in both the baseline cases and the LHV scenarios.

Table 78. Financial value of pollutants (£/tonne)

	SO2	Nox	PM	Carbon
2006	2,747.00	1,708.00	43,448.00	78.66
2007	2,801.94	1,742.16	44,316.96	79.70
2008	2,857.98	1,777.00	45,203.30	80.73
2009	2,915.14	1,812.54	46,107.37	81.77
2010	2,973.44	1,848.79	47,029.51	82.80
2011	3,032.91	1,885.77	47,970.10	83.84
2012	3,093.57	1,923.49	48,929.50	84.87
2013	3,155.44	1,961.96	49,908.09	85.91
2014	3,218.55	2,001.19	50,906.26	86.94
2015	3,282.92	2,041.22	51,924.38	87.98
2016	3,348.58	2,082.04	52,962.87	89.01
2017	3,415.55	2,123.68	54,022.13	90.05
2018	3,483.86	2,166.16	55,102.57	91.08
2019	3,553.54	2,209.48	56,204.62	92.12
2020	3,624.61	2,253.67	57,328.71	93.15

C.5 References

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Appendix D. Analysis of impacts on Infrastructure

D.1 Introduction

If LHVs were to be permitted they could have a wide range of effects on the UK road network. The assessment of these effects therefore forms a very important part of the analysis of the net effects and costs and benefits. The assessment of infrastructure has been considered to include:

- Congestion of the network
- Structural effects of LHVs on bridges
- Road wear
- The availability of suitable parking facilities, rest areas or coupling/de-coupling points
- The need for route restrictions and how they could be defined
- Enforcement of restrictions

D.2 Methods

The analysis of infrastructure issues was based on reviews of scientific literature, the use of standard analysis tools and input from the wider information gathering exercise. All of the information gathering contributed to the findings to some extent, but contributions generated from focus group meetings with infrastructure owners, enforcement agencies, road safety organisations and representatives of other road users (e.g. car drivers, cyclists etc.) were especially important. The views expressed in these meetings that are reported in this appendix are set alongside other analyses in the section most relevant to the topic discussed.

The analysis of congestion impacts was carried out predominantly based on a review of scientific literature and a simplistic assessment of the use of road space.

The effect of LHVs on bridges was assessed using standard Highways Agency protocols for assessing the loading imposed by vehicles on structures. The number of bridges on the trunk road network built to different construction standards was assessed using the Highways Agency Structures Management Information System (SMIS) database of bridge loading capacities.

The implications of LHVs for structural road wear were estimated using the standard assumption that wear is proportional to the fourth power of the axle weight. In addition, the effects on surface wear of multi-lane carriageways were examined.

Investigations of parking facilities, whether route restrictions would be required if LHVs were permitted, what type of roads vehicles might be restricted to, and how restrictions could be defined and enforced were carried based predominantly on the information gathering exercise, and the focus groups in particular, supported by the review of scientific literature. It should be noted that the effects that any route restrictions would have on the level of use of LHVs, if they were permitted, was assessed by modelling the routes used by current road freight operations and in the focus group information gathering sessions with the road freight industry. These activities are reported in other annexes.

D.3 Results

D.3.1 Analysis of Impacts on congestion

Two main factors will influence the effect of LHVs, if permitted, on congestion. These are:

- Any change in the total distance travelled by HGVs

- Whether any aspect of LHV design or operation would be likely to cause different levels of disruption to traffic that it interacts with compared with an existing HGV

The changes to the total distance travelled by HGVs was assessed in detail in the costs and benefits section (Appendix H), taking account of the proportion of freight that might be expected to shift from existing road vehicles, from other freight modes and any additional freight growth induced by a reduction in road transport costs. As an interim assessment, a simple evaluation of the amount of relative road space vehicles occupy was carried out.

The relative amount of road space occupied by LHVs was estimated by dividing the vehicles' capacities (maximum payload or maximum pallet capacity) by the road space occupied assuming a 50m headway (2 seconds at 90 km/hr) (see Table 79).

Table 79: Relative Use of Road Space

Vehicle Type	Gross Vehicle Weight (tonnes) and number of axles	Relative use of road space (assuming full vehicle and 50m headway)	
		By Payload (tonnes per metre of road space)	By Pallet Capacity (pallets per metre of road space)
1 (base single-deck)	44 tonnes / 6-axle	1.00	1.00
2 (base double-deck)	44 tonnes / 6-axle	0.90	2.00
3 (longer semi-trailer)	44 tonnes / 6-axle	0.91	1.19
4 (B-double)	44 tonnes / 8-axle	0.71	1.36
5 (rigid + semi-trailer)	44 tonnes / 8-axle	0.72	1.36
6 (B-double)	60 tonnes / 8-axle	1.20	1.36
7 (rigid + semi-trailer)	60 tonnes / 8-axle	1.20	1.36
8 (C-train)	82 tonnes / 11-axles	1.59	1.58

In terms of payload, the 60 and 82 tonne LHVs had higher (more efficient) use of road space than the single-deck base vehicle. Vehicles 3, 4 and 5 had a less efficient use of road space in terms of payload because these are restricted to current weight limits. In terms of pallet capacity, all the LHVs assessed had higher use of road space than the single-deck base vehicle, but lower use than the double-deck base vehicle (all LHVs were assumed to have a single-deck).

This more efficient use of road space would normally be expected to reduce congestion and mechanisms exist for assigning financial values to the reduction in congestion. In theory it would be possible to use these mechanisms to assign congestion costs to the costs and benefits model used in Appendix H. However, this would require an assumption that the congestion caused by an LHV was the same as an existing articulated vehicle when the quantity of load carried was ignored.

Although LHVs would be expected to make more efficient use of road space in terms of the load carried, they also have the potential to create additional congestion in their immediate surroundings. A comprehensive survey of truck size and weight issues in the USA (ORD, 2001) suggested that length itself was not a significant factor in congestion, but that the main factors were the power to weight ratio, the gradient of the road and the type of road. On flat major dual-carriageways and wider roads, the impact of LHVs would not be expected to be that much different from other standard HGVs. On single carriageway especially those with many bends and steep gradients their effect may be much greater than HGVs. The problem is that it is difficult to specify what the impact will be in the UK. Whilst there is evidence of the impact in the USA of various types of LHV and estimates can be made for the longest and heaviest types using models developed for assessing the impact of abnormal loads (discussed later in this section) their behaviour on single carriageway roads is more problematic. Even microsimulation studies would, in general, be problematic since most microsimulation models in current use, model overtaking on single carriageways badly if at all. The microsimulation package REVS developed by MVA for the Scottish Executive was designed to model overtaking opportunities in rural areas but its current status in unknown. In addition to this most of the evidence that is in existence focuses on vehicles with increased weight limits. Reviewing the US evidence (Ord, 2001) would suggest that LHV types where weight limits are not increased would have substantially less effect on the surrounding traffic than those where the GVW was substantially increased.

Table 80, below, is extracted from Table 7 of the DOT publication (ORD, 2001). An inspection of the values shows some unexpected variations, for instance the capacity effect of LHV's is larger on a dual carriageway (4 lane road) than on a single carriageway (2 lane road) which is not what one would intuitively expect, but the effect of length is normally very small.

Table 80: Reproduction of Table 7 of the ORD report (2001)

Table 7. Vehicle Passenger Car Equivalents -- Rural Highways

Roadway Type	Grade		Vehicle Weight to Horsepower Ratio (pounds/horsepower)	Truck Length (feet)		
	Percent	Length (miles)		40	80	120
Four-Lane Interstate	0	0.50	150	2.2	2.6	3.0
			200	2.5	3.3	3.6
			250	3.1	3.4	4.0
	3	0.75	150	9.0	9.6	10.5
			200	11.3	11.8	12.4
			250	13.2	14.1	14.7
Two-Lane Highway	0	0.50	150	1.5	1.7	Not Simulated
			200	1.7	1.8	Not Simulated
			250	2.4	2.7	Not Simulated
	4	0.75	150	5.0	5.4	Not Simulated
			200	8.2	8.9	Not Simulated

One should be wary of translating such values directly to the UK context, especially because most of the roads surveyed as part of the ORD study were in the mid-west of the USA where the characteristics of the roads are normally very different to that found in most parts of rural UK.

Both the German (Glaeser *et* al, 2006) and Dutch (Arcadis, 2006) studies of LHVs have reached slightly different conclusions to those reported above. Overall these studies have concluded that there would be little overall effect on congestion, although the German study noted that the total traffic on the roads could be reduced but that if LHVs were permitted on non-motorway roads, there could be adverse effects at intersections and railway crossings.

No specific work on the effects of LHVs on congestion has been carried out. However, there has been a study of the effect of Abnormal Indivisible Load movements on congestion. An Abnormal Loads calculator was developed to estimate the congestion effects along routes used by abnormal loads. However the term 'abnormal loads' is normally considering loads much heavier, longer and importantly wider than those associated with the LHVs considered in the this study. The Abnormal Loads Congestion Cost Calculator is not sensitive enough to model usefully the effect of a normal

HGV moving at a 'fair' speed in a traffic stream, because it predicts only queues caused by excess of demand over capacity, and additional delays caused by slowing down when passing, which are not normally significant when passing HGV-sized vehicles. Unless the HGV is moving quite slowly, the more significant delays are likely to be caused by other traffic preventing an overtaking manoeuvre. Under average conditions this is absorbed within the free-flow speed/flow relationship assumed on the road section. Standard DfT empirical speed/flow relationships (e.g. COBA) include a factor to allow for the proportion of HGVs in the traffic.

In general, the important factors determining the impact of a moving bottleneck are its speed and lane take-up, and the ambient traffic volume. As the traffic volume approaches the effective capacity of the road, a queue will develop, but the effective capacity depends not only on how many vehicles can pass the bottleneck, but also on the speed at which it is moving. This is illustrated by some examples taken from an Abnormal Load study.

The effect of bottleneck speed on whole-carriageway capacity is illustrated by Figure 78. This is a rather extreme case where a 3-lane motorway with normal capacity 7200 vehicles/h is reduced at the bottleneck to one lane with capacity 1800 vehicle/h as measured by a stationary observer. The effective capacity is very sensitive to bottleneck speed, when the bottleneck is slow-moving.

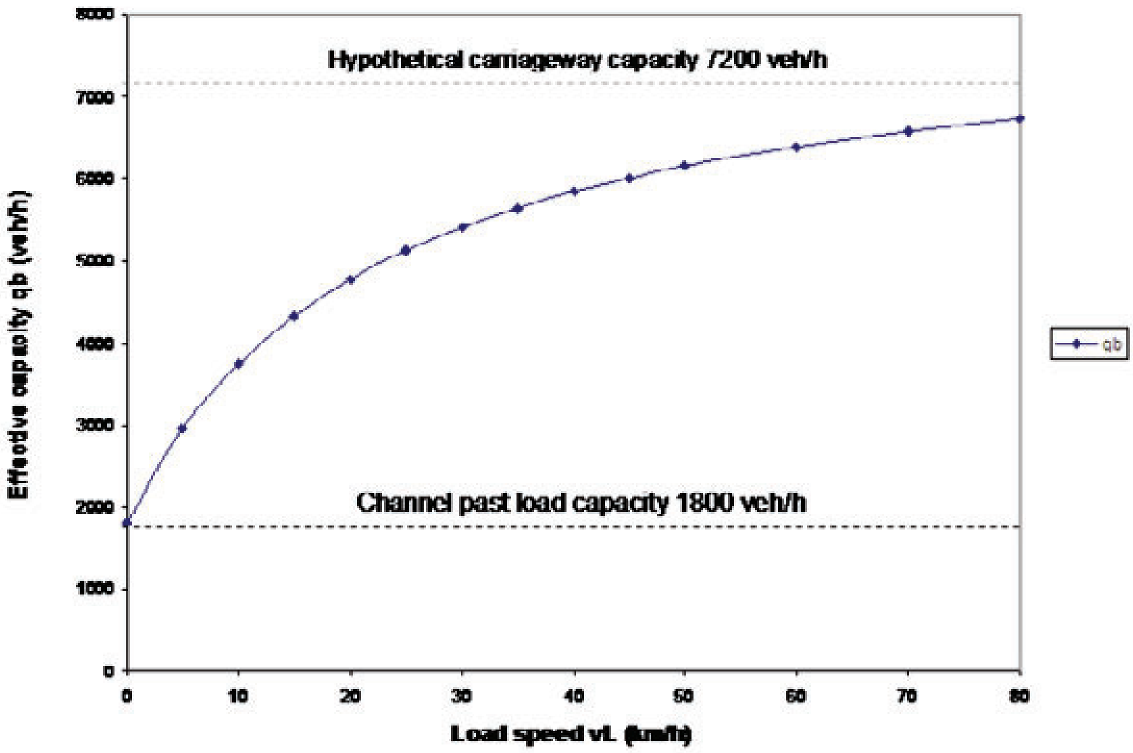


Figure 78: Effect of bottleneck speed on effective road capacity, assuming a normal carriageway capacity of 7200 veh/h, channel capacity of 1800 veh/h, and the Duncan/Banks speed/flow model

Figure 79 shows how delay (expressed as a cost using a cost-per-hour conversion factor) depends on the speed of an Abnormal Load and the ambient demand on a motorway section. It is evident that sensitivity increases at lower speeds and higher levels of demand, and it is also evident that it is not possible to give a 'typical' value of delay.

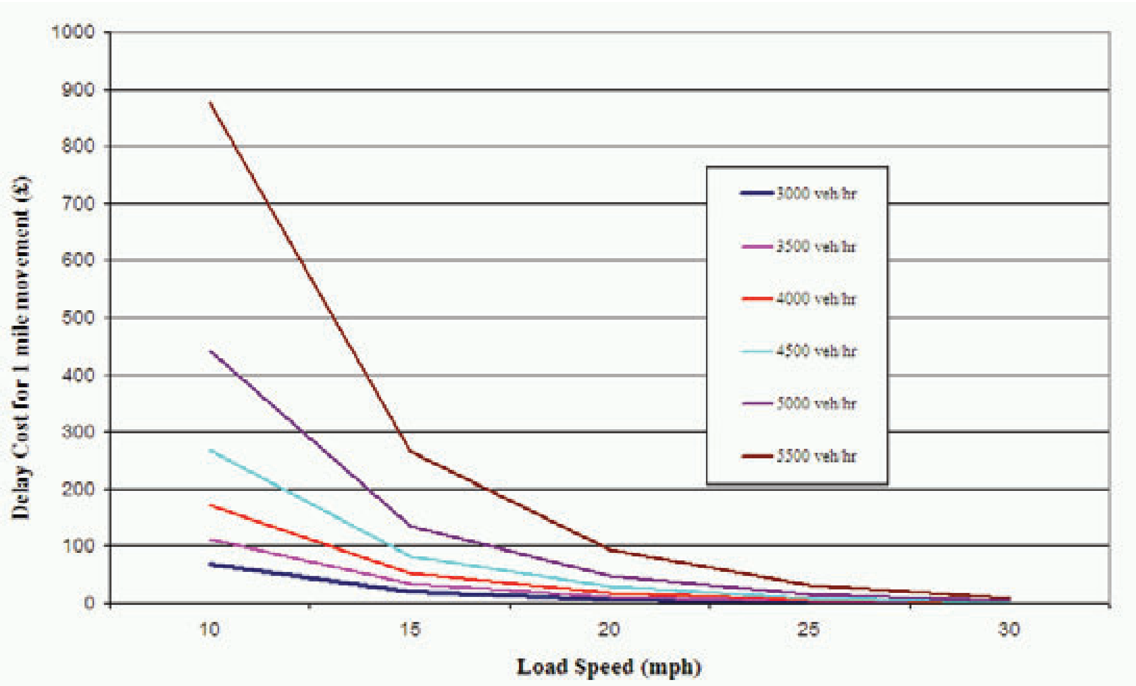


Figure 79: Effect of load speed on delay cost on 1 mile section of 3-lane motorway

Figure 80 shows how delay cost varies with demand, for an Abnormal Load nominally taking up 1 or 2 lanes, 'channel capacity' being the capacity of the remaining lanes. Again, the steepness of the curves makes it impossible to state 'typical' values. Furthermore, in all these scenarios queues increase with time, so delay depends on the length of section over which the bottleneck moves.

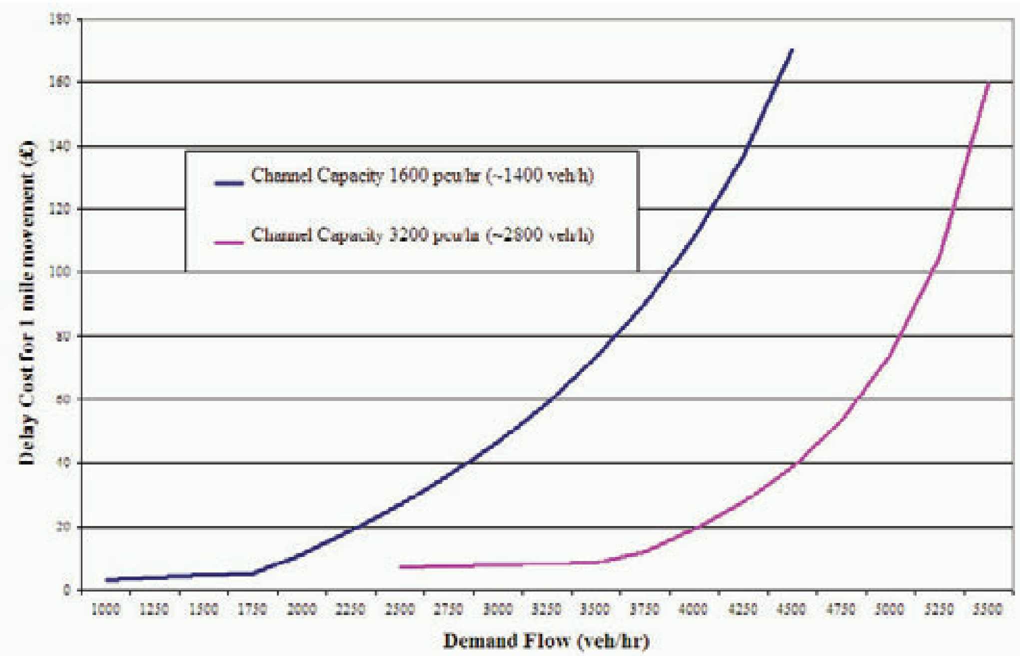


Figure 80: Effect of demand and capacity on delay cost on a 1 mile section of 3-lane motorway

It seems unlikely that the sort of vehicles considered in the project, large HGVs occupying one lane and ranging in length between 16.5 and 34 m, will fall into the range for which the Abnormal Loads model is useful unless they move significantly slower than normal HGVs, and/or on single carriageway roads where overtaking is difficult.

It can be seen that the conclusion of the work on abnormal loads is that speed is the key. This is consistent with the importance of the power to weight ratio in the US study. This suggests that to minimise the impact of the LHVs, if permitted, on other traffic they should not be subject to lower speed limits and the tractor units are adequately powered. Uncertainty remains regarding the effect of the use of LHVs on single carriageways.

Several stakeholders have commented on concerns that LHVs may cause congestion while overtaking, or being overtaken by, other HGVs or LHVs on dual carriageways or motorways, where the additional length would be expected to increase the amount of time required for the manoeuvre, thus forming a bottleneck for faster moving vehicles. It has not been possible to quantify this effect. It would be possible to avoid this by restricting LHVs to lane one, although similar effects could be found with standard HGVs overtaking LHVs.

Concern has also been expressed about congestion caused at junctions due to an increased time to clear them. Research has been identified to support this concern but the findings were strongly inter-related with safety aspects and were reported in section B.6

The uncertainty in the data available regarding whether or not LHVs would be likely to cause more localised disruption to interacting traffic has meant that it has not been possible to assign congestion costs in the later analysis of costs and benefits. This means that the benefit or disbenefit of a change in total HGV kilometres driven has not been included within the estimate of total cost change.

D.3.2 Analysis of the effect on structural road wear

The structural road wear attributable to vehicles is normally assumed to be proportional to the fourth power of the axle weight (Atkinson, Merrill and Thom, 2006). Thus, a 10 per cent increase in axle weight is assumed to increase structural wear by 46 per cent. Structural road wear is measured in terms of "standard axles", where one standard axle is defined as the wear associated with an 8.16 tonne axle and the wearing power of a heavier or lighter axle is calculated as:

$$\text{Road wear factor (standard axles)} = (\text{axle weight in tonnes} / 8.16)^4$$

Road wear factors were calculated for the 8 vehicle types assessed in this project. For each vehicle, factors were calculated for a fully-laden vehicle and using typical lading patterns from the 2005 CSRGT data. The typical lading patterns were based on self-reporting by vehicle operators and do not include any provision for overloading, etc (and therefore are lower than the values used in road design). However, the same assumptions have been used for each vehicle and the figures can therefore be used to compare the relative wear associated with the different vehicles.

Table 81: Relative Road Wear Factors for Vehicles

Vehicle Type	Gross Vehicle Weight (tonnes) and number of axles	Relative wear factor (standard axles) for a typical lading pattern	
		per vehicle	per 100 tonnes of goods
1 (base single-deck)	44 tonnes / 6 axles	1.00	1.00
2 (base double-deck)	44 tonnes / 6 axles	1.06	1.18
3 (longer semi-trailer)	44 tonnes / 6 axles	1.04	1.11
4 (B-double)	44 tonnes / 8 axles	0.55	0.68
5 (rigid + semi-trailer)	44 tonnes / 8 axles	0.61	0.75
6 (B-double)	60 tonnes / 8 axles	1.46	1.08
7 (rigid + semi-trailer)	60 tonnes / 8 axles	1.48	1.09
8 (C-train)	82 tonnes / 11 axles	1.80	0.90

Generally the calculated wear factors per vehicle (see Table 81) increased with increasing Gross Vehicle Weight (GVW) and decreased with increasing number of axles. The lowest values were for the 8-axle 44 tonne GVW vehicles (numbers 3 and 6) and the highest values were for the 82 tonne vehicle (number 5). Only the 8-axle 44 tonne vehicles had wear factors lower than those for the base vehicle (vehicle 1). The lading pattern wear factors for vehicles 2 (double-deck semi-trailer) and 8 (longer semi-trailer) were higher than those for vehicle 1 (standard semi-trailer) because their unladen weights were higher and therefore the road wear factors when unladen and at each stage of loading were higher.

Once the movement of 100 tonnes of goods is taken into account, three vehicles had wear factors lower than those for the base vehicle. These were the two 8 axle 44-tonne GVW vehicles (vehicles 3 and 6) and the 82 tonne GVW vehicle (vehicle 5). The highest wear factors were for the 44 tonne articulated vehicle with double-deck semi-trailer (vehicle 2) where the relatively high unladen weight increased the number of vehicles required to carry 100 tonnes. All the proposed LHVs (vehicles 3 to 8) had lower wear factors per 100 tonnes than those for this vehicle which is permitted under existing regulations.

Previous increases in maximum permitted weight aimed to reduce the wear factors per 100 tonnes. Table 82 shows the relative factors for 32.52 tonne 4-axle articulated vehicles (maximum weight vehicle between 1964 and 1983), 38 tonne 5-axle articulated vehicles (maximum weight vehicle between 1983 and 1999) and 44 tonne 6-axle articulated vehicles (maximum weight vehicle since 2001) (Newton and Frith, 1993).

Table 82: Trends in Road Wear Factors per 100 tonnes of goods

Vehicle	GVW per axle (tonnes)	Relative Road Wear Factor per 100 tonnes (32.52 tonne 4-axle articulated = 100)
32.52 tonne 4-axle articulated	8.13	100
38 tonne 5-axle articulated	7.60	90
44 tonne 6-axle articulated	7.33	75

If a similar approach were to be taken, only the 8-axle 44 tonne and the 82 tonne vehicles would be permitted. However, the wear factors for the 8-axle 60-tonne vehicles were lower than those for the double-deck 44 tonne 6-axle vehicle and therefore could lead to reduced road wear if they replaced double-deck semi-trailers (but not if they were used to replace the base vehicle).

It is possible to quantify the cost of road wear per standard axle and Table 83 below shows an estimate of those costs for different types of road.

Table 83. Financial costs of road wear

Road Type	£ per Standard Axle-km
Motorways	£0.03
Other trunk	£0.04
Local authority prin	£0.08
Local authority othe	£0.32
All roads	£0.06

The costs reported were calculated on the basis of the data that was used in a NERA study to assess lorry track and environmental costs (Dodgson *et al*, 2000) updated for the effects of inflation. They have been combined with the information on the standard axles associated with each vehicle type (i.e. not per 100 tonnes carried), the tonne kms likely to be transported by each vehicle type, if LHVs were permitted, the predicted average load carried by each vehicle type, and the different road restrictions that might be applied to LHVs (if permitted) in order to generate a financial effect on road wear for a range of scenarios. This has been embodied in the final model of costs and benefits.

D.3.3 Assessment of the effects on surface road wear

Although traditionally road pavement designs have been based on the assumption that structural road wear is proportional to the fourth power of the axle load, more recent research has shown that thick well constructed fully flexible pavements do not weaken gradually through the effects of cumulative traffic loading but maintain their strength with time. For these pavements, the deterioration is not structural but generally occurs only at the surface. Provided that non-structural deterioration is detected and remedied before it has serious impacts on structural integrity, these pavements remain structurally serviceable for indeterminate periods without the need for any structural maintenance (i.e. maintenance is limited to the replacement of the wearing course at regular intervals and the underlying layers are “permanent”).

A significant proportion of the trunk road network is classified as “long life” (i.e. the pavements are sufficiently strong so that the structural life of the pavement is independent of vehicle loads) and this is accounted for in the costs per standard axle calculated in the preceding section.

However, there are also a range of defects in the surfacing of roads which could potentially be influenced by the level of traffic loading. The extent of deformation is related to the level of strain and hence rutting or deformation in the wheel paths will be dominated by vehicle loading. An investigation of the effect of traffic loading on pavement wear conducted by Merrill *et al.*, (2000, 2002) showed an almost linear response of area to load (i.e. an increase in wheel load would result in a proportional increase in rutting).

The simple analysis of congestion effects showed that if LHVs were permitted they would have the potential to offer more efficient use of road space. This could lead to an increase in the total weight of vehicles in lane 1 (and a consequent reduction in the total weight of vehicles in lane 2). In theory, this could lead to increased rutting in lane 1 and therefore more frequent resurfacing. However, it is considered that the introduction of LHVs, if permitted, would be unlikely to lead to a substantial change in the total weight of traffic carried in each lane because:

- Analyses in this report suggest that the distance driven by LHVs, if permitted, would be a relatively small proportion of all HGV travel.
- The benefits of more efficient use of road space would mainly apply in congested conditions - in light traffic most goods vehicles will be in lane 1.

D.3.4 Effects of LHVs on bridges and other infrastructure

One problem that may be associated with permitting the use of LHVs on the road network is the ability of bridges and other highway structures to carry these bigger vehicles and what effect they might have on structural performance. While bridges are routinely designed for loads considerably larger than those imposed by vehicles currently in use, this design loading must take account of other effects that might increase the applied loading, such as dynamic effects, overloading, etc. It cannot, therefore, be automatically concluded that LHV loading is catered for by the current loading specifications, even when the LHV is composed of currently permitted trailer units.

The potential effects of LHVs on bridges include:

- Increased magnitude and frequency of loading due to different axle and vehicle configuration and load (including dynamic and overloading effects)
- Increased horizontal load arising from braking and centrifugal effects
- Increased collision requirements for parapets
- Increased collision requirements for bridge supports and decks
- Increased wear and tear on joints and bearings
- Increased wear and tear on surfacing.

The ability of a bridge to carry LHVs will depend on the axle load and spacing for particular LHV configurations, and whether these are more onerous than a train of current vehicles. The main issue, therefore, is to consider how the loading imposed by LHVs differs from the axle load configurations used to derive the design loading. If the loading imposed by LHVs is greater than that used to design bridges then the risks associated with wear and failure of bridges would be expected to increase.

The assessment has focussed on the shear forces and bending moments generated by the LHVs on a range of bridge spans to verify that their load effects do not exceed those for which structures are designed. Wear and tear was not considered except for particular bridge components which have a lower service life, for example, joints, bearings, waterproofing, and surfacing. Wear and tear on these components has a knock-on effect on the structure because they induce dynamic effects. However, these are taken into account in the design loading, as discussed above.

D.3.4.1 Review of current bridge loading rules

The current loading specification used for bridges in the UK is given in the Design Manual for Roads and Bridges (DMRB) standard BD 37. Two types of loading are used. Normal traffic loading (HA) is based on loading generated by the current mix of vehicle types and configuration complying with the current Construction and Use and Authorised Weights regulations. In effect, HA loading represents the most severe loading that can be envisaged as a result of a span being full loaded by Heavy Goods Vehicles (HGVs).

Abnormal loading (HB) consists of a notional vehicle with a Gross Vehicle Weight (GVW) of up to 180 tonnes and is used to cater for the various heavy vehicles and trailers which are used to transport very heavy Abnormal Indivisible Loads (AIL) around the UK. Loading models for specific categories of “special” abnormal vehicles have also been developed. The loading specifications include the vertical loads due to heavy vehicles and the horizontal forces transmitted through the deck as a result of vehicle braking and centrifugal effects.

A comparison of the traffic loading specified in BD 37 with the anticipated loading from the LHVs assessed in this project needs to consider the following issues:

- Factors used in bridge design and their relevance to LVHs and their operation, including:
  - Partial load factors
  - Overloading
  - Dynamic amplification of loads
  - Lateral bunching
- Methods used to calculate load effects and how these effects are converted into the nominal loads given in BD 37
- Bridges are also designed for abnormally heavy vehicle loads (HB loading to varying specified levels). If the effects of the LHVs exceed that of normal loading, will the HB loading criteria be adequate to cater for their use.
- Bridges are designed for the extreme loading expected to occur during the service life of 120 years: this would arise from the worst combination of normal and abnormal vehicles.

HA loading

For bridge design, loading models have been developed to provide, with an adequate margin of safety, an envelope for the load effects (bending moments, shear forces, etc) that may be generated in service for a wide range of structures. Different national codes adopt different forms of loading model. In the UK, the model consists of a uniformly distributed load (UDL) and a knife-edge load (KEL) to represent "normal" traffic, that is, vehicles complying with the current Construction and Use (C&U) and Authorised Weights regulations. The use of a combined UDL and KEL was required so that the same model could be used for both flexure and shear. This is given the title HA loading and was devised by considering the effects of a train of vehicles acting on a bridge of varying span. The UDL to be applied to structures having a span of 50m or less was obtained deterministically while for spans greater than 50m a probabilistic analysis was carried out. The HA UDL is shown in Figure 81.

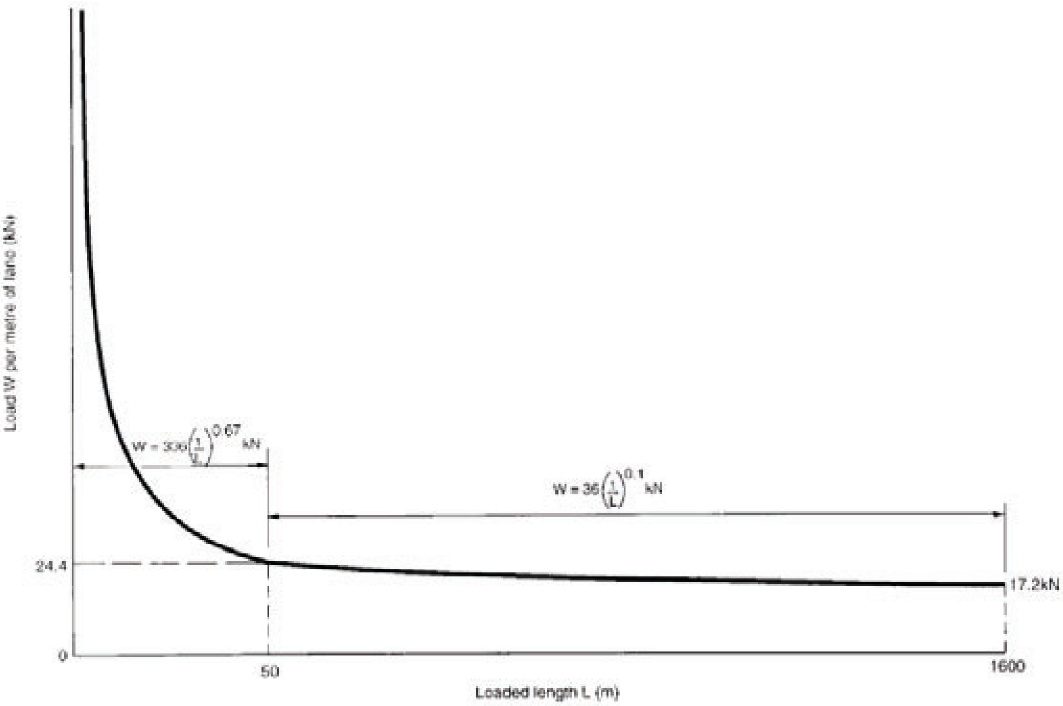


Figure 81: Loading curve for HA UDL (extract from figure 10 of BD 37)

The HA KEL consists of a single 120kN line load acting uniformly across the width of the lane across the lane, positioned to give the most onerous load effect being considered.

HA loading is intended to produce the worst loading to be expected from normal traffic, that is, vehicles complying with the C&U regulations, during the design life of the bridge. It was devised using a train of vehicles that contained a random mix of heavy and light vehicles. HA loading also takes account of:

- Dynamic effects due to bumpy roads, potholes, joints and suspension systems
- Lateral bunching of traffic in congested situations
- Overloading of vehicles beyond their legal limit
- Contingency of 10% to allow for future increase in vehicle weights.

In the derivation of HA loading, a 3m gap was assumed to exist between the last axle of the preceding vehicle and the first axle of the following vehicle.

An dynamic amplification factor of 1.8 was included only in the single vehicle cases (i.e., for bridge spans that can only accommodate one vehicle) and was only applied to the worst (heaviest) axle load.

An overloading factor of up to 40% is included in HA loading. The factor is taken as 1.4 for spans between 2m and 10m, reducing linearly to 1.0 for spans between 10m and 60m. For spans greater than 60m, no overloading is considered, because it would be expected that overloaded vehicles would be balanced by partially loaded ones.

In addition to the gross weight of a heavy vehicle, the loading imparted to a bridge or part of a bridge is dependent on a single heavy axle or wheel load. HA loading includes the requirement to apply a single nominal wheel load of 100kN placed anywhere on the carriageway. This is to take into account of local effects on the bridge or part of the bridge.

With HA loading, three span categories can be defined which have different critical loading condition:

(i) 0 - 10m, where single axle or bogie loading is dominant

(ii) 25m - 40m, where multiple vehicle loading is dominant

and (iii) a transition region from 0m to 25m where the dominant loading changes from axle/bogie to vehicle dominant

<u>HB loading</u>

To cater for non-complying or abnormal vehicles, HB loading is also specified. This consists of an arrangement of patch loads to represent a notional HB vehicle with four axles and a total length varying between 10m and 30m. It should be noted the HB vehicle does not relate to a particular vehicle configuration but is intended to represent a range of abnormal vehicles with total weight up to 180 tonnes and axle loads up to 45 tonnes.

The magnitude of the HB loading to be used in design is expressed in terms of a number of “units”, where 45 units represents an axle load of 450kN, or a total applied load of 180 tonnes. HB loading is intended to take account of vehicles that are not in compliance with the C&U regulations. In the UK, bridges are designed for a number of units of HB depending on the class of structure:

Motorways and trunk roads	45 units (total load of 180 tonnes)
Principal roads	37.5 units
Other public roads	30 units
Accommodation bridges	0 units

D.3.4.2 LHV types assessed

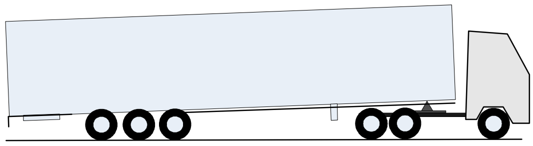
In this project the load effects resulting from the specified LHV types were determined and compared with those derived from the loading specified in BD 37. The LHVs types are shown below. It should be noted that the bridge loading models are based on maximum permitted axle weights and the sum of those weights. The sum of the maximum permitted axle weights always exceeds the permitted gross weight to allow for variation in weight distribution on the loaded vehicle. Therefore, the total weights used in the bridge loading model and quoted below exceed the permitted GVW.

1) Baseline - 6 axle articulated vehicle

GVW 44 tonnes

Maximum axle weight and minimum axle spacing

1:	7,100	
2:	7,100	3.000m
3:	10,500	1.370m
4:	8,000	5.392m
5:	8,000	1.360m
6:	8,000	1.360m
Total:	48,700kg	



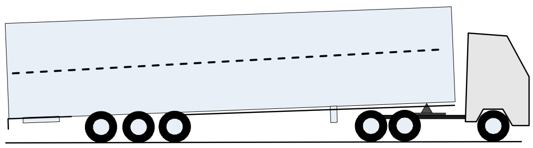
Vehicle 1 is a typical HGV with 44 tonne GVW which complies with the current C&U regulations. The loading imposed on a bridge is therefore covered by the current bridge loading specified in BD 37.

2) Improved inside current limits (double deck)

GVW 44 tonnes

Maximum axle weight and minimum axle spacing

1:	7,100	
2:	7,100	3.000m
3:	10,500	1.370m
4:	8,000	5.392m
5:	8,000	1.360m
6:	8,000	1.360m
Total:	48,700kg	



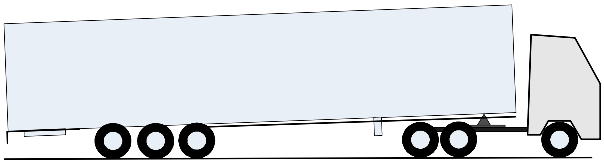
Vehicles 1 and 2 are identical except for increased vehicle height. The maximum wheel/axle configuration is the same. Vehicle 2 need not be considered separately.

3) Tractor, 16 m semi-trailer

GVW 44 tonnes

Maximum axle weight and minimum axle spacing

1:	7,100	
2:	7,100	3.000m
3:	10,500	1.370m
4:	8,000	7.792m
5:	8,000	1.360m
6:	8,000	1.36m
Total:	48,700kg	



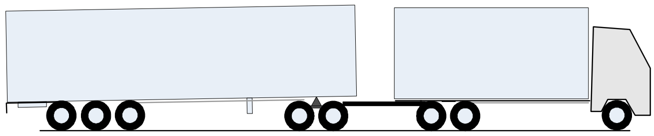
Vehicle 3 is similar to Vehicle 1 but with a longer wheel base: the GVW is limited to 44 tonnes.

4) Rigid truck, converter dolly (A), semi-trailer (increased length only)

GVW 44 tonnes

Maximum axle weight and minimum axle spacing

1:	8,500	
2:	11,500	4.500m
3:	7,500	1.370m
4:	8,000	5.015m
5:	8,000	1.310m
6:	8,000	7.337m
7:	8,000	1.360m
8:	8,000	1.360m
Total:	67,700kg	



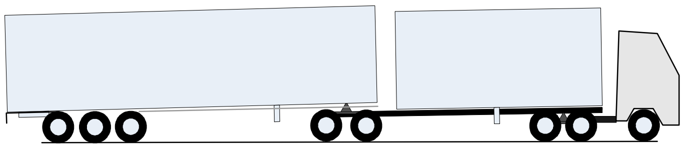
Vehicles 4 and 6 are essentially the same except that in Vehicle 4 the GVW is limited to 44 tonnes. Therefore there is no need to consider vehicle 4 because 6 is a heavier vehicle.

5) Tractor, ‘interlink’ semi-trailer, semi-trailer (B-double) (increased length only)

GVW 44 tonnes

Maximum axle weight and minimum axle spacing

1:	7,100	
2:	7,100	3.000m
3:	10,500	1.370m
4:	9,000	10.210m
5:	9,000	1.810m
6:	8,000	7.097m
7:	8,000	1.360m
8:	8,000	1.360m
	Total:	66,700kg



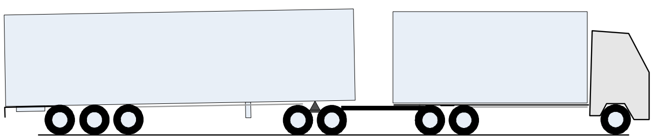
Vehicles 5 and 7 are essentially the same except that for Vehicle 5 the GVW is limited to 44 tonnes. Therefore there is no need to consider vehicle 5 because 7 is a heavier vehicle.

6) Rigid truck, converter dolly (A), semi-trailer (increases length and weight)

GVW 60 tonnes

Maximum axle weight and minimum axle spacing

1:	8,500	
2:	11,500	4.500m
3:	7,500	1.370m
4:	8,000	5.015m
5:	8,000	1.310m
6:	8,000	7.337m
7:	8,000	1.360m
8:	8,000	1.360m
	Total:	67,700kg



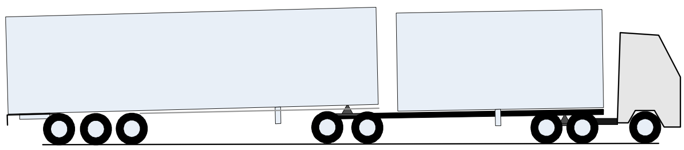
Vehicle 6 is a combination of a semi-trailer coupled to a rigid truck.

7) Tractor, 'interlink' semi-trailer with fifth-wheel coupling, semi-trailer (increased length and weight)

GVW 60 tonnes

Maximum axle weight and minimum axle spacing

1:	7,100	
2:	7,100	3.000m
3:	10,500	1.370m
4:	9,000	10.210m
5:	9,000	1.810m
6:	8,000	7.097m
7:	8,000	1.360m
8:	8,000	1.360m
	Total:	66,700kg



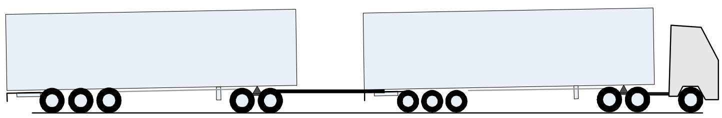
Vehicle 7 is a second semi-trainer coupled directly to the first semi-trailer using a fifth wheel coupling mounted to the first semi-trailer.

8) Tractor, semi-trailer, converter dolly (C), semi-trailer (C-train) (Increased length and weight)

GVW 82 tonnes

Maximum axle weight and minimum axle spacing

1:	7,100	
2:	7,100	3.000m
3:	10,500	1.370m
4:	8,000	5.392m
5:	8,000	1.360m
6:	8,000	1.360m
7:	8,000	5.688m
8:	8,000	1.310m
9:	8,000	7.337m
10:	8,000	1.360m
11:	8,000	1.360m
	Total:	88,700kg



Vehicle 8 is a combination of an articulated vehicle coupled to second semi-trailer using a converter dolly.

D.3.4.3 Comparison of HA and HB loading with LHV loading

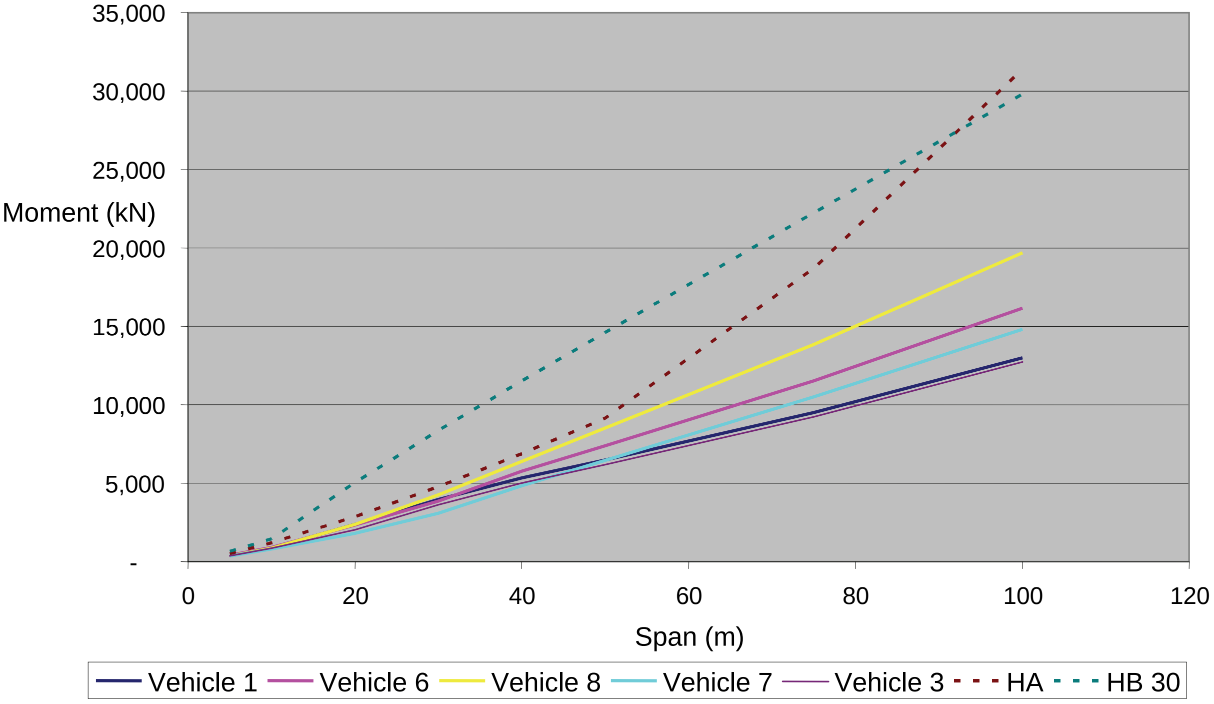
The analysis of the effects that might be expected if the LHVs assessed were permitted consisted of determining the maximum mid-span bending moment and the maximum shear force using an Excel spreadsheet to carry out the calculations.

The analysis consisted of allowing each LHV to roll across a simply supported “bridge” with a particular span carrying one lane of traffic. Transverse effects were not considered. The maximum moments and shear forces were determined. The analysis was then repeated for different spans in the range 5.0m to 100m. The following assumptions were made in the analysis:

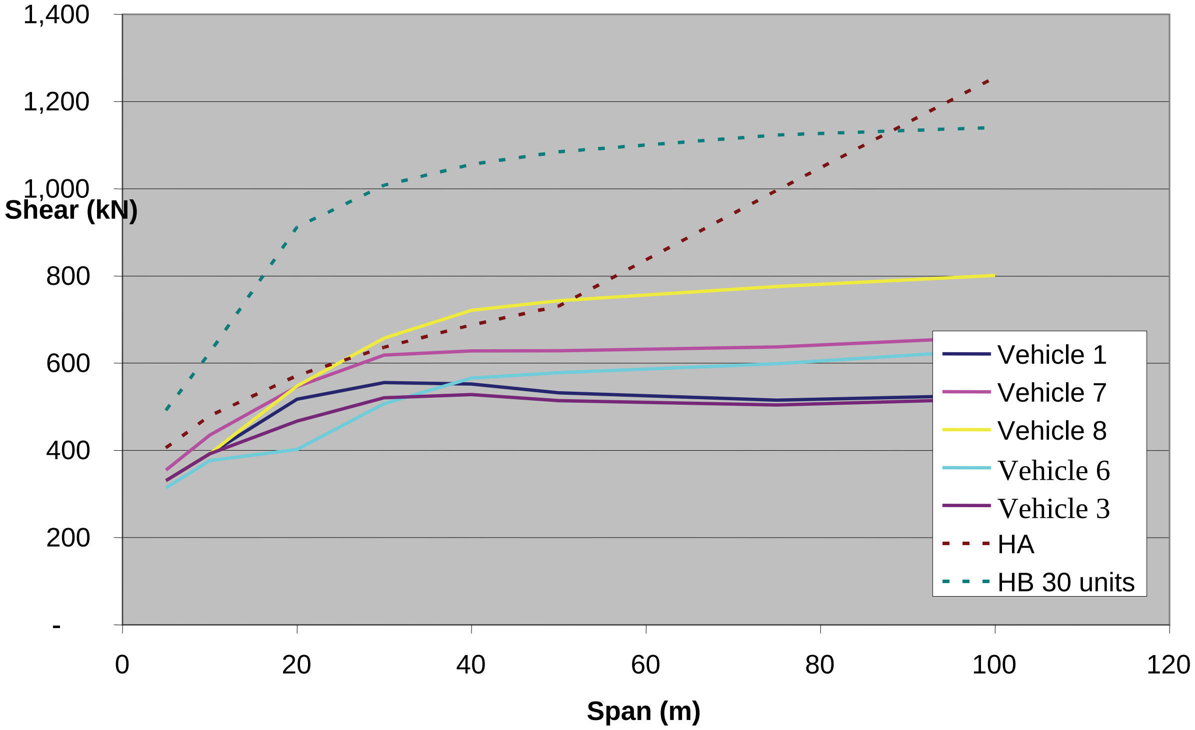
- The individual axle loads were taken as the maximum allowable values for each axle. This gives a GVW about 10% greater than that allowed. This is a conservative simplification to limit the number of loading configurations required.
- The axle spacings used were obtained for particular vehicles. It is possible that more extreme effects may be obtained if a reduced axle spacing were to be allowed.
- Only single span, simply supported cases were considered: spans in the range 5-100m were examined.
- An impact factor of 1.8 was applied to the heaviest axle of the LHV
- An overloading factor was applied to all axles. This consisted of a factor of 1.4 for spans between 2m and 10m, reducing linearly to 1.0 for spans between 10m and 60m. For spans greater than 60m, no overloading was considered.
- Partial load factors were taken as 1.0, which represents a conservative analysis.
- The effect of lateral bunching was not considered.
- Only single LHVs acting alone were considered. No other traffic loading was imposed.

As stated above, only a single LHV acting alone was considered in the analysis. In a design or assessment situation it would be necessary to include the effects of co-existing HA loading on lane section not covered by the LHV where it is possible that “ordinary” traffic could conceivably co-exist with the LHV. However, in this case, the impact factor of 1.8 on the heaviest axle could be removed, because it is normally only applied for single vehicle cases. In addition, this would only affect spans greater than the length of the LHV. For these reasons, co-existing HA loading was not thought to be significant.

The results of the analysis are summarised in Figure 82, which presents a) the calculated bending moments, and b) the calculated shear forces as a function of span using the above assumptions. Vehicles 2, 4 and 5 were not considered, for the reasons described above. For comparison, the design bending moments and shear forces for HA loading and 30 units of HB loading are also shown. The moments and shear forces are “nominal” values, that is, no partial load factors are included.



a) Maximum mid-span moment



b) Maximum shear force

Figure 82: Maximum load effects for the different LVH scenarios.

The following conclusions were drawn from the results of the analysis:

- As expected, the maximum moments and shear were produced by Vehicle 8, an LHV with a GVW of 82 tonnes.
- The bending moments produced by each of the LHVs assessed are less than those obtained from HA loading in all cases. This was because the LHVs are composed of a combination of standard tractor/trailer units.
- For short spans, up to 10m, the loading is controlled by the single heavy axle or bogie in the vehicle configuration. For these cases, the moments produced by all LHV scenarios are very close to those from the HA loading.
- For spans up to 40m or so, the LHV moments are again very close to those for HA loading. This is because each LHV is similar to two conventional vehicles placed close together.
- For spans greater than 40m, the HA loading becomes more onerous than the LHV loading. This is because, with HA loading, the whole span is loaded while for the analysis carried out here, the LHV is acting alone.
- Similar conclusions can be drawn for shear. However for vehicle 8 travelling on bridge spans in the range 27.0 - 51.0m, the shears are marginally greater than those obtained from HA loading. The HA values are exceeded by up to 5%.
- All of the LHVs assessed are comfortably covered by 30 units of HB loading for both bending and shear.

D.3.4.4 The design loads for existing bridge stock

The preceding analysis has shown the effects that LHVs would be expected to have on the loading of bridges built to current design standards. However, these design standards are only applied to new bridges on the trunk road network. Older trunk road bridges may be in existence that do not meet these requirements.

Data extracted from the SMIS database of bridge loading capacities are shown in Figure 83. This shows the loading criteria used to design the Highways Agency’s 5,800 under-bridges (i.e. bridges carrying the motorway / trunk road network).

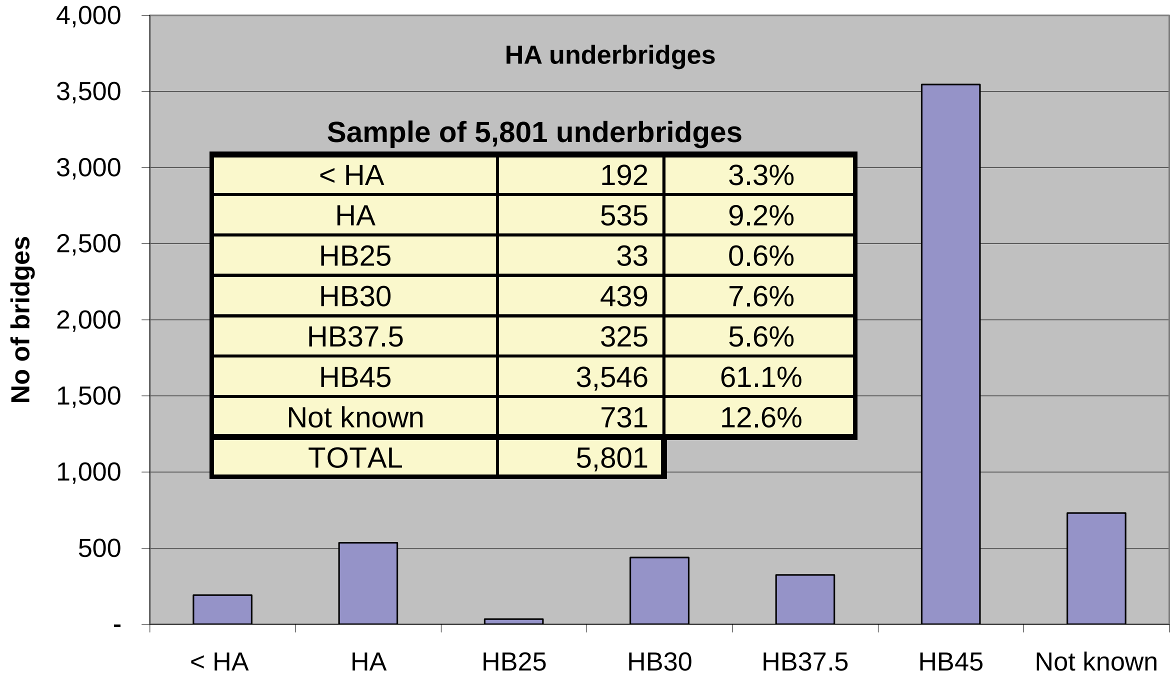


Figure 83: Loading standards for HA bridge stock

Figure 83 shows that approximately 75% of these bridges were designed for at least 25 units of HB and are thus likely to be adequate for all of the LHVs assessed. Nine percent of bridges were designed only to HA loading criteria, meaning that they would be expected to be adequate for all the LHVs assessed except for the 82 tonne variant when the bridge span is between 27m and 51m. Just over 3% of the bridges were constructed to standards lower than HA and thus would not be suitable for existing 44 tonne vehicles or any of the LHVs. Twelve percent of bridges were built to unknown standards.

A maximum of approximately 25% of trunk road bridges would be affected if the C-train were to be permitted. However, the span of the bridges was not taken into account, so it is not known how many of these bridges have spans in the critical 27-51m range. If 60 tonne LHV combinations were permitted only the 3.3% of bridges known to be constructed to less than the HA standard (plus whatever proportion of the 12.5% unknowns fell into this category) would be at risk. LHVs at 44 tonnes would offer no threat to bridges over and above that already in existence in relation to 44 tonne articulated vehicles.

No comparable information was available for local authority owned bridges. However, at a focus group meeting with infrastructure owners and enforcement agencies the stakeholders present suggested that a much greater proportion of local authority bridges would be at risk at each level of increased weight. Stakeholders suggested that if LHVs were to be permitted there would either need to be a comprehensive review of the bridge loading standards of those bridges owned by local authorities (and for those trunk road bridges where the standard was unknown) or LHVs would have to be prohibited from travelling on non-trunk roads.

If any LHVs were to be permitted with an increased GVW then it will be necessary to survey the bridges where the load that they are designed to is currently unknown. If 82 tonne LHVs were permitted it is likely that up to 25% of trunk road bridges and a greater proportion of local authority bridges would be at risk. If the LHVs were prohibited from passing over these bridges it would be likely to substantially limit the routes that they could travel on or a substantial capital investment would be required to upgrade the bridges. If LHVs were permitted at a GVW of 60 tonnes then a similar exercise in route restriction or bridge upgrading would be required but the route limitations or capital investment would be substantially smaller in magnitude. If LHVs were permitted at a GVW of

44 tonnes then no adverse effects on bridge loads would be expected over and above those already applied to standard 44 tonne vehicles. Payload neutral options were not studied in detail at this stage and may have adverse effects on those bridges constructed to less than HA standards but the number of bridges affected would be expected to be substantially less than for the 60 tonne vehicles.

D.3.4.5 Other effects

In addition to vertical loads, permitting LHVs could have other structural implications which need to be considered. These are discussed in the following sections. The intention is to highlight the issues involved, indicate the scale of the problem and identify where more detailed consideration may be required.

Collision loads

Bridge supports must be designed to resist the loads that may result from strikes by errant vehicles. The collision loading to be used is specified in BD 60 (this superseded the lower loads previously given in BD 37) and is shown in Table 84.

Table 84: Collision loads on supports for highway bridges (from BD 60).

	Load normal to the carriageway	**Load parallel to the carriageway**	**Point of application**
Main load component	500 kN	1,000kN	At the most severe point between 0.75m and 1.5m above carriageway level
Residual load component	250 kN (100kN)	500kN (100kN)	At the most severe point between 1m and 3m above carriageway level

Note: Figures in brackets are the residual loads to be applied to foot/cycle track bridges in urban locations with robust plinths.

The loading consists of two separate loads applied at different points and in different directions. These loads are intended to ensure that bridges are sufficiently strong or adequately protected so that they can resist collision forces. The overall structural integrity of the bridge should be maintained, although local damage to part of the structure is acceptable.

It should be noted that these collision are based on the impact loads produced by a 30 tonne vehicle travelling at 72 km per hour (40mile/h). Thus, they do not represent the worst collisions that could occur with vehicle classes already permitted. A 44 tonne vehicle travelling at 56 mile/h would be expected to apply considerably higher loads than prescribed by the standard. It could, therefore, be argued that permitting LHVs with higher maximum weights would not increase the risk because 44 tonne vehicles already present the same risk. However, if structures are constructed to exceed the minimum standards it is possible that they may survive collisions with 44 tonne vehicles but may not survive the same collision with a 60 tonne vehicle.

However, there are a number of unknowns for this simplistic analysis. For example, stakeholders at a focus group meeting for infrastructure owners suggested that vehicles with multiple articulation points may not apply the worst case loads imagined because the trailers may rotate around their pivot points during the collision, thus reducing the peak loads applied. However, it was also considered that this behaviour could cause secondary problems in that many bridge supports are now protected by crash barriers. Concern has been expressed that the initial impact with the front of an LHV combination could damage the barrier such that it was unable to prevent a secondary collision with a trailer rotating about its pivot point. Stakeholders suggested that older pedestrian bridges were likely to be most at risk because many of these had relatively weak support structures. Reducing the maximum speed that heavier vehicles could travel at would form one way of mitigating this risk. Abnormal loads do travel already on the UK road network at weights of more than 300 tonnes. However, these vehicles are limited in speed such that vehicles between 44 and 50 tonnes GVW can travel at the same speeds as 44 tonne HGVs, those between 50 and 150 tonnes are limited to 40 mile/h on motorways (35 mile/h on dual carriageways and 30 mile/h on other roads) and those in excess of 150 tonnes are limited to 12 mile/h on all roads. It is clear that more detailed analysis, likely to include physical testing, would be required to establish whether LHVs would or would not present a higher risk in collisions with bridge supports, compared with vehicles that are already permitted.

TRL have investigated the economics of increasing the design collision loads for both new construction and the strengthening of existing bridges (Daly and McMahon 2006). Using two typical bridges as case studies, the increased costs for new construction were between £4.0k and £67.0k per bridge column depending on the type and layout of each individual structure and on the method adopted (increased strength, very high containment barrier, etc). For existing bridges, the costs of strengthening are dominated by user delay costs, the total cost being in the range £40.0k to £285.0k per bridge column.

Collision loads on bridge decks (bridge strikes) may be increased if LHVs with increased GVW were to collide with them. However, stakeholders have suggested that the biggest problem with deck collisions is with flat bed vehicles carrying machinery where the height of the vehicle is not readily defined. The risk of such a collision occurring would be controlled by ensuring that the clearance under bridges is well in excess of the maximum height of vehicles. The clearance under bridges is a minimum of 5.03m on UK motorways and trunk roads. If LHVs were permitted on trunk roads only then they will not present a bridge strike hazard. However, assessment of any local authority roads to be used will need to consider this issue. Stakeholders have also suggested that an increased use of double decked vehicles on non-trunk roads could also present an increased risk of bridge strikes and that if such an increase occurred more sophisticated warning systems may need to be considered.

It has not been possible to derive an estimate of cost for ensuring that bridges are sufficiently strong to withstand collisions with LHVs with increased GVW because of the difficulty of separating the concerns that the requirements are insufficient for current vehicles, the fact that heavier vehicles do use the network albeit at reduced speed, a lack of information about the structures of the current bridge stock and the lack of testing to determine what additional loads LHVs would apply and how effective barriers were at deflecting them. Further research would be required in this area if further consideration was given to permitting LHVs with substantially increased GVW.

Centrifugal forces need to be considered when vehicles travel at speed on bridges curved in plan with radius of curvatures less than 1,000m. BD 37 specifies the centrifugal force to be used as 40,000/(r+150) kN, where r is the radius of curvature of the lane. The load should be applied in any two notional lanes in each carriageway at any number of points at 50m centres, oriented radially. This load produces lateral bending in both the deck and the support system.

The BD 37 load was developed from tests carried out at TRL in the 1970s to determine the maximum centrifugal accelerations that drivers can tolerate (from the point of view of vehicle safety rather than personal comfort) when cornering in a car and a truck. The constant in the force equation has been adjusted through different versions of the bridge load specifications to allow for increases in vehicle weight.

The maximum centrifugal force generated by an LHV travelling on a curved bridge is a direct function of the gross weight. The critical case would be for Vehicle 8 (GVW 82 tonnes): this would impart similar centrifugal forces as two separate semi-articulated vehicles, although it is unlikely that two such vehicles would be travelling so close together at speed over a tightly curved bridge. It is likely that the specified centrifugal force is conservative, bearing in mind that it is based on the maximum acceleration that vehicle occupant can tolerate.

Braking forces are longitudinal forces acting on a bridge and its supporting structure imposed by a braking vehicle. These loads are transmitted to the bridge through friction between the tyres and the road surface. The specified loads are also intended to cover traction forces. The normal (HA) braking load model given in BD 37 was derived by assessing the likely loads generated by trains of HGVs braking simultaneously. The nominal longitudinal load is 8kN per metre span plus 250kN, up to a maximum of 750kN, in one lane only. This is intended to reflect the likelihood that for spans greater than 60-65m, in an emergency situation, the first vehicle in a convoy will have come to rest before the last vehicle has started braking.

For HB loading, the specified longitudinal load is 25% of the total HB load. In addition, an accidental skidding load should also be considered, consisting of a single 300kN load in one lane acting in any direction. However, it should be noted that HB loading is related to vehicles carrying abnormal loads and the minimum standards of brake performance for the heaviest of these vehicles is lower than that of standard HGVs and it would be expected that if LHVs were permitted they would be required to meet at least the same standard of brake performance as current 44 tonne vehicles.

A simple way of determining the longitudinal load expected from LHVs is to apply the 25% value used for HB loading. The worst case assessed in this project would be Vehicle 8, which has an 82 tonne gross weight and a length of 30m. The longitudinal load can be estimated to be 205kN based on this method. However, the legal minimum standard for brake performance of standard HGVs is a deceleration of at least 0.5g. This level of deceleration would imply a longitudinal load of approximately 402 kN. Measurements made at TRL suggest that deceleration levels for modern HGVs can be as much as 0.78g (Knight *et al*, 2002). This would give a braking load for the 82 tonne vehicle of 627kN and a load of 337kN for a 44 tonne vehicle.

The nominal HA longitudinal load to be used in the design of a bridge with a 30 metre span is 8x30 + 250 = 490kN. For limit braking a “partial factor” of 1.25 is added to this such that the maximum limit is 613kN. Thus, it can be shown that the design requirements for longitudinal loads are adequate for even the best brake performances of current HGVs. It would also be adequate for a 60 tonne vehicle achieving the best likely deceleration for a modern vehicle (460kN) and for an 82 tonne vehicle just meeting the minimum standard of brake performance (402kN). However, if the 82 tonne vehicle were capable of achieving deceleration equivalent to the best modern 44 tonne articulated vehicles, then the braking forces would exceed the HA design requirement. The threshold level for deceleration that would result in a vehicle just exceeding the design limits would be 0.76g. This exceedance is only likely to hold true for medium span bridges where the LHV is the only vehicle that can fit on the bridge. For shorter spans the HB design loading is sufficient to cover all of the LHV loads and on longer spans the presence of multiple vehicles on the structure is likely to mean that the load from LHVs is covered.

If the braking systems of LHVs are further improved in comparison with the best standard 44 tonne articulated vehicles, then higher braking forces might occur which may mean that 60 tonne vehicles could exceed the bridge design requirements. However, improvements in deceleration over 0.8g are likely to be difficult to achieve in practice because the performance will quickly become limited by the available friction between the tyres and the road surface.

As for the vertical loading, if 82 tonne LHVs were to be permitted the bridge stock would have to be reviewed to assess whether they were capable of taking the additional braking loads. Any bridge that was not would have to be excluded from any permitted routes for LHVs or strengthened. If strengthening were required, the costs would be similar to those quoted for column strengthening for collision loading, above.

D.3.5 Rest stops, parking facilities and interchange points

If LHVs were to be permitted it would be essential that they could gain access to sufficient parking facilities to enable drivers to take their mandatory rest breaks. In some areas of the country there is a shortage of Heavy Goods Vehicle parking, with “fly parking” occurring in illegal or undesirable areas such as on hard shoulders. Many stakeholders from all of the focus groups (including the road freight hauliers groups) have expressed concern that permitting LHVs would exacerbate this problem as described below.

Goods vehicle parking at Motorway Service Areas (MSAs) was designed to accommodate the maximum length vehicles in use at the time they were built. Some MSAs are more than 20 years old and were not designed to accommodate 18.75m vehicles already in use. A significant number have back-to-back parking for two Heavy Goods Vehicles and an LHV could, therefore, use two spaces. However, this could have an adverse effect on capacity even if the use of LHVs did lead to a reduced number of goods vehicle trips. Even if zero mode shift or induced demand occurred only the largest LHV type assessed here would reduce the number of trips by the same factor as the number of available parking spaces would be reduced if each LHV took two existing spaces. For any other type assessed, and for all types if any mode shift or induced demand occurred, then the reduction in the number of goods vehicle trips would be less than the reduction in available parking spaces. It is possible that the occupation of multiple parking bays by a single vehicle would constitute a breach of the parking capacity requirements (number of heavy goods vehicles) set out in the MSA operator agreements.

At many MSAs, HGV spaces are single bays and there would be no spaces available for LHVs without substantial changes to the layouts. If no changes were made this would substantially reduce the number of MSAs that LHVs could use to take their rest breaks.

Newer MSAs would have parking bays designed to accommodate 18.75m drawbar combinations and so the 18.75m articulated vehicle type of LHV, if permitted, would not be expected to create any additional parking problems over and above those already in existence and may reduce the existing problems if the measure reduced or limited the expected growth in overall goods vehicle traffic.

There may also be problems with the access and internal roads at many MSAs. These are not required to conform with HA design standards for motorways and there are some areas where existing length vehicles can only negotiate the geometries at very slow speeds. This would be a particular concern for any LHV types that were not capable of meeting current manoeuvrability requirements.

Some MSAs are designed in a way that allows them to accommodate vehicles carrying Abnormal Indivisible Loads (AIL), which can be longer than the LHVs assessed in this report and are not required to meet existing standards of manoeuvrability. This means that there will be some MSAs to which LHVs could physically gain access but these MSAs are typically only designed to accommodate one or two AIL vehicles. The HA has some data, generated by police forces, highlighting areas where suitable lay-bys and MSAs do exist but also where problems are experienced even with the relatively low number of AIL movements. A sample table of such facilities is included in section D.4. Further data regarding lay-bys for AIL vehicles may be generated as part of a future project assessing the scope of moving AILs at night and this could contribute very useful information to any further study of parking issues for LHVs, if further activity in this area is considered.

There are currently 92 MSAs in England if two sided facilities are counted as separate facilities. Six more are at various stages of the planning or development process and while it is possible that more new facilities will be proposed it is anticipated that there will not be many more. At this stage it is not known how many would be capable of accommodating LHVs but stakeholders have suggested that all of them would require at least some physical alteration if LHVs of more than 18.75m in length were to be permitted

Truck stops are often better equipped for Heavy Goods Vehicles and may be better equipped for LHVs. However, they are often situated on poorer quality roads and there have been problems with closures of truckstops in recent years. However, the EC has recently commenced a pilot project (www.SETPOS.eu) which it is part funding that aims to develop much improved truck stops. As part of this project a secure truck stop will be developed at Ashford and the intention is that the project will encourage further development of secure parking facilities on the Trans European Road Network

Some stakeholders in this study and some of the European studies of LHVs have suggested a potential mode of operation whereby an LHV would carry a load along the main trunk route (e.g. motorway) before stopping at a special interchange point where the vehicle would be split into two for onward distribution into urban areas. Such interchange points would not require many special facilities – the vehicles could be separated into their constituent parts at any suitable parking area provided that there is appropriate access, and space to manoeuvre and securely park trailers, dollies, etc as required. However, such sites do not currently exist in the UK and the use of existing MSAs would be problematic because of available space, health and safety constraints, and a lack of incentive for MSA operators to invest in such facilities.

Stakeholders have suggested that the improvement of current facilities would be difficult because of substantial constraints associated with land availability and planning permission and because the HA has no power to require MSA operators to undertake the necessary works. For example, it has been suggested by stakeholders that many MSAs have already developed to the maximum size that they have available, and surrounding land may be privately owned and/or developed for other purposes such as housing and/or industrial premises. It has been suggested that improvements at existing sites would, therefore, have to be a matter of negotiation between the HA and each operator and that this would take substantial time and resources and offers no guarantees of success.

Stakeholders have suggested that it would be more practical to build dedicated facilities, if LHVs were to be permitted, although these would still be subject to the difficulties of land availability and planning permission. It was suggested that, based on a previous study considering the possible introduction of free-standing motorway picnic areas, that a cost of £5m to £7m plus land acquisition costs could provide access and egress slip roads, parking space for in the region of 6 LHVs (>18.75m) and a toilet facility. It was suggested that, based on an estimate that such facilities would be required every 30 miles, this would equate to a cost of approximately £1m per mile of LHV route network. It was suggested that construction of such sites would take in the region of 3 to 5 years from the point the instruction was given assuming that the financial and physical resources were made available and guaranteed.

Several attempts have been made, in consultation with stakeholders, to estimate the number of such facilities that may be required without detailed analysis. Although it is possible to make simplistic estimates it was considered that these estimates were not sufficiently robust to enable the investment cost required to be reliably estimated. For example, if it were assumed that away from the motorway network sufficient opportunities existed to park in lay-bys, industrial estates and operators premises but that dedicated rest stops would be required every 30 miles on the motorway network, it can be estimated that 146 stops would be required at a cost of approximately £4.5 billion. This is a considerably greater number of rest areas than is currently provided for standard vehicles (92), which reflects an assumption that limitations on access to lesser roads would mean that on-line facilities would be required for LHVs, whereas many existing motorway service areas are located at junctions and are, therefore, able to serve both carriageways. If access limitations were such that parking facilities at junctions were acceptable then the number of required facilities could be reduced. A further reduction could, in reality, be achievable because the demand for use by LHVs on certain parts of the motorway network may be insufficient to warrant their inclusion in the routes available to such vehicles.

In addition to this, the modelling of existing trip data from the CSRGT (see Appendix G) suggested that 93% of existing trips by articulated vehicles lasted less than 4.5 hours. In theory at least this would mean that if suitable facilities were available at origins and destinations then the majority of rest stops could be taken at warehouses and depots. However, this is not necessarily consistent with the fact that it is generally considered that there is a current shortage of parking facilities.

What these simplistic analyses are really showing is that predicting the demand for LHV parking spaces is likely to need a complex analysis including factors such as the:

- number of trips undertaken by LHVs,
- proportion of those trips where drivers hours could be exceeded,
- availability of rest facilities at origins and destinations,
- time of day the trip is undertaken,
- preferences of individual drivers

- propensity to pay of drivers in different market sectors

Most of these factors could not be objectively considered within the scope of this study.

It was clear from the fact finding activities that there are existing problems in relation to parking current vehicles and that these would be exacerbated by the introduction of LHVs, even if the overall number of vehicle trips was reduced as a result. The extent to which these problems would be exacerbated, and the exact number of MSAs and Truckstops that would have difficulties in accommodating LHVs, is not currently known. The initial views of stakeholders and the simplistic analyses carried out have principally served to highlight the complexity of this problem and a lack of detailed knowledge about the national use of rest stop facilities by the haulage industry at the moment. Without this important baseline data it is not possible to reliably estimate the overall effect that the introduction of LHVs>18.75m would have and what investment might be required. Clearly, this would need to be considered carefully if LHVs >18.75m were to be permitted. However, it should be noted that permitting longer articulated vehicles of up to 18.75m would not be expected to exacerbate any of the existing parking problems.

It is understood that a national truck parking study is to be undertaken by the Highways Agency and DfT. This study is likely to generate at least some of the baseline information regarding the existing use of facilities that would be necessary to allow a more detailed study of the impact that LHVs, if permitted, would be likely to have on parking provision.

D.3.6 Assessing the need for route restrictions

Virtually all of the stakeholders involved in the fact finding exercise, including infrastructure owners, enforcement agencies, representatives of other road users, safety organisations, freight shippers and hauliers, agreed that it would be undesirable to permit LHVs on all road types, although opinions varied about the specific restrictions required and which vehicles, if permitted, would require more or less restriction

The views of infrastructure owners generally supported the analytical work showing that the heaviest vehicles being assessed presented a risk to a substantial proportion of current bridges and that although 60 tonne vehicles could be accommodated by most bridges on the trunk road network there was likely to be a much greater proportion of local authority bridges that would be at risk. Local authority pavements are also much less likely to be constructed to “long life” standards and road wear may become an issue.

Stakeholders expressed considerable levels of concern with respect to manoeuvrability, field of view and the interaction with other road users, particularly cyclists and pedestrians. It was highlighted that although excluding LHVs from urban areas would substantially reduce any risks from interaction with vulnerable road users it would not eliminate it because, for example, a substantial number of cyclists do use rural “A” roads and more occasionally dual carriageways.

Comparing the views of stakeholders and the objective analyses of safety (see Appendix B) showed that in the main there was also agreement on these issues. However, it is worth noting that in a few cases the objective analyses did not support the views of stakeholders. For example, one frequently cited concern was that permitting LHVs would worsen the existing problem of left hand drive trucks side-swiping adjacent cars when changing lanes to the right on dual carriageways and motorways. However, the objective analysis of field of view showed that the field of view to the immediate side of the vehicle when travelling in a straight line was the same for all LHVs assessed as for the reference baseline vehicle.

The safety analysis showed that a number of the physical risks, particularly those relating to manoeuvring and field of view, would be more of a problem on urban or minor roads. Analysis of accident data suggested that larger vehicles had disproportionately higher casualty rates on minor roads and suggested that restricting access for LHVs to motorways and rural trunk “A” roads would result in an LHV casualty rate comparable to the current overall rate for all HGVs on all roads.

In addition to the safety concerns, stakeholders expressed a range of other concerns relating to the manoeuvrability of LHVs. It was noted that if low speed off-tracking increased it was likely that there would be increased damage to infrastructure at junctions and roundabouts as a result of vehicles running over the road edges. It was also noted that, although most new trunk roads and particularly motorways were designed with geometries likely to be able to accommodate LHVs, there were many older junctions even on motorways that included very tight radius bends on slip roads and small roundabouts that stakeholders believed may create problems for any LHV types that exhibited increased off-tracking. In general, there was a consensus among the infrastructure, enforcement and road safety stakeholders that if LHVs were to be permitted, it would be highly desirable to maintain the current minimum standards for turning circles and manoeuvrability, even if they were restricted principally to the motorway network.

Some stakeholders highlighted potential congestion and network capacity impacts in areas where there were a large number of junctions and cross-roads and safety risks in terms of railway crossings. It was considered that these effects would increase with vehicle length. This was a view supported by scientific literature on the subject. A number of studies (e.g. Glaeser, 2006, Ramsay, undated) reported that the increased length of vehicles in urban areas was likely to lead to problems because of an increased time to clear junctions when manoeuvring and because of requirements for a longer inter-green time at traffic light controlled junctions.

Experience in other countries also supports network restrictions. The trials in Germany and the Netherlands all imposed route restrictions and it is routine practice in countries such as the USA, Canada, Australia and New Zealand to restrict LHV access. Sweden and Finland allow 25m vehicles on many of their roads but do prohibit such vehicles from urban areas.

It is also important to note that there is a strong interaction between vehicle design and route restrictions applied to any vehicle. Whilst the information gathering exercise has highlighted a number of concerns in terms of safety, congestion, and the ability to negotiate junctions, it should be noted that these could be controlled either through route restrictions, vehicle construction requirements or through a combination of both. An example of this is the performance based standards under development in Australia (Moore, 2007). This defines a series of vehicle performance tests and four performance levels. Route restrictions are applied depending on which of the four performance levels the vehicle satisfies. This would mean that the road network would also need to be categorised into several levels according to risk.

D.3.7 The definition of route restrictions

A range of road network definitions are in existence and these are described below with an indication of their suitability for use as part of a definition of road restrictions.

- Motorways – Motorways are defined by a legal act, the motorway regulations, and are thus very clearly defined. Most motorways are expected to be suitable for LHVs but stakeholders have suggested that some risks remain and some junctions built to older standards may still present difficulties.
- Dual carriageways are easily defined in a technical sense but are not separately defined in any legal act. In most cases it is likely that dual carriage ways would also be suitable for LHVs but dual carriageways often only form part of any route along the same road with transitions between single and dual carriageways
- Trunk roads – Trunk roads are defined as any road where the Secretary of State is defined as the road authority. In theory this could be any road but in practice all trunk roads are “A” roads or motorways. Not all of the trunk road network was considered likely to be suitable for LHVs because it includes lots of single carriageways and small roundabouts and can pass through urban areas and villages. There are two additional complications with defining LHV use on the trunk road network:

  - The identity of the road authority is not clear and there is no visible clue for hauliers and drivers such that it would be difficult for them to know what roads were permitted and what were not.
  - In some specific cases, such as the M6 toll road, the Secretary of State is the road authority but not the owner of the road. In the case of the M6 toll, the road is privately owned by a company that then has a contract with the Secretary of State and the owner could possibly have the power to restrict the use of LHVs on their roads.

- Principal roads – Principal roads are generally defined as all “A” class roads, regardless of whether they are under HA or Local Authority control. Many “A” roads can be found in towns and city centres so it is unlikely that this would be a suitable definition for an LHV road network, if LHVs were to be permitted.
- Primary Route Network – Primary routes are defined in signing regulations as those that are designated by road authorities to form the main route between places of traffic importance. All non-motorway roads on the primary route network will have white on green signs whereas other non motorway roads will have black on white signs. Roads on the Primary Route Network are also shown in green on road maps. In terms of an LHV network this would have a key advantage in terms of the fact that it would be obvious to drivers and hauliers whether they were on a permitted route. However, not all of the roads on the primary route network would be of a high quality and many are likely to be unsuitable for use by the larger LHVs (>18.75m). In addition to this, there can be boundary problems where one authority designates a road as a primary route but an adjoining authority does not such that a road can change from primary to non-primary at authority boundaries.
- Urban/Rural roads – Many different definitions of an urban or rural road exist and these can be very subjective. It was, therefore, considered that such definitions would be unsuitable for use in defining an LHV road network.
- The Trans-European Road Network (TERN) – The TERN is defined by an EC Directive and is intended to cover the routes considered essential to international movements, for example between ports and airports. It is, therefore, possible to use this definition for an LHV road network but this is not necessarily desirable:
  - Firstly, some very poor quality roads are included in the TERN, although actions to improve this network are being undertaken.
  - Secondly, the roads defined in the TERN may not be those that the UK freight industry would gain most benefit from operating LHVs on.

Based on the safety and infrastructure analyses as well as the views of stakeholders, it is considered that, if LHVs >18.75m in length were to be permitted, the most suitable restrictions would be to motorways and rural trunk “A” roads that were principally dual carriageway. However, such a definition would have to be created, probably on a road by road basis and would possibly need to be applied through a legal Act. The central estimates in the analysis of costs and benefits have been made using the closest approximation to this definition which essentially includes all rural “A” roads because single and dual carriageway cannot be easily separated in current freight and traffic data. However, the analysis also showed that there was considerably less justification for restricting the routes that an 18.75m articulated vehicle conforming to current manoeuvrability criteria could travel on, thus, the central estimates of costs and benefits assessed this vehicle on the basis of access to all roads that current 44 tonne vehicles are permitted on.

The above findings notwithstanding, the information from stakeholders suggested that a more practical and cost-effective solution could potentially be found although this would depend on the volume of LHV traffic that might be undertaken by LHVs, if they were permitted. If the number of LHV movements was relatively small, it is likely that the most effective way to define route restrictions would be on a case by case basis using the “special order” system currently used for abnormal indivisible loads. This would involve hauliers to applying for permission to use specific

LHVs on specifically defined routes for a defined period of time. It would provide the advantage that each route could be individually assessed taking into account all of the risk factors including road geometry and layout, the number of junctions and the available facilities for parking and rest breaks. A system for approving movements (Electronic Service Delivery for Abnormal Loads, ESDAL) is already in existence and could, theoretically, be expanded to deal with LHVs. However, there may be a high administrative cost associated with this approach and if LHV movements were numerous it would become very expensive.

If LHVs were permitted and their use was expected to be more widespread, a potential compromise solution would be to permit blanket access to the Primary Route Network but allow road authorities to apply for restrictions at specific locations considered unsuitable for LHVs, which could then be clearly signed. This could imply a substantial cost in terms of providing the relevant signage and this would depend on how many locations were considered unsuitable for LHVs.

It is possible that, if LHVs were permitted, an additional factor defining the route network available to LHVs would be the availability of parking facilities. The earlier discussion highlighted that suitable parking may be limited and, thus, the availability of suitable facilities could be made a condition of use. Knowledge of the extent to which this would limit the network will depend on the outcome of any further studies of the parking issue and the actual limitations in practice may depend on whether, or how much, investment is made to provide increased facilities.

There was a general consensus among stakeholders that it LHVs were permitted only on routes defined according to the type of broad definition above (for example, motorways and dual carriageways) then efficient use of LHVs would not be possible unless a certain amount of "off-network" travel was also permitted in order for the vehicles to gain access to loading and delivery points. However, it was also generally agreed that this would need to be very carefully controlled and could only be permitted on roads with adequate infrastructure and low risks of interaction with other, particularly vulnerable, road users. It was considered that such access could only be granted by Special Order for a defined number of movements or for a defined period of time.

Stakeholders suggested that VOSA have the power to apply route restrictions; an example of where these are currently used is to limit where buses and coaches can drop people off at football matches. Therefore, any of the above definitions of road network considered suitable could potentially be applied using this system, although it is likely that this would imply an administrative cost.

One substantial difficulty that was identified with respect to defining a sub-network of roads that could be suitable for LHVs was that if such a network was defined there would still be a problem with diversions in the event of accidents or road works. Stakeholders identified that there were difficulties associated with current HGVs being diverted onto roads that were not well suited to them and in relation to drivers' hour's regulations where drivers could no longer stop at the place originally planned. It was considered likely that these existing problems would be substantially exacerbated if LHVs were to be permitted. Currently, a range of diversionary routes have been defined for road closures on many major roads but these may be unsuitable for LHVs. It was considered that stopping LHVs at accidents or roadworks to await arrival of additional tractive units in order to separate the combination may not be practical because of limited available space for them to wait and difficulties with getting additional vehicles through the traffic to the isolated LHV. In legal terms, there was less of a concern in the event of an accident because in current law HGVs are permitted to travel on roads where they would not normally be permitted provided it is at the direction of a police officer. It was considered that a police officer would always be present when a road was closed because of an accident. However, where a road was closed for roadworks it is highly unlikely that a police officer will be present and the LHV driver will be faced with a choice between stopping his vehicle, and possibly causing further disruption, or travelling on a road where his vehicle is not permitted without being directed there by the police. It was considered that the additional size of LHVs would exacerbate existing problems with driver's hours on diversions because it would make it more difficult to find somewhere suitable to stop.

In addition to the above, the actual layout of roadworks that close just part of a road (e.g. contra-flows or single direction closures etc) may need to be amended to accommodate LHVs, if they cannot meet current manoeuvrability criteria

The extent of these potential problems will vary depending on the type of LHV considered. An 18.75m articulated vehicle at 44 tonnes GVW that met current manoeuvrability criteria would not be expected to cause greater problems than current vehicles. LHVs at 25 metres and 44 tonnes GVW or payload neutral would be expected to increase the problems to some extent but this would be considerably less than 25 m or longer vehicles at 60 tonnes or 82 tonnes.

D.3.8 Enforcement of route restrictions.

A large number of stakeholders, particularly from the group representing other road users and road safety organisations, expressed concerns that existing HGVs were frequently driven on inappropriate routes and that existing route restrictions (i.e. those roads with weight, height or width restrictions) were not adequately enforced. There was, therefore, considerable concern that even if LHVs were permitted and were theoretically restricted to a limited route network it could not be adequately enforced and some LHVs would either deliberately or accidentally use inappropriate routes, potentially causing safety, congestion and infrastructure damage problems.

Stakeholders involved in enforcement activities stated that enforcement of current route restrictions was carried out by the Police and/or VOSA carrying out either routine or targeted patrols and stop-checks. Such enforcement was, therefore, practically constrained in terms of the amount that could be carried out and at any particular site would only be periodic. However, it was also stated that patrols were now equipped with enforcement cameras for this type of activity which was improving the effectiveness of patrols. If LHVs were to be permitted and restricted to certain routes it would be expected that this would be the minimum level of route compliance enforcement expected. It was suggested that this type of enforcement could potentially be more effective for LHVs because it would be easier to visually identify that they were failing to comply because the additional size would be obvious whereas a standard vehicle exceeding a weight limit is not always obvious.

Similar concerns were expressed with respect to overloading and defects and the effects that these could have on infrastructure and safety. Representatives of enforcement agencies stated that weight enforcement was currently carried out mainly by stopping vehicles and checking, either using mobile weighpads or by directing the vehicle to an appropriate weigh bridge. However, it was generally stated that this activity was becoming more targeted, using intelligence gathering to target operators considered more likely to be overloaded. In addition to this, the recent development of a network of weigh-in-motion (WIM) devices was also leading to increased effectiveness in enforcement of weight limits. WIMs are buried in the road surface and weigh all vehicles as they pass over them. These systems are not 100% accurate but have been successfully used to identify vehicles that are over their weight limit and these vehicles can subsequently be stopped and directed to a calibrated weigh bridge. Studies have suggested that a high proportion of those identified by WIM have been proved to be overweight.

Stakeholders considered that if LHVs were permitted it would make weight enforcement more difficult. The main reason for this was the concern that the longer vehicles may not be able to access all of the sites currently used for enforcement purposes. This concern would obviously be more relevant to any LHV type that was not capable of meeting current manoeuvrability criteria. There was particular concern with respect to weighbridges. The full weighbridges (those that weigh the whole vehicle at once) would not be long enough to weigh any of the LHV types assessed that were greater than 18.75m in length. Although partial weighing (weighing different groups of axles at different times) could potentially be carried out on full weighbridges and single axle weigh bridges could still be used, there would be a requirement for sufficient flat level ground either side of the weighbridge to allow the whole vehicle to remain in a straight line on a flat level surface to enable accurate weighing. Not all current facilities were expected to have such space, particularly if the longest combinations were to be permitted. It was suggested that the development of WIM would help to overcome this problem but could not eliminate it unless WIMs became sufficiently accurate to be used directly for enforcement without the need for referral to a weighbridge and there were sufficient numbers on the road network to enable complete coverage.

Enforcement of vehicle standards and roadworthiness is currently carried out by annual inspection, checks carried out at operator's premises and checks at the roadside. Again, the use of targeted enforcement is increasing such that operators with less impressive records are the focus of more in-depth investigations. If LHVs were permitted, it is likely that many of the test stations used for annual inspection could not be accessed by the whole combination. This is because many of these stations are located in urban areas and would be unlikely to be on roads deemed to be part of an LHV approved route. However, because such vehicles are formed of fairly standard modules and the roadworthiness inspection is applicable only to individual vehicles and trailers not combinations of vehicles, LHVs could be divided into separate standard vehicles and taken to annual test in that form. Some stakeholders suggested that freight hauliers would not like that option. There were no specific questions about annual inspection put to the freight industry focus groups and none of those attending raised it as a separate issue.

If LHVs were to be permitted it would be unlikely to affect random checks at operator's premises. However, inspections at the roadside could be affected by the ability of the vehicles to access current enforcement sites in a similar way to the problems with enforcement of weight but without the problems relating specifically to weighbridges.

Stakeholders noted that the consequences of current patterns of defects could be greater if the patterns remained the same for LHVs. For example, it was noted that it was much more common to find brake defects on trailers than it was on prime movers. In a 6-axle 44 tonne combination, half of the brakes are on the prime move and half are on the trailer, meaning that defective trailer brakes could reduce the braking very approximately by half. For the largest LHV, 8 of the 11 axles are on trailers. If trailer brakes were defective on such a combination the overall effect on the net braking performance could be much greater.

Many of the stakeholders that were part of the information gathering exercise expressed concerns about how any requirements and restrictions that would be applied to LHVs, if permitted, could be enforced for vehicles from other countries that were visiting the UK but not registered here. This was cited by a concern that such visiting vehicles were found to more frequently infringe the UK regulations. This view can be supported by the VOSA effectiveness report (VOSA, 2007) shows that of those vehicles stopped and checked 8.3% of UK vehicles and 25.1% of visiting vehicles were issued prohibitions for drivers hours offences and 13.1% of UK vehicles and 17.5% of visiting vehicles were issued with prohibitions for overloading.

VOSA (2006) states that the enforcement on visiting vehicles is being improved with mechanisms now in place to issue delayed prohibitions to non-UK vehicles and for roadworthiness offences identified in the UK to be communicated to the licensing agency in the country of origin. If LHVs were to be permitted it may not substantially change the pattern of offences but the consequences of the offences may be greater, thus meaning that the higher level of offences recorded for foreign vehicles may cause more problems if the pattern was repeated on LHVs.

Currently, infringements of any of the rules on routes, weights or defects can be prosecuted criminally but can also be penalised through the operator licensing (O-licensing system). In general stakeholders considered that the penalties that could be imposed through the O-licensing system (anything up to revocation of the operator license, effectively putting a company out of business) were likely to be more of a deterrent than fines etc imposed by criminal courts. As such, the O-license system would be expected to form a crucial regulatory and enforcement tool if LHVs were to be permitted.

If LHVs were permitted, the enforcement difficulties described above may have the potential to increase the risk to infrastructure and safety. A first step in controlling that risk could be to increase the consequences of infringements, that is, imposing more severe penalties on LHV infringements than the same infringement would receive for an ordinary HGV. However, the compliance of operators with all of the various regulations is now monitored by the enforcement authorities. It may be possible to use the economic benefits of LHVs as a tool to improve the standards in the industry by only allowing operators with good track records to operate them. Currently there are three categories of O-license:

- Restricted
- National
- International

Stakeholders suggested that it would be possible either to amend the restricted category or to create an entirely new category for LHV operations. If this was implemented it would be possible to be much more restrictive on what was required to gain and keep an LHV operators license. If holding an LHV license was in addition to an ordinary national or international license it could also provide a powerful enforcement tool in terms of the ability to revoke the LHV license if operators failed to fulfil the requirements, for example, exceeding driver’s hours, travelling outside of permitted routes, or poor maintenance etc. Stakeholders considered that this approach would have merit but it was stated that it would require a substantial amendment to the current operator licensing regulations. It was also noted that if VOSA and/or the Police had to increase their levels of enforcement in order to deal with LHVs they would need to increase their income in terms of fees and levies.

There were some stakeholders who shared the concerns described above but who believed that it really ought to be possible to use modern technology to overcome the problems. It was commonly suggested by a range of stakeholders including those from the infrastructure, enforcement, road freight and road safety sectors that telematics and navigation systems could potentially be used very successfully to enforce route restrictions. Another approach could be to use CCTV in combination with Automatic Number Plate Recognition (ANPR) technology. Such technology is currently used by VOSA together with Weigh in Motion sensors to detect overloading and in London the traffic authorities have powers allowing it to be used to enforce existing 7.5 tonne and 18 tonne weight restrictions. New legislation extending that option to the rest of England is expected in 2009. However, it was acknowledged that systems may need to be further developed to be suitable. One problem discussed was that most satellite navigation systems were developed with passenger cars in mind such that they could actually cause problems by directing existing HGVs onto roads for which they were unsuited or that had weight or height limits. A second problem was that current systems could not easily be LHV specific without relying on operator input. This is because such systems are fitted in the cabs of the prime mover, or are based on the registration number of the prime mover, and there are no connections or devices to enable the systems to automatically know whether the trailer(s) being towed conform with existing length requirements or constitute an LHV.

There is currently considerable research underway to improve the use of such systems for the existing haulage fleet. For example, the HeavyRoute project (www.heavyroute.fehrl.org), funded by the EC aims to develop an intelligent route guidance system for heavy vehicles that could include:

- Route planning before the journey
  - Static and periodic road and bridge data
  - Vehicle attributes (type, size, suspension type, weight etc)
  - Goods attributes (type, dangerous goods attributes, weight or density etc)
- Driver support during journey, providing information on
  - Speed limits
  - Overtaking restrictions
  - Location of service areas/rest stops
  - Re-routing due to congestion or accidents
  - Warnings of safety risks and recommended speeds (e.g. rollover warning based on speed and upcoming bend geometry)

- Monitoring of HGVs during journeys
    - Speed regulation in critical situations
    - Regulation of distance to vehicle in front
    - Re-routing to avoid exceeding load capacities of roads and bridges
- Fleet and vehicle management applications

Although this project may not necessarily consider LHVs specifically and will take time to deliver production systems, it is clear that it would have the potential to provide systems capable of controlling many of the risks identified and forming part of a comprehensive enforcement tool.

D.4 Data regarding parking facilities for AIL vehicles

The following data was provided by the Highways Agency and relates to a sample of data they hold on parking facilities used by Police for the management of abnormal load movements and an indication of some problems experienced. It is not intended to be exhaustive or nationally representative, merely providing examples of sites that may be physically able to accommodate longer vehicles.

POLICE AUTHORITY	Holding Site Location			Easting	Northing	TRUNK	Further Comments
	Road	Location	Details				
Beds							
Cambs	A1	Tinwell	lay-by	500963	306834	Y	Better facilities required on all routes
		Carpenters Lodge	lay-by	503904	304361	Y	
		Wyboston NB	lay-by, northbound	516088	255691	Y	
		Stibbington Diner	transport café	508035	298805	Y	
		Kates cabin	transport café, northbound	513442	295064	Y	
		Wittering	lay-by, southbound	506407	302078	Y	
		Brampton Hut	services	519252	271840	Y	
		Woolley	lay-by, north/southbound	519256	273432	Y	
		Alwalton	lay-by	512445	296491	Y	
		Southoe	lay-by, southbound	518772	264486	Y	
	A14	Alconbury	truckstop services	519567	276294	Y	
		Bythorn	lay-by, east/westbound, separated from carriageway	SEE NORTHANTS	SEE NORTHANTS	Y	
		Higham, (Risby)	"Yorkies" transport café	SEE SUFFOLK	SEE SUFFOLK	Y	
		Exning	A14/A142 lay-by westbound	SEE SUFFOLK	SEE SUFFOLK	Y	
		Swavesey	services	536095	265504	Y	
		Cambridge Crematorium	lay-by	540060	262655	Y	
	A47	Walsoken	lay-by	548913	310714	Y	
		Duddington	lay-by	499102	301206	Y	
	M11	J9, Hinxton	lay-by off A1301,off motorway, on local route, not always acceptable, SEE ESSEX	550001	244783	Y	
	A505	"Noons Folly"	Royston to Duxford, RHS, lay-by	SEE HERTS	SEE HERTS	N	
	A11	Red Lodge	B1085 transport café	SEE SUFFOLK	SEE SUFFOLK	Y	
	A1101	Tydd Gate	lay-by	545060	317995	N	
	A15	Market Deeping bypass	lay-by	513105	311436	N	
	A1073	Crowland	lay-by	524742	310684	N	
	A10	Brandon Creek	lay-bys	SEE NORFOLK	SEE NORFOLK	N	
		A505 Royston bypass	Little Chef, by arrangement with management	533516	240466	Y	
	A1198	Bassingbourn	lay-by	534692	244045	N	
	A428	Weald Corner	lay-by westbound	522992	259969	Y	
		Girton	A428/A14, lay-by	541565	261192	Y	
	A1307	Horseheath	lay-by	SEE SUFFOLK	SEE SUFFOLK	N	
	A605	Warmington/Elton	services	SEE NORTHANTS	SEE NORTHANTS	N	
		Xtra Services	Peterborough	SEE NORTHANTS	SEE NORTHANTS	N	
	A428	Hardwick	Enterprise café	537520	259629	Y	
	A603	Cambridge, lay-by	Hangman's Corner, Barton Road, lay-by	544332	257461	N	
Dorset	A31	Avon Park	country park, facilities	412238	103116	Y	Abnormal load movements difficult along several stretches of A31/A35, many existing sites not wide enough
		Corfe Mullen (Sleight)	no facilities	398227	98533	Y	
		Sturminster Marshall	East of Roundhouse r'bout, no facilities	395610	98575	Y	
		Bere Regis	North of A31/A35 r'bout, no facilities	385359	95745	Y	
	A35	Dorchester	East of Stinsford r'bout, no facilities	371399	92120	Y	
		Waldltch	East of Bridport, no facilities	348280	93144	Y	
		Bridport	Picnic site at Eype, on bypass, facilities	345155	92191	Y	
		Morcombelake	East of village, no facilities	341104	93538	Y	
Essex	M25	Junction 31	Gated lay-by, loads to and from Dartford Crossing, SEE KENT	557319	178884	Y	
		South Mimms	J23 services, no convenient location in Essex	SEE HERTS	SEE HERTS	Y	
	M11	Chigwell Works Unit	Just south of J5, for handovers with Met police, SEE MET	543449	194553	Y	
		J9, Hinxton	lay-by off A1301, handover point with Cambs, SEE CAMBS	SEE CAMBS	SEE CAMBS	Y	
		Birchanger Services	Junction 8	551188	221363	Y	
	A12	M25 (J8) slip	prior to sliproad, southbound, can be full	557120	192719	Y	
		Birchwood Services	southbound	603457	231363	Y	
		SB, Chitts Hill	Southbound, before A1124 slip, can be full	595925	225258	Y	
		M25 (J28) slip	Northbound, lay-by just after sliproad	556865	192569	Y	

Hampshire	A27	Langston Bridge	westbound, A3023 sliproad, not really suitable	471908	105749	Y	The only places for laying up loads for any length of time are the M3 Fleet and M27 Rownhams services; of the lay by at Tothill. Loads often have to be taken to final destination (even if considerably beyong county boundaries) or transferred between police forces whilst on the move.
	A3090	Pitt	lay-by, used for high loads	445446	128169	N	
	A34	Just north of A343	north/southbound, purpose-built lay-by	444444	164313	Y	
		Sutton Scotney	Services, only suitable for smaller loads	445941	140012	Y	
		South Wonston	temporary lay-up	445916	136607	Y	
	A35	Roeshot lay-by	often used by roadworks contractors	418701	932295	Y	
	M27	Rownhams Services		438855	117706	Y	
		Just east of J9	proposed site for services, temporary site	453245	108314	Y	
		M27/A27 J9	lay-by in industrial estate, loads into Fareham, Swanwick Marina and Warsash	452563	108095	Y	
	M3	Fleet Services	surrey police have to travel into Hampshire	479866	155827	Y	
		A335, nr J12	lay-by, only normal lay-by width	445454	121646	Y	
		Just north of J7	proposed site for services, temporary site	459681	147298	Y	
Herts	M25	Under J17	Purpose-built lay-by	503166	240466	Y	Limited provision off of trunk and motorway
		South Mimms	J23 services, lay-bys on each side of lorry park, SEE ESSEX	522915	200210	Y	
	M1	Junction 10	on junction r'bout, technically in Beds, SEE BEDS	508771	218423	Y	
	A505	"Noons Folly"	A505 Royston to Duxford, RHS, SEE CAMBS	538410	241050	N	
	A1(M)	Junction 10	"Extra" service area, by arrangement with management	523494	266281	Y	
Kent	M25	Clacket Lane	Services, by owner's consent	542373	154574	Y	
		Junction 31	Ab-loads lay-by, A282, Essex, prior to Dartford Crossingby arrangement with Le Crossing	SEE ESSEX	SEE ESSEX	Y	
		Dartford Crossing	Ab-loads lay-by, A282, prior to Dartford toll booths, Kent, by arrangement with Le Crossing	555874	175053	Y	
	M2	Farthing Corner	Services, M2 from J4 to coast, not Ab-load route	581740	163480	Y	
	A296	Bean	"Merry Chest", coastbound, for loads to M2 coastbound, 5m width restriction (used for A2)	559011	172875	N	
	A2	Gravesend east	"Nell's cafe", Valley Drive, large car park, tight access, limited space	566094	170508	Y	
		Brenley Corner	lay-bys prior to M2 junction 7	605233	159463	Y	
	A299	Brenley Corner	lay-bys prior to M2 junction 7	604788	160905	N	
	M20	Junction 4	Lay-by on A228, Malling road prior to Snodland, limited availability for loads to Maidstone	569552	160268	Y	
		J10, Ashford	Truckstop on A2070, Bad Munstereifel Road	603668	141049	Y	
	A228	Chattenden	Four Elms Hill, Rochester to Grain	575629	171704	N	
	A229	Chatham Road	Blue Bell Hill (M2 to M20)	574460	162314	N	
	A249	Detling Hill	lay-by, not very wide, limited use	579144	158416	N	
		Isle of Sheppey	Humphries Loop, parking place, due to be closed	592661	170604	N	
	A256	Guston to Ramsgate	lay-by, limited width, location unspecified	630606	151345	N	
	A258	Dover to Deal	lay-by, limited width, location unspecified	635662	147539	N	
	A299	lay-bys	several, both directions, locations unspecified	614289	165555	N	
	A21	lay-bys	several, both directions, locations unspecified	550690	154926	Y	
Met							
Norfolk	A10	Brandon Creek	lay-by, NB, service road to Ship PH, see CAMBS	560679	291721	N	Pick-up points identified for exchange of loads between county forces
		Brandon Creek	lay-by, SB, service road to telephone exchange, see CAMBS	560836	291864	N	
	A11	Thetford (Elveden)	East.westbound, lay-by at Sainsbury's r'bout prior to B1107, see SUFFOLK	584618	281491	Y	
	A12	Gorleston	South of Hopton, Millenium Monument	SEE SUFFOLK	SEE SUFFOLK	Y	
	A17	Cross Keys Bank	East/westbound, Walpole Keys, Lincolnshire border	550280	319983	N	
	A47	Wisbech	East/westbound, junction with A1101, 200m E of Elm r'bout	546947	307747	Y	
	A140	A143, Scole	large lay-by, both directions	SEE SUFFOLK	SEE SUFFOLK	N	
		Eye	airfield industrial park, for loads over 15'	613595	275702	N	
	A134	Barnham Cross		586475	280815	N	
	A146	Beccles	Norwich Road, Gillingham marshes	642097	291393	N	
Northants	M1	Misterton	Works Unit, South of J20, NB/SB	454930	282223	Y	Few problems with abnormal loads as have adequate provision on major routes and they avoid transporting during peak periods.
		Newport Pagnell	Services, J14 to J15 NB/SB	485878	243491	Y	
	A14	M1 (J19)	Gated lay-by, EB/WB	456297	278815	Y	
		Bythorn	gated lay-by, east/westbound, SEE CAMBS	503639	276847	Y	
	A5	Lilbourne	BP truck stop, NB/SB	455362	276450	Y	
	A428	A428/A509 Warrington	BP Garage, by prior arrangement	489892	254860	N	
	A605	Elton	lay-by or Little Chef, by arrangement with Cambs Police, SEE CAMBS	506902	291051	N	
		Peterborough	"Extra" Services, by arrangement with Cambs Police, SEE CAMBS	513414	293267	N	

	A43	Easton-on-the-Hill	lay-by, SB	502012	304761	N	
		Evenley	Lay-by, SEE THAMES VALLEY	457959	234205	Y	
		Cherwell Services	by arrangement with Thames Valley Police, SEE THAMES VAL	455160	228119	Y	
	A6	Sharnbrook	County border, by arrangement with Beds police, SEE BEDS	501110	259956	N	
Suffolk	A11	Elveden	lay-by, NB/SB, south end of Thetford by-pass	SEE NORFOLK	SEE NORFOLK	Y	Apart from lay-bys at level crossings, there are no specially constructed lay-up points. Suffolk has relatively few large roads so that any load that has to leave the trunk network is likely to cause difficulty and disruption.
		Elveden	lay-by near war memorial, rarely used as above are better	582267	279959	Y	
		Barton Mills	NB/SB, lay-bys "fiveways" roundabout	572735	274022	Y	
		Red Lodge	limited space, SEE CAMBS	569466	269991	Y	
	A12	Stratford St Mary	NB, lay-by	605267	234931	Y	
		Langham (Essex)	end of slip from Stratford St Mary	603528	232086	Y	
		Copdock	NB & SB, large lay-bys	611859	240668	Y	
		Copdock Mill	services, lorry park, frequently full	612664	242300	Y	
		Bucklesham	lay-bys NB/SB, only suitable for loads up to 3.86m (13') wide	623844	242970	N	
		Martlesham by-pass	NB, just after A1214 r'bout, suitable for very large loads	624018	246717	N	
		Martlesham by-pass	SB, between B1079 & Seckford r'bouts, only suitable for loads up to 3.65m (12') wide	624126	247091	N	
		Woodbridge by-pass	NB/SB lay-by prior to B1079 r'bout	625027	247882	N	
		Wickham Market by-pass	lay-bys, NB/SB, suitable for loads up to 4.3m (14') wide	629830	253870	N	
		Wickham Market by-pass	slip roads to B1078, NB/SB, suitable for very large loads	631270	256674	N	
		Farnham	NB/SB, lay-bys, suitable for loads up to 3.65m (12') wide	636054	260108	N	
		Benhall	NB, lay-by	638442	266744	N	
		Yoxford	SB, lay-by in village, suitable for loads up to 4.6m (15') wide	639245	267992	N	
		Darsham	lay-by each side of level crossing	640954	270325	N	
		Blythburgh	Tobys Walks, lay-by in each direction	644451	274366	N	
		Frostenden	NB lay-by, also accessible SB	648398	281813	N	
		Pakefield	near Safeway r'bout	655131	293221	Y	
		Gorleston	Corton/Hopton on Sea, both directions nr Millennium monument, SEE NORFOLK	652851	298397	Y	
	A14	Newmarket	lay-bys both directions, nr Rowley Mile on Newmarket racecourse	559295	262373	Y	
		Exning services		559523	262654	Y	
		Exning	lay-bys near A142 junction, SEE CAMBRIDGE	563403	265982	Y	
		Higham, (Risby)	"Yorkies" transport café, SEE CAMBRIDGE	579693	265855	Y	
		Saxham	EB/WB, lay-bys opposite industrial estate	580388	265654	Y	
		Bury St Edmunds	lorry park, off A134, close to A14	586905	263347	Y	
		Rougham	lay-bys, both directions, suitable for loads up to 4.1m (13'6") wide	591063	263432	Y	
		Woolpit	EB, end of A1088 slip	597835	263036	Y	
		Haughley	EB, lorry park, Tothill Services	603723	260486	Y	
		Haughley	WB, end of A1308 slip	604033	259998	Y	
		Creeting St Mary	EB, end of A140 interchange slip	610239	254724	Y	
		Coddenham	Beacon Hill service area, both directions	610857	254391	Y	
		Sproughton	EB, prior to A12/A14 Copdock Mill interchange	612381	243010	Y	
		Wherstead	EB/WB, lay-by prior to A137 exit	614965	240943	Y	
		Nacton	EB, after Orwell bridge prior to A1189	619017	240974	Y	
		Nacton	WB, between A12 and A1189	621369	241110	Y	
	A140	Mendlesham	SB, large lay-by, usable, both directions, but busy café	611865	265952	N	
		A143, Scole	large lay-by, both directions, SEE NORFOLK	614881	279154	N	
	A143	Gillingham	lay-bys, for Norfolk/Suffolk transfers	639697	292949	N	
	A146	Beccles by-pass	lay-bys either side of level crossing	642955	291120	N	
	A1307	Horseheath	lay-by, SEE CAMBS	562106	246697	N	
Surrey	A30	Crooked Billet, Staines	for handovers for Surrey, Thames Valley and Met	504354	171948	Y	
	A3	Ockham	lay-by, NB	507042	158133	Y	
	A22	Caterham	lay-bys, close to M25	534898	154538	Y	
	M25	Poyle Place Park	J14, for handovers for Surrey, Thames Valley and Met	503402	175613	Y	
Sussex							
	A30	Crooked Billet, Staines	by-pass, long lay-by each direction	SEE SURREY	SEE SURREY	Y	
	A34	Newbury bypass	dedicated lay-bys both c/ways, Herts/Berks border				

Thames Val	A43	Evenley	lay-by, NB/SB, just south Brackley	SEE NORTHANTS	SEE NORTHANTS	Y	would like lay-up point on A404 between Handy Cross and A404M
	M1	Newport Pagnell	Services, J14 to J15, restricted access due to high kerbs and narrow entry	SEE NORTHANTS	SEE NORTHANTS		
	M25	Underneath J17	purpose built but no facilities	SEE HERTS	SEE HERTS	Y	
		Off J13, on A30	towards Staines, lay-by, good handover point for Surrey	502865	172405	Y	
		J14, Poyle lorry park	private area with permission, off Horton Road	SEE SURREY	SEE SURREY	Y	
	M4	Reading Services	J11 - 12, restricted entry/exit				
		Membury Services	J14 - 15, Wilts/Berks border, SEE WILTS				
		"Parkway"	A312 between M4 and Middx, lay-bys both c/ways, SEE MET	510618	177430	Y	
	M40	Barn Hill (Warwick)	Services, J13 - 12	SEE WARKS	SEE WARKS	Y	
		Oxford Services	Junction 8a				
		Cherwell Services	Junction 10	SEE NORTHANTS	SEE NORTHANTS	Y	
		J1, NB, MP 9295A	rarely used	504390	185806	Y	
		midway J3-4, MP 8475	Abbey Barn, both c/ways	487942	190932	Y	
Warks	M6	J1, NB exit slip	lay-by on h/shoulder, limited space	451801	279075	Y	Other lay-bys are off the main routes and likely to b unsuitable. This raises concerns in case of major diversions as special arrangements have to be made to take abnormal loads off-route.
		Harborough Magna	J1 to J2, NB/SB, disused services	448451	280033	Y	
		Corley Services	J3 - J4, restricted access to very long loads	430880	286047	Y	
	M42	Junction 3	NB, end of entry slip, lay-by off hard shoulder	412978	272416	Y	
		north of J6	NB, lay-by off hard shoulder, dangerous exit onto main c/way, no facilities	419826	283329	Y	
		south of J6	SB, lay-by on hard shoulderno facilities	419640	282525	Y	
		Junction10	within junction island, moderate width	424392	300722	Y	
		Tamworth Services	frequently full	424425	300965	Y	
	M40	J16 to J3A of M42	SB, lay-by off hard shoulder, no facilities, limited space	413913	271994	Y	
		Warwick Services	J12 - 13, frequently full	434042	257770	Y	
	M69	Just prior to M6 (J2)	Southbound, wide area of unused road, no facilities	439169	283117	Y	
	A46	Sherbourne	south of M40 (J15), large lay-by, frequently full, requires closing off before loads arrive	424673	261224	Y	
Wiltshire							

POLICE AUTHORITY	Holding Site Location			Easting	Northing	TRUNK	Further Comments
	Road	Location	Details				
Cheshire	M6/A500	Cheshire/Staffordshire WMPG area A500	Lay-by on A500 at bottom of N.Bound Exit slip to A500. Large lay-by which can accommodate virtually any length AIl - used by all loads irrespective of direction.	377700	352370		
	M6	Cheshire /GMP Area	Rob Lane Dependent on size and manouverability of AIL Rob Lane Unit is used for both North and Southbound traffic.	368850	396500		
	M56	Cheshire/GMP Border A556/A56 - M56	(Bowden) AILs are placed on the Traffic Island situated at junction of A556/A56 and M56 at Bowden. This lay-by is capable of taking virtually any length load but problems can be experienced whe manouvering out of lay-by onto main roads. This location is used for AIls travelling both East and Westbound along the M56 and for those loads which are travelling the A556 to access the Southbound M6 at Junction 19.	374395	385855		
	M56/M53	Cheshire/N Wales boundaries & M53 Cheshire/Merseyside boundary.	This area is lacking in suitable lay-up points for larger AILs. Purpose built AIL lay-by recently reconstructed on Cheshire/N.Wales Police Area to South of M53 (Westbound) just before Welsh border. There has always been a hope that the larger loads would be handed over (to whom?) to avoid the problems of laying them up!!	342100	372900		
	M62	Cheshire/Merseyside area East/Westbound	Burtonwood Services	357730	391300		
	M62	Cheshire/GM Area)	Widened sections of the hard shoulder at Holcroft Lane (between J11 & Cheshire GMP boundary) were constructed some years ago. However, the wider AIL encroaches onto the hard shoulder with an increased danger to the driver attendant when walking round their vehicle.	368700	393600		
Cleveland	A19	North/South Bound	North of Tees Flyover near to Holme House Prison.	446150	520770		
	A19	North	?				
	A66		East/West of Longnewton	438050	516620		
Cumbria	M6		Tewfield M6 Southbound just prior to J 36.	351880	473625		
	A66	Westbound	Stainmore Cumbria County Boundary	389510	512380		
	A66	Eastbound	Crossthwaite	325322	524352		
	A590	Westbound	Milton lay-by	352720	482980		
Derbyshire		North Road Policing Area					The North Traffic Sergeant suggests that these locations are suitable as they are divided by the road by wide grass verges, or other suitable locations.
	A616	Whitwell	Eastbound, between Clowne and Cresswell (Grid Ref: 507 756)	450840	375570		
	A619	Chander Hill	Westbound at Chanderhill (Grid Ref: 326 705)	432950	370370		
	A6	Ranch Corner - Whatstandwell	Northbound, between Ambergate and Whatstandwell (Grid Ref: 338 530)	433880	353010		
	M1	Southbound	Tibshelf - Grid Ref:448 604 (Extra wide section before services, separated by Armco barrier)	444870	360480		
	M1		None (Section at Tibshelf is used to move the load over to release backlog of traffic but not suitable for load parking)				
		South Road Policing Area					Most suitable due to width of road/hard shoulder at given locations. Not suitable for overnight stays as not protected in most cases.
	A38	M1 from Jct. 28	No suitable locations - all have to be taken on move				
	A38	Clay Mills (Near Egginton Bridge)	South Bound - Grid Ref:270 272	427000	327200		
	A610	Near M1 Jct. 26	Nottingham Police Force Area	451880	343900		

	A50	Doveridge (Near Staffs Border)	Grid Ref: 148 330	415130	332950		
	A50	Shardlow	(Near Services but not on OS map)	442730	330090		
Durham	A1M	Washington Services	Northbound and Southbound	428380	555070		
		Jct. 56	Barton Lorry Park, Southbound	421810	508100		
		Scotch Corner	Northbound Slip Road onto A1(M) - No Lay-by!	421500	505550		
	A19	Seaton - Nr Seaham	Northbound and Southbound at Lay-by Junction with A1018	440140	549700		
		Sheraton	Northbound and Southbound. Pickup at the Junction with A179	444200	534270		
	A66	Ivanhoe near Sadberge	Westbound and Eastbound in general Lay-by.	434200	516530		
		Stainmore Summit (TransPennine)	General Lay-by each side Westbound and Eastbound	389510	512380		
		Sedbury East of County - (TransPennine)	1 Lay-by	?	?		
	A689	Wynward - Westbound and Eastbound to Cleveland	Lay-by on each side of the road (Eastbound only on map)	442700	527100		
Humberside	A15		Redbourne	496140	399200		
	A16		Houghton Le Clay (Holton le Clay?)	528300	402600		
	M180/ A180		Barnetby Top	505100	411050		
	M180	J2	No actual lay-up point - habd(?) over point from South Yorks.	479350	408720		
	M18		North Ings	?	?		
	A1079		Kexby	?	?		
Greater Manchester	M56	Bowden Island Junction 7	In Cheshire Police area Access from Westbound M56 limited due to bridge weight restriction.	374395	386865		
	M62	East and Westbound Junction 11	Site actually in Cheshire Police area but used by both forces as a handover/collection point.	368700	393600		
	M62	Westbound 2 miles West of Junction 22	GMP area.	398100	414750		
	M6	Northbound Knutsford Services	Motorway Service area Cheshire Police area.	373330	378280		
	M6	North/Southbound Charnock Richard Services	Lancashire Police Area	354425	415215		
	M61	North/Southbound Bolton West Services	Lancashire Police Area	362120	411660		
	M62	East/Westbound Birch Services	GMP area.	384770	407930		
	A560	Shaftsbury Ave. Altrincham Westbound lane and junction with Brooklands Road	GMP area.	379535	389275		
	A6	Ardwick Green (Northwest of its junction with Hyde road)	Ardwick, Manchester GMP area	385250	397140		
	A62	Eastbound at Scoutham (Scouthead?) Oldham	Can be used for East/Westbound traffic. GMP area	397580	406156		
	A62	Motormans Café Marsden	Able to take East & Westbound traffic West Yorkshire Police area	404800	411530		
Merseyside							
Lancashire							

Northumbria	A19	Durham to Northumberland	Seaton	440140	549700		
	A1/A19 Interchange	North	N lay-by	423430	573650		
	A1/A19 Interchange	South	S lay-by	423430	573650		
	A1		Washington services	428380	555070		
	A1	A1/A19	Seaburn Interchange At end of A1	423250	574500		
	A1		Bockenfield (Morpeth?)	417950	585035		
	A1		Adderstone Services	413230	630030		
	A1		Marshall Meadow (Scotland)	397400	667050		
	A69		West of Hexham (bridge-end) lay-by	394170	565160		
	A69	East	Past A68 Interchange (East and West lay-bys)	403370	563780		
	A69		Blenkinsop lay-by	?	?		
	Off A188/9		Peter Barracks Garden Centre at Gosford Park	426300	570790		High Loads
North Yorkshire	A1	Northbound carriageway -	Wetherby Kirk Deighton (Purpose made Police lay-by)	440300	450400		
	A1	Southbound carriageway -	Wetherby South Boston Spa (Purpose made Police lay-by) (within W Yorkshire Police boundary)	441750	444160		
	A1	North	At Barton Lorry park	421810	508100		
	A19	North	At Exelby Services ?Exlby is on A1	?	?		
	A19	South	At Exelby Services ?Exlby is on A2	?	?		
South Yorkshire	M1		Woodhall Motorway Service Area - signed for use of abnormal loads tho' get used for other traffic also.	447930	380080		
	M1		Woolley Motorway Service Area - signed for use of abnormal loads tho' get used for other traffic also.	429980	413950		
	M18	South of Junction 5 (N/Sbound)		467270	410450		
	Any other locations	Not stated	Parking facilities restricted to 'normal' lay-bys (also used by any other traffic).				
West Yorkshire	M62	Westbound West of Junction 34,	Hard-standing area 3.30m wide - hard shoulder 3.40m wide (6.7m before protrudes into carriageway.) Useable length 125m. According to WSP the structure and drainage channel are able to withstand use for abnormal loads up to max. allowed transferred to the road surface by individual axles under con & use regs. SOS phone nearby. No overhead lighting.	455450	422250		
	M62	Eastbound Prior to Junction 34	The hard-standing is 2.90m wide - hardshoulder is 3.10m wide (6.0m before protrusion into carriageway). Useable length is 76.0m There is SOS phone nearby. No overhead lighting. According to WSP the structure and drainage channel are able to withstand the use for abnormal loads up to max. allowed transferred to road surface by individual axles under con. and use regs.	455450	422250		

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Appendix E. Regulatory Implications of LHVs

E.1 Introduction

The regulatory framework in the UK and the EU is, in the main, not designed with LHVs in mind. There are, therefore, a variety of regulations that would have an effect on, or be affected by, any decision to allow such vehicles in the UK. These include:

- Regulations that would need to be amended to permit LHVs in national transport
- European Regulations limiting what can be permitted in Member States national transport
- Existing regulations that may impose constraints on LHV use, if they were to be permitted
- New regulation or amendments to existing legislation that may be required in order to enforce constraints considered desirable on LHV construction and/or use

This Appendix considers the implications, if a decision to permit LHVs were to be made, of the constraints applied by existing regulations and the new and/or amended legislation that would be required if certain restrictions were to be placed on their use. It should be noted that whilst this assessment has been carefully considered, it is but one interpretation of the regulations and further consideration by legal experts may be required to reach a definitive view.

E.2 UK regulations on Weights and Dimensions

In the UK, the maximum weight of vehicles in national transport is prescribed by The Road Vehicles (Authorised Weight) Regulations 1998 (SI 1998 number 3111) as amended by SI 2000 number 3224 and SI 2001 number 1125. It is these regulations that specify the current maximum permitted 44 tonnes on six axles equipped with road friendly suspension for articulated vehicles and rigid vehicles towing drawbar trailers. If consideration was given to permitting LHVs in excess of 44 tonnes, it is possible that this regulation could be amended to permit their general use, but any changes would need to conform with the requirements of EC Directive 96/53/EC.

In theory, it would be possible to include additional vehicle construction requirements in these regulations if it was amended to permit LHVs because it already permits different weights for differing axle numbers and vehicle constructions (e.g. vehicles with “road friendly suspension” are permitted to have higher axle weights). However, this may not be appropriate because additional construction requirements such as overall length are not the primary purpose of these regulations.

The maximum dimensions of vehicles are specified by The Road Vehicles (Construction and Use) Regulations 1986 (SI 1986/1078). These implement the dimensional requirements of EC Directive 96/53/EC and if LHVs were to be considered they could be amended to permit their use, but as with the Authorised Weight Regulations, any amendment would need to respect the Directive.

The Road Vehicles (Construction and Use) Regulations could be a suitable regulation for setting out any special design or performance standards that may be considered necessary for LHVs. In theory such requirements would apply to any such vehicle used on UK roads, not only those operated by domestic companies. However, in practice, it could be difficult to enforce such requirements effectively on visiting vehicles not subject to the UK Plating and Testing regulations. Importantly, any special requirements would need to respect the rules governing free movement within the EU.

E.3 European regulations on Weights and Dimensions

In Europe, the dimensions of goods vehicles in national and international traffic are prescribed by Directive 96/53/EC. This Directive harmonises the maximum dimensions of goods vehicles circulating in national and international traffic within the EU (16.5m length for articulated vehicles, 18.75m for drawbar combinations). It also prescribes the maximum weight of vehicles (40 tonnes on 5 axles) that will guarantee free circulation in international traffic within the EU. It also prescribes the minimum standard for manoeuvrability for vehicles in traffic in the EU via the minimum turning circle requirements of being able to turn within the space between two concentric circles of 5.3 and 12.5 metre radius.

However, Directive 96/53/EC is extremely important in relation to any decision whether or not to permit LHVs because it does permit, in national transport, certain deviations from the dimension requirements, as described below:

> *"Member States may allow vehicles or vehicle combinations used for transport which carry out certain national transport operations that do not significantly affect international competition in the transport sector to circulate in their territory with dimensions deviating from those laid down in points 1.1, 1.2, 1.4 to 1.8, 4.2, and 4.4 of Annex 1"*

This means that vehicles can be used in national transport, under certain conditions, that are not subject to the requirements concerning:

- Maximum length
- Maximum width
- Manoeuvrability (turning circle) requirements
- The maximum distance between the rear axle of a towing vehicle and the lead axle of a trailer
- The maximum distance between the king-pin of a semi-trailer and the front and rear of the trailer

National transport operations are deemed not to significantly affect international competition if one of the following conditions is fulfilled:

a. *"the transport operations are carried out in a Member State's territory by specialised vehicles or specialised vehicle combinations in circumstances in which they are not normally carried out by vehicles from other Member State's e.g. operations linked to logging and the forestry industry."*

b. *"the Member State which permits transport operations to be carried out in it's territory by vehicles or vehicle combinations with dimensions deviating from those laid down in Annex I also permits motor vehicles, trailers and semi-trailers which comply with the dimensions laid down in Annex I to be used in such combinations as to achieve at least the loading length authorised in that Member State so that every operator may benefit from equal conditions of competition (modular concept)"*

Additionally, in respect of trials:

> "*Member states may allow vehicles or vehicle combinations incorporating new technologies or new concepts which cannot comply with one or more requirements of this Directive to carry out certain local transport operations for a trial period. Member states shall inform the Commission thereof."*

The implications of condition (b) could be significant in that if a Member State permits vehicles, or vehicle combinations, in national traffic that do not comply with the requirements of Annex I of the Directive, then it must permit combinations of motor vehicles, trailers or semi-trailers of equivalent loading length (modular concepts) that meet the requirements individually.

For example, if a Member State decided that it wished to permit vehicle combinations at 25.25 metres, but considered that the characteristics of a B-double combination was preferred because it suffered less rearward amplification, it could permit in domestic legislation the use of vehicles conforming to those characteristics; but once having done so, condition (b) would in effect require that Member State also allow the use of modular concepts that have at least the same loading length even if those combinations could not comply with the requirements laid down in the Member States' domestic legislation. This would mean that other types such as rigid vehicles towing semi-trailers or articulated vehicles towing drawbar trailers could legitimately be used even though they had not been authorised in domestic legislation. What is not entirely clear is whether Member States can limit the modular concepts to those that may only be formed by vehicles which, when combined, minimise the extent to which the loading length authorised in that Member State is exceeded. Although there would be a risk that limiting the length of modular concepts could be challenged and ruled unlawful by the European Court of Justice, a recent interpretation in the Commission staff working document SEC (2006) 1581 on the continuous carriage of 45’ containers in national road transport suggests that Member States have the right to limit the length of modular concepts, provided that there is at least one concept that is readily available in other Member States, The working document states that:

“*A road train of 18,75 metres prescribed in Directive 96/53/EC constitutes a 'modular concept' in accordance with the relevant definition in Article 4(4) because it is composed of 'modules' (a motor vehicle, trailer and semi-trailer) "which comply with the dimensions laid down in Annex I" to the Directive, in “such combinations as to achieve at least the loading length authorised in that Member State”. Such a 'modular' road train of 18,75 metres has a loading length of 15,65 metres which is longer than the loading length needed for a 45’ container (i.e. 13,72 metres). Because all Member States allow the concept of 18,75 metres to freely circulate in their territories, they can, consequently, by referring to Article 4(4) and informing the Commission of the measures taken, also allow 45' containers to be carried on articulated vehicles by road in their national territories from/to intermodal terminals. When applying Article 4(4) of Directive 96/53/EC, the Member State would be entitled to limit the application of the article to only those deviations that are indispensible for carrying 45’ containers*”

Likewise, if a Member State wanted to permit articulated vehicles that were 18.75m long, it would be obliged to accept longer modular concepts unless the loading length of articulated vehicles were limited to the 15.65m specified for 18.75m drawbar combinations. However, such a decision could, despite the existence of the Commission document, be subject to legal challenge.

E.4 Regulating LHV Safety

One of the considerations associated with any decision on whether LHVs could be permitted in the UK is whether maintaining an acceptable level of safety requires any special vehicle design criteria to be applied that are not already applied to standard goods vehicles. Whilst it should be feasible to apply this type of requirement in national regulations it is unclear whether this would contradict the requirements relating to international competition in Directive 96/53/EC. In Sweden, combinations of up to 25.25m are permitted and are exempt from the manoeuvrability criteria in the EC Directive. However, an alternate national standard is applied, presumably to minimise the risk associated with the exemption from the criteria in the Directive, which reduces the minimum standard for manoeuvrability to the extent that standard vehicles conforming to Annex I can pass the test and, thus it cannot be said to influence international competition. If LHVs were to be permitted in the UK but it was considered desirable to apply to them the manoeuvrability requirements in 96/53/EC, then vehicles would have to be fitted with steering axles in order to conform. Although it is probable that this would be deemed to affect international competition, the interpretation of the Directive and other relevant European law is by no means certain and a view taken either way could again be subject to legal challenge.

Therefore, in general mandating additional technical requirements, at least for vehicles other than those that might be involved in trials, could be considered contrary to European law given the need not to frustrate the free movement of goods and services, and to accept vehicles which are already lawfully in circulation within the Community. On the other hand, European law did not foresee LHVs as regular vehicles, so one could envisage that a Member State might legitimately specify additional requirements if such requirements were considered necessary to ensure that LHVs would not compromise road safety

It is also worth noting that even if such safety measures could be applied without contradicting 96/53/EC, it may be difficult to enforce the requirements on visiting vehicles. Such vehicles would not be subject to UK O-license regulation or annual roadworthiness testing, leaving roadside enforcement as the only mechanism by which conformance could be checked and failures penalised.

If the UK wished to permit any non-modular vehicle, to restrict modular vehicles only to types with certain safety characteristics or to those fitted with certain safety equipment, then to ensure legal certainty that the UK and other Member States would not be obliged to accept vehicles that were considered to be unsuitable, an amendment to 96/53/EC would be required..

One exception to all of the above would be the use of LHVs only in operations conforming with condition (a) described above. This would mean only permitting their use in specific types of operation where it can be demonstrated that foreign operators do not currently compete with domestic operators. The example given in the Directive is that of the forestry industry but other sectors of the UK market could, potentially, comply and it is understood that certain "low loader" trailers are already permitted under this clause. In these cases it would appear possible to permit any vehicle considered suitable and apply any suitable restrictions without the consequences described above. However, the number of operations possible under this clause, which would not affect international competition, are likely to be limited in number.

A further exception applies in respect of a trial, provided such a trial conformed with the conditions laid out in Directive 96/53, in particular being limited to "local transport operations". If the UK decided that permitting LHVs could potentially be beneficial but wished to first carry out a trial to generate real world data to better assess their affects before proceeding to more widespread use, then it should be possible to impose whatever restrictions might be deemed necessary without incurring the consequences of permitting unwanted modular concepts during the trial period.

European Directive 97/27/EC, as amended, effectively implements the mass, dimension, and manoeuvrability requirements of Directive 96/53/EC (which refers only to national and international traffic circulating in each territory) in the technical requirements for individual vehicles subject to the type approval requirements (70/156/EC).

Directive 97/27/EC appears to be the only Directive that refers specifically to a converter dolly, the device used to enable rigid vehicles to tow semi-trailers. In this Directive, a dolly is not defined as such but it is stated that *"when a semi-trailer is coupled to a dolly it is considered to be a drawbar trailer"*. This could potentially raise some issues. If a two axle semi-trailer is coupled to a single axle dolly, 97/27/EC would define this as a 3 axle drawbar trailer. In 96/53/EC the maximum weight that would allow free circulation for a 3-axle trailer is 24 tonnes. Assuming that the rear axles of the semi-trailer are rated at 8 tonnes each then the maximum load that can be imposed on the kingpin is 8 tonnes minus the weight of the dolly. This is likely to be considerably less than the weight that could be imposed on a standard two or three axle tractor unit if the same semi-trailer was being carried in a standard configuration. Similarly, if a two axle dolly was coupled to a three axle semi-trailer then 97/27/EC would define this as a 5 axle trailer. However, there are no requirements in 96/53/EC in relation to a 5 axle trailer. This could be interpreted as an inconsistency of approach and may make the implementation of the regulations more difficult.

The fact that dollies are not rigorously defined in regulation has the potential to create a range of other anomalies. It can certainly be argued that a dolly is effectively an O3 or O4 trailer (a trailer with a maximum mass exceeding 3.5 tonnes but not exceeding 10 tonnes (O3) or one exceeding 10 tonnes (O4)) depending on its maximum weight. Treating the dolly as a separate trailer is in many cases the most appropriate route to take because a semi-trailer towed by a dolly will have different characteristics to an equivalent full trailer where the front axle is linked to the trailer via a fixed turntable. For example, the full trailer would be expected to have better static roll stability than the semi-trailer on a dolly because of the elimination of the roll degree of freedom permitted by a fifth wheel coupling. However, in theory at least, this would mean that the type approval regulations would require it to be fitted with a rear underrun protective device, which is, in practical terms, unnecessary. If the use of dollies was to be permitted more widely as part of a move to permit LHVs it may be desirable to formalise their status within the current regulations in order to eliminate these anomalies.

E.5 Speed limits

Schedule 6 of the Road Traffic Regulation Act 1984 specifies the speed limits for vehicles of certain classes. The Table in Part I of Schedule 6 gives specific consideration to Heavy Goods Vehicles (GVW>7.5 tonnes) towing more than one trailer. Such vehicle combinations are currently subject to speed limits of 40 mile/h on motorways and 20 mile/h on all other roads. Based on this regulation, if LHVs were to be permitted then it is likely that all of the options assessed by this project, with the exception of the longer semi-trailer, would be subject to these speed limits.

In the Road Vehicles (Construction and Use) Regulations, a semi-trailer supported by a converter dolly is considered for the purposes of certain aspects of those regulations to be one trailer (defined as a composite trailer). However, the equivalent provisions are not contained within the Road Traffic Regulation Act and therefore it would seem that a composite trailer should be considered as two trailers for the Road Traffic regulations and the lower speed limits would apply. On the other hand, this could be contrary to Directive 97/27/EC as discussed above, and this inconsistency provides another reason why the status in regulations of a semi-trailer towed by a dolly should be reviewed.

Other research reviewed as part of this project has suggested that speed is a very important factor when considering the congestion effects of larger vehicles. From this point of view a reduced maximum speed would be undesirable and it would also substantially reduce the economic advantages of using such vehicles. If it was considered that certain types of LHVs should be permitted and should be allowed to travel at the same road speed as other HGVs, then an amendment to the Road Traffic Regulation Act would be required to allow those specific types to do so. This could be achieved by way of an Order under the positive resolution procedure and would not require primary legislation.

E.6 Operators licensing

The Goods Vehicle (Licensing of Operators) Act of 1995 requires that no person may use a goods vehicle on a road for hire or reward or in connection with any trade or business carried on by him except under an operator’s license. The operators licensing regulations provide traffic commissioners with a great deal of power over goods vehicle operators and are the principal means by which the industry is regulated and enforced.

There are a wide range of powers conferred by these regulations and it enables the Traffic Commissioners to specify the number and type of vehicles (motor vehicles or trailers, weight restrictions etc) that may be operated by any company. However, the regulations are written in respect of individual vehicles and combinations currently permitted by other regulations (principally the Construction and Use regulations and the Road Traffic Act). It is possible that the operators license could be used as a means to permit and restrict LHV use but it seems likely that it would require amendments to the construction and use regulations and potentially the Road Traffic Act.

The Goods Vehicle (Licensing of Operators) Act 1995 also allows conditions to be attached to licenses *“for securing road safety”*. This has the potential to be a mechanism by which, if LHVs were permitted, certain requirements could be introduced to require a higher specification vehicle or operating standard. However, the Goods Vehicle (Licensing of Operators) Act 1995 only permits the traffic commissioner to impose conditions between the operating centre and the point at which the vehicles join the public road. It is likely, therefore, that to use such conditions as a way of implementing vehicle construction or use restrictions on standard vehicles used in combination to form an LHV would require a substantive amendment to the regulations and that construction and use requirements would be better controlled by other legislation.

E.7 Infrastructure

If LHVs were to be considered, it is expected that their use would need to be limited to a sub section of the UK road network. Therefore a network would need to be defined both legally and practically. Motorways are the only "special" roads defined in regulatory terms - The Motorways Traffic (England and Wales) Regulations 1982 and their Scottish equivalent - but clearly LHVs would need to have access to a wider network. All other roads are covered by the Road Traffic Regulation Act 1984. If LHVs were to be permitted on a sub-network that was to include motorways and other roads, it is considered that other steps would be required. In many respects, the primary route network - as defined by signage erected by the road authority under the Traffic Signs Regulations and General Direction (TSRGD) 2002 Regulations 1984 - would appear suitable as the basis of such a network, mainly because it would be visible to drivers through map labelling and signage. During the information gathering exercise some stakeholders suggested that this definition could potentially be used as a basis for a sub-network for LHV use (subject to local restrictions). However, an extensive review and inevitable upgrade of signage would be necessary to ensure clarity and consistency.

Also, many parts of the primary route network would not be suitable for LHVs, particularly if their manoeuvrability was limited. Therefore, if LHVs were to be considered, it is likely that they would need to be confined to specific roads. Restricting a type of vehicle from using a specific route is common. The Road Traffic Regulation Act, 1984, empowers traffic authorities to restrict or prohibit by Traffic Regulation Order any class of traffic for a variety of safety and/or environmental reasons so it is unlikely that any further powers would be needed. The prohibition of pedestrians and cyclists on motorways is perhaps the only example of a national restriction on a specific class of road. Nationally restricting a particular type of vehicle to certain classes of roads is quite different and is likely to require changes to primary legislation to define the new network. Such a new network would almost certainly need a clear and visible identity like motorways, to ensure compliance and effective enforcement.

Another point to bear in mind is that each designated route would need to have an alternative route for diversions in response to accidents, works, etc. This would mean a wider network than perhaps originally anticipated, which would no doubt have to be upgraded to meet required standards. Also if LHV routes are defined in legislation (secondary rather than primary) there needs to be a mechanism to allow change, especially as bypasses, etc are built.

It is also apparent that if LHVs were permitted they must have access to suitable rest areas to allow drivers to comply with drivers' hours regulations and the working time Directive. However, stakeholders have raised concerns that, depending on their size and manoeuvrability, they may not be able to access a large number of existing Motorway Service Areas (MSAs). In addition to this, they may not be able to safely park at MSAs even if they can access them because parking bays will be designed for existing vehicles of up to 18.75m in length.

Most MSAs are now privately owned and operated and are situated on land either owned privately or leased from the Highways Agency (HA). It should be noted that the HA has no powers to force operators to make changes to current sites. Any changes would, therefore, have to be made via agreements with the operators of each MSA individually. Given current practices there seems to be no economic incentive for MSA operators to modify their sites to permit LHV entry and parking (reduced number of paying customers, drivers, per square metre of parking space occupied) they would be likely to charge more for LHV parking or demand that the government meets the cost of the work and pays compensation for loss of business during the works and potentially for ongoing loss of business as a result of the reduced number of drivers that can be accommodated in the parking area.

Many MSAs have already been developed to use all of the land available and any additional parking facilities may, therefore, need to be developed outside of their existing boundaries. The Highways Agency does have powers available under the Highways Act to use Compulsory Purchase Orders to make the land available but these could only be used in conjunction with a successful planning application.

The HA does, however, have the power to influence the design of new MSAs but can only impose requirements relating to vehicles which are currently permitted on UK roads. It would not, therefore, be possible to require parking bays for LHVs unless such vehicles had already been permitted.

E.8 Special Types (General Order)

The Road Vehicles (Authorisation of Special Types) (General) Order 2003 (STGO) permits the use of special types of vehicles on the public highway which do not comply with the requirements that generally apply to road vehicles. This regulation covers a wide range of vehicle types such as special vehicles for agriculture, vehicle recovery and for the haulage of abnormal indivisible loads. The Order places a wide variety of restrictions on such vehicles, including those relating to construction and those relating to their use on the road network, in many cases there are requirements to notify relevant authorities of intended routes. It may be considered that, if they were to be permitted, LHVs could be considered as a special type and this regulation could be amended to permit and control their use.

This may be particularly relevant if LHVs were to be permitted only in certain sectors of industry, such as for forestry operations, where it was deemed that there was no significant international competition in accordance with the requirements of 96/53/EC.

If different regulations were to be used to permit LHVs then it would not be expected that their use would come into direct conflict with the STGO regulations. However, the STGO regulations do permit heavy goods vehicles of up to 150 tonnes and greatly exceeding the maximum dimensions with a range of exemptions from construction and use as well as a range of additional requirements, providing that they are carrying an abnormal indivisible load (AIL) that could not be divided into smaller units for carriage on a standard HGV. The LHVs assessed as part of this study could be considered to be similar in nature to some of these STGO vehicles. For example, a 25.25m combination at a GVW of 60 tonnes would be quite similar to a category 2 AIL vehicle and the C-train could be considered similar to a category 3 STGO in terms of their gross weight and overall lengths.

While it is not considered that the requirements would be in direct conflict it may be that the respective industries may note an inconsistency of approach. When an AIL vehicle exceeds the weights and dimensions normally permitted the vehicles are exempt from certain construction and safety features such as the requirement to fit ABS and a reduced requirement for stopping distance. To compensate for this they are limited to lower speeds than standard trucks, are required to notify authorities of their movement who may require an escort vehicle to be present when certain limits are exceeded. Although the STGO regulations could be used to permit LHVs there may, therefore, be a need to carefully consider how this would be implemented to avoid aspects of the existing regulation, such as any unique vehicle requirements and exemption from plating and annual roadworthiness testing, from being carried forward into the requirements for LHVs.

E.9 Special Orders

The Secretary of State for Transport has limited powers under section 44 of the Road Traffic Act to grant individual Special Orders which permit vehicles on the public highway not complying with the all the requirements generally applicable to road vehicles. They are used for diverse reasons ranging from permitting vehicles that do not conform with all construction and use requirements to be used on the road for the purpose of research into road safety, through to permitting vehicles in excess of 150 tonnes GVW to be used to carry exceptionally large indivisible loads. Special Orders could, therefore, be used to permit the use of LHVs, whether domestic or visiting, on a case by case basis, including the imposition of any specific route restrictions or safety features required for any particular movement. This would avoid the need for amendment to other regulations but would incur an administrative cost for each Order which for existing orders is currently provided free of charge by the Department for Transport. It would, however, offer a suitable means of administering any trial activity if such a trial was considered to be appropriate. However, Special Orders cannot be used to grant exemption from the speed limits described in section E.5 so the Road Traffic Regulation Act (1984) would still require amendment if a meaningful trial was to be administered using Special Orders.

Appendix F. Analysis of industry response to LHVs

F.1 Introduction

This appendix presents the results of the industry fact-finding exercise which was undertaken between March and June 2007. The fact finding was undertaken using two main methods; an on-line survey and focus group discussions. The aim of the on-line survey was to gain quantitative data on the freight operations of a range of road hauliers and shippers. The aim of the focus groups was not to obtain a representative view of UK industry on the subject of LHVs but rather to explore, in an interactive forum, a range of issues regarding LHVs.

The section begins by outlining the methodology employed and range of LHV scenarios considered before summarising the main results. Sections A.4 to A.13 discuss industry views on the likely use of LHVs if permitted, their potential benefits, operational constraints on their use and the possible effects on the road haulage industry. Section A.14 discusses the possible impact of LHVs on the railfreight market. Feedback from companies in the maritime sector suggested that the introduction of LHVs would have little effect on the waterborne freight market. Section A.15 considers the claims made by several stakeholder groups that the use of LHVs would generate additional freight movement, thus offsetting some of the environmental benefit of load consolidation. One of the objectives of the industry fact-finding exercise was to provide guidance on the choice of key parameter values for input into the LHV cost model. The appendix ends with discussion of the derivation of these values.

This section presents the views of a wide range of stakeholders directly involved in the freight transport industry and focuses on the logistics, operational and economic issues that these stakeholders are best placed to consider with reference to the affects on other parameters where the stakeholders expressed an opinion. The views of other stakeholders such as infrastructure owners, enforcement agencies and representatives of other road users are presented in other sections of the report that deal in more detail with the wider issues that would be affected if LHVs were to be permitted.

F.2 Methodology

F.2.1 Focus Group Discussions

It was originally intended that focus group discussions would be used to gain more in-depth information from a few key stakeholders in order to enhance the findings of an online questionnaire survey and, in particular, to gain information on the likely mode shift effect. However, given there was a relatively low response to the online survey, such that statistically meaningful results could not be obtained. For this reason, the number of focus group sessions was increased to obtain a broader cross-section of industry views on the likely use of LHVs, if permitted, and related issues. Four organisations also agreed to host focus group discussions: Rail Freight Operators Association (RFOA), the Freight Transport Association, Society of Motor Manufacturers and Traders and Confederation of Forest Industries / Timber Transport Forum. A total of eight focus group discussions were held in three locations, London, Birmingham and Edinburgh:

Table 85: Composition of focus groups

location	date	delegates	composition
London	1st March	5	directors from the two main railfreight operators
London	30th March	11	producers and hauliers
Edinburgh	2nd April	8	members of the Timber Transport Forum
Edinburgh	11th April	16	producers, hauliers, retailers, port operator, railfreight co.
London	12th April	11	producers and hauliers
London	17th April	30	FTA Rail Freight Council
Birmingham	24th April	15	retailers, producers, hauliers.
London	2nd May	13	commercial vehicle manufacturers

All the discussions were facilitated by the project team from Heriot-Watt University and lasted between 2 and 2 ½ hours. The delegates at the focus groups were presented with background information about the project, such as the scope and objectives of the project and the vehicle types and scenarios being assessed (see section F.3 for more details). They were asked to consider a range of questions, which varied according to the particular audience but generally included:

- To what extent could efficiency and vehicle utilisation be improved within existing weights and dimensions regulation?
- Should LHVs be considered and if so;
  - For which of the LHV options, if any, did they have a preference?
  - What would be the effects of restricting LHVs to different classes of road?
  - What role could be seen for LHVs in supply chains?
  - What benefits would companies derive from using LHVs?
  - What factors might constrain the use of LHVs?
  - What levels of vehicle utilisation would operators of LHVs be likely to achieve?
  - What effect would LHVs have on freight modal split?
  - What would the wider implications of LHVs be for logistics and supply chain management? In particular, would their use be likely to generate more freight movement?
  - What other issues related to LHVs should be considered?

The focus groups were interactive forums designed to explore managerial opinions rather than collect quantitative data. On most topics it was not possible to quote specific figures or percentages but it was possible for the facilitators to gain a subjective impression of general views on particular issues. Overall, the findings have been summarised in a way that reflects the balance of opinion across the focus groups, indicating areas of agreement and disagreement and, where significant, the views of individual delegates.

Delegates were assured that 'Chatham House' rules would be applied and that no comments would be attributed to particular companies or individuals. All the sessions were recorded and, in most cases, notes were also taken during the discussion. Some organisations subsequently volunteered written submissions for use in the project and information from these submissions has been appropriately attributed.

F.2.2 Composition of the Focus Groups

In the case of the four industry focus groups organized by Heriot-Watt University, a total of 180 invitations were mailed or emailed to companies, in most cases providing a choice of date and location. Forty-five of these companies participated in the general focus groups, representing a 25% response rate. Attendance at the remaining focus groups was arranged by the organizations hosting these events. Altogether 109 delegates from a total of 72 organisations took part in one of the industry focus group discussions. A broad spread of hauliers, logistics companies, manufacturers, retailers, rail companies and other agencies expressed their views at these forums (Table 86). This sample of organizations is not necessarily representative of UK industry. It was a self-selected sample of delegates / companies that volunteered to take part. Companies interested in using LHVs were more likely to attend these events, apart from those organized by the RFOA and FTA National Rail Council many of whom expressed concerned about the likely adverse effects of LHVs on the railfreight sector.

In order to reach a wider audience, Heriot-Watt also incorporated a 30-40 minute discussion of LHVs into a separate series of seven workshops that it had organised as part of an EPSRC-funded research project on Green Logistics. These events were attended by delegates from around 50 other organisations, most of them users or providers of logistics services. Views expressed at these events have been incorporated in the general analysis of industry opinion summarized in this section of the report.

Table 86: Composition of the Sample of Companies Attending LHV Focus Groups

Type of organisation	Number of Companies	%
Haulier	13	18%
Logistics Service Provider	13	18%
FMCG Manufacturer	9	13%
Other Manufacturer	7	10%
Primary Producer	6	8%
Food retailer / wholesaler	5	7%
Non-food retailer	5	7%
Rail sector	5	7%
Trade bodies	4	6%
Ports / shipping	3	4%
Other	2	3%
Total	**72**	**100%**

F.3 LHV Scenarios

The delegates were presented with a list of eight scenarios for LHVs. These scenarios were defined with respect to vehicle length, gross vehicle weight and number of axles. The specific vehicle design or equipment employed to achieve that length and weight was not specified as part of these scenarios.

In the development of these scenarios, the concept of 'payload neutrality' was introduced. This is applied when the gross weight of an LHV is increased by a sufficient margin to cover the additional tare weight of the larger vehicle but not to increase the maximum payload weight. Three of the eight scenarios, described below, embodied this concept.

- *Scenario A: Baseline*
  - Retention of current regulations relating to maximum vehicle weights and dimensions. It may be possible for companies to achieve greater efficiency within these regulations by plating more lorries at 44 tonnes, double-decking more of their articulated vehicle fleets and / or improving the utilisation of vehicle capacity. Of the vehicle types assessed only vehicle 1 and vehicle 2 would be permitted under this scenario
- *Scenario B: LHV with longer semi-trailer with maximum length of 18.75m and maximum gross weight of 44 tonnes.*
  - 18.75 m is currently the maximum length of a drawbar trailer combination. Within this overall length limit it would be possible to increase the length of the semi-trailer to 16 m accommodating two additional rows of three industry standard pallets. This

vehicle would run on six axles and be restricted to a gross weight of 44 tonnes. Although unladen weights of existing vehicles vary, the baseline case as described in Appendix A assumed that the payload was 29,109kg, based on averages of actual vehicles studied. The additional unladen weight of the longer semi trailer was assumed to reduce the maximum payload weight from 29.109 tonnes to 27.322 tonnes. Although in reality it would be expected that weights would vary, this was considered a realistic typical value. This scenario would permit vehicles 1, 2 and 3 described above

- *Scenario C: Payload-neutral version of the longer semi-trailer LHV with maximum length of 18.75 m and maximum weight of around 45 tonnes.*
    - This vehicle would have the same pallet capacity as in scenario B but also have the same weight carrying capacity as a standard 44 tonne artic with 13.6 m trailer. This type of vehicle was not assessed in detail in the impact analysis.
- *Scenario D: LHV with maximum total length of 25.25 m and a gross weight of 44 tonnes.*
    - The 25.25 m length conforms to what has become known as the “European Modular System” as currently used in Sweden and Finland. This would increase the number of pallet slots from 26 on a 13.6 m trailer to 40. Imposing a gross weight limit of 44 tonnes on this vehicle, however, would reduce its weight carrying capacity by approximately 5 tonnes, corresponding to its additional tare weight. This scenario would permit vehicle types 4 and 5 as well as the baseline vehicles 1 and 2.
- *Scenario E: Payload-neutral version of the LHV with maximum total length of 25.25 m.*
    - Raising the gross weight of this vehicle to approximately 49 tonnes would allow it to carry the same maximum payload as a 44 tonne HGV. This scenario does not specifically permit any of the vehicle types assessed in detail and objective analysis relies on interpolation between vehicles 4 or 5 and 6 or 7.
- *Scenario F: LHV with maximum total length of 25.25 m and a gross weight of 60 tonnes.*
    - The 25.25 m combinations would run on 8 axles. If maximum axle weights remained at their present level, it would be possible for this vehicle to carry a maximum payload of 39-40 tonnes, roughly 32% more than a 44 tonne HGV. This scenario would permit vehicle types 1, 2, 4, 5, 6 and 7.
- Scenario G: *LHV with maximum total length of 34 m and a gross weight of 60 tonnes.*
    - Restricting this vehicle, comprising two 13.6 m trailers, to a 44 tonne gross weight limit would reduce the maximum payload weight by over a third and limit its use to only a small group of very light commodities. It was proposed, therefore, that the lower gross weight limit for this vehicle be set at 60 tonnes. However, the detailed analysis of a vehicle of this type was only carried out for the heaviest scenario
- Scenario H: *LHV with maximum total length of 34 m and a gross weight of 82 tonnes.*
    - This 34 m combination would run on 11 axles allowing it, within current axle loading limits, to carry up to 82 tonnes. This scenario would permit vehicle types 1, 2 and 8.

Figure 84 was presented to the delegates to provide an indication of the volume and weight-carrying capacities associated with each scenario. Detailed numerical values are assigned to these scenarios in section 4.2 of the main body of this report.

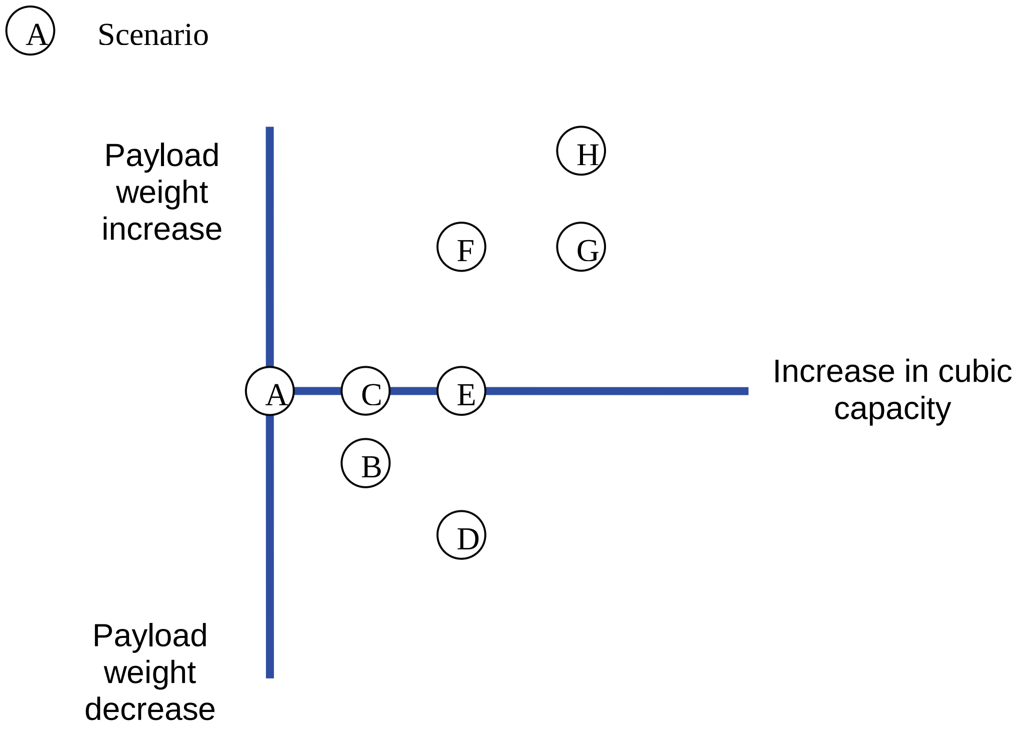

Figure 84: Impact of LHV Scenarios on vehicle carrying capacity.

F.4 Preferences for LHV Scenarios

Delegates attending six of the eight focus groups were asked to rank the eight LHV scenarios in terms of the amount of benefit that their company could gain from using the corresponding vehicles. Figure 85 shows the result of this opinion survey.

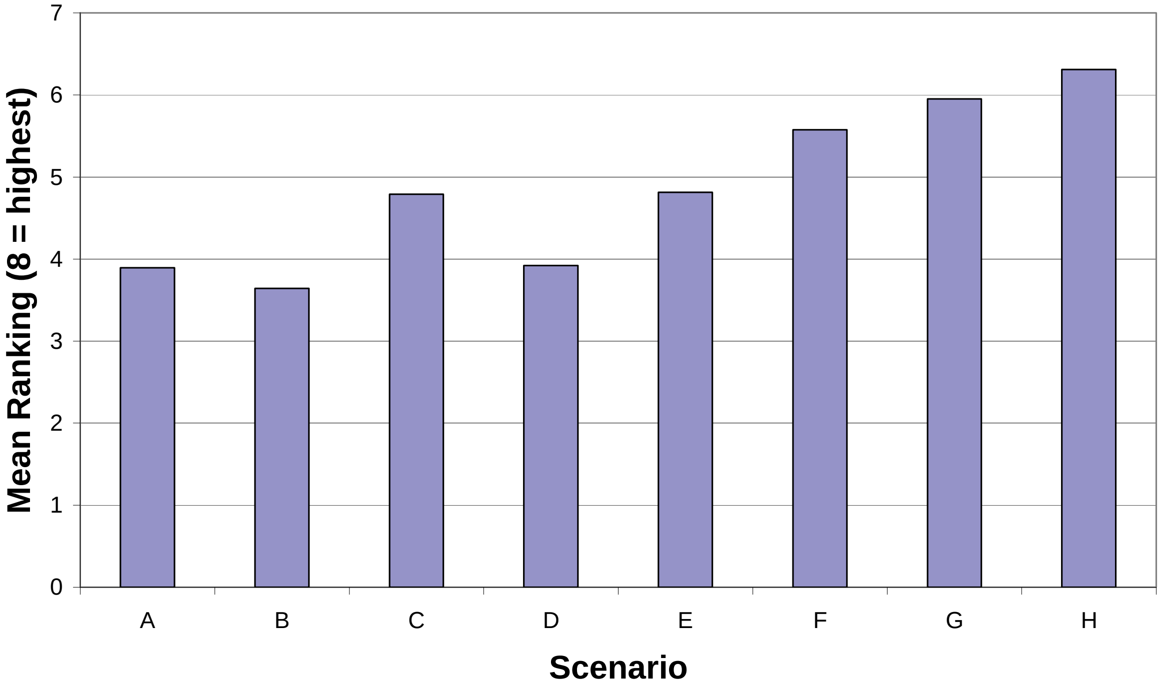

Figure 85: Ranking of the LHV Scenarios by Focus Group Delegates

Based on an arithmetic mean of the responses, the ranking correlates closely with the size and weight of the vehicle. The most popular option was Scenario 8, permitting the coupling of two 13.6 m trailers at a gross weight of 82 tonnes. In subsequent discussion, delegates offered three reasons for their preference for this LHV:

- maximum carrying capacity,
- use of standard equipment
- minimal additional capital cost.

The next three rankings are in line with declining vehicle capacity. The payload neutral version of the longer semi-trailer LHV received more votes than a 25.25 m combination restricted to 44 tonnes. The substantial loss of payload weight on the latter vehicle proved unpopular, even among companies distributing low density products. The least popular option, rated worse on average than retaining the status quo, was the 44 tonne version of the longer-semi-trailer vehicle.

These results require qualification. First, delegates were told to assume that all vehicle scenarios would be applied to the road network currently accessible to HGVs. In practice, it is likely that the larger and heavier the vehicle the tighter will be the network restrictions. Equally, it is possible that a longer semi-trailer of the same length as current drawbar combinations and meeting manoeuvrability requirements may be permitted to travel anywhere current articulated vehicles can. A subsequent attempt to get delegates to indicate their likely level of usage of scenario ‘vehicles’ at different degrees of network restriction yielded a poor response. This required an intimate knowledge of the company’s pattern of road freight flow and a rather complex evaluation of the scenarios against different routing options, which was generally considered too complex an analysis to give an immediate qualitative view on within the short time available at the workshop. Second, transport and logistics managers would have a natural inclination to set limits on vehicle weights and dimensions at the highest possible levels to maximise their freedom of action. Even if they seldom used the available capacity, the opportunity would exist to do so. Third, these different vehicle scenarios would be likely to attract different levels of vehicle excise duty. In the absence of VED rates for these hypothetical categories, delegates are likely to have ignored tax differences.

The ranking varies if measures other than the arithmetic mean are considered. This is shown by the disaggregate data and alternative descriptive statistics in Table 20, below.

Table 87. Individual ratings and descriptive statistics for focus group responses

Scenario	Number of respondants giving each ranking								Total number of respondants	Arithmetic mean rating	Mode rating
	1	2	3	4	5	6	7	8			
No change	13	2	2	5	1	8	4	3	38	3.9	1.0
18.75m 44 tonnes	5	14	4	4	6	3	4	2	42	3.6	2.0
18.75m c.46 tonnes	0	1	15	6	6	6	3	6	43	4.8	3.0
25.25m 44 tonnes	3	8	6	10	3	1	5	2	38	3.9	4.0
25.25m c.50 tonnes	0	4	6	7	14	3	7	2	43	4.8	5.0
25.25m 60 tonnes	3	4	3	1	2	17	10	7	47	5.6	6.0
34m c.63 tonnes	1	3	5	0	3	6	15	9	42	6.0	7.0
34m 82 tonnes	5	2	0	3	2	2	7	24	45	6.3	8.0

The desire to gain the largest possible capacity increase to maximise flexibility can be seen in the data above where the mode rating is calculated for each scenario. The mode rating is that with the most frequent response. It can be seen that the largest proportion of respondants simply rated the scenarios directly in line with vehicle capacity. In addition to this, although on average (arithmetic mean) the 18.75m 44 tonne vehicle received a lower score than maintaining the status quo the distribution of response differed considerably. In the main, respondants tended to be for or against maintaining the status quo with 34% of respondants giving it the lowest possible score and 39% rating it at 6 or above. In contrast, only 12% of respondants gave the longer semi-trailer at 44 tonnes the lowest score and 21% scored it at 6 or above. These results suggest that a longer articulated vehicle at 44 tonnes could prove very useful to a smaller proportion of companies but would be of only low usefulness (compared with the other options evaluated) to a larger group of companies.

F.5 Likely Characteristics of LHV Usage

A general consensus emerged in the focus group discussions that LHVs would have specific applications and not become a standard vehicle type as the 44 tonne artic with 13.6 m semi-trailer has become over the past six years. The number and extent of these specialist applications would depend on the network restrictions and gross weight limits imposed on LHVs. According to focus group delegates, it is likely that LHV operations, if permitted, would have several characteristics:

- They would be used on longer hauls.
- They would handle mainly regular flows of products.
- They would cater mainly for lower density loads requiring greater cube.
- Most of their deliveries would be undertaken on a contractual basis for particular clients or as part of a network service.
- They would be applied mainly to primary movements between points of production and / or warehouses, with very limited use in secondary distribution to shops.
- They will tend to be used on routes with good backloading opportunities, resulting in them having below average empty running.
- The 25.25 m combinations would be used mainly on a point-to-point basis with limited coupling / decoupling of units *en route*.
- Coupling / decoupling would be much more common in the case of the 34 m A / C – train vehicles, particularly if, as widely expected, their movements were confined to the motorway network.

There was a general belief that the 25.25 m combination would have a significantly higher capital cost than a standard 44 tonne artic and that few general hauliers would speculatively upgrade to this type of vehicle. Its specialist role combined with uncertainty about loading opportunities would deter hauliers from making a speculative investment in LHVs for use in the spot haulage market.

The 34 m LHV, on the other hand, would require minimal investment in an additional dolly while, by combining two standard 13.6 m semi-trailers, it would offer greater flexibility than the 25.25 m LHV. Its application would be limited mainly by network restrictions. Opinions differed on the likely demand for these vehicles as ‘motorway road trains’. Those predicting limited demand argued that:

- Few point-to-point loads would be large enough to fill such an LHV
- Coupling / de-coupling of the trailers would only be economically viable where the motorway trunk haul was long and off-motorway feeder journeys short
- There was limited capacity for trailer parking at motorway junctions and little prospect of new capacity being added in the near future.
- Companies transporting more valuable loads (e.g. whisky) would only be prepared to detach and park trailers in locations offering adequate security. Few such locations exist at present.

Those envisaging higher usage argued that:

- Large numbers of major production and distribution sites were located within a few miles of motorway junctions. If granted off-motorway access within a range of several miles, significant use could be made of these vehicles without the need for coupling / decoupling.
- These sites could fulfil the role of coupling / decoupling points if required.
- Approved networks could be ‘customised’ for specific companies and enforced using vehicle telematics systems.
- Cost savings and reduced demand for drivers would be attractive to many operators.

F.6 Likely Demand for LHVs

It has proved difficult to judge the likely overall demand for LHVs in the UK. It was hoped that the online questionnaire survey would provide an indication but this generated a poor response despite extensive marketing, both directly and through the trade associations (e.g. FTA), and the extension of initially tight completion deadlines. Possible reasons for this low response are discussed below:

- This could suggest a general lack of interest in the possible use of LHVs, although this conclusion would be contrary to the relatively high response rate (25%) to invites to the focus group meetings.
- The questionnaire was quite long and detailed and the response rate to questionaires of this length is generally quite low.
- The questionnaire did not simply seek companies’ qualitative views. It also sought quantitative data about their freight transport operations. Although confidentiality was guaranteed, many managers may have been reluctant to provide this data or may simply have lacked the time to assemble it. This would be consistent with the fact that only a small proportion of a substantial number of visitors to the questionnaire website actually completed the questionnaire.
- The Ministerial decision in December 2006 not to approve an LHV trial in the UK was widely reported in the trade press and may have led many potential respondents to think that the prospects of LHVs being legalised in the UK were remote.

- The diversity of vehicle designs and scenarios under consideration complicates the LHV issue and makes it difficult for managers to form a view.

The final issue described above was one that was thought to be a problem by the FTA, which they raised in a formal letter to the project team.

In the case of the last changes in maximum lorry weight from 38 tonnes to 44 tonnes (between 1999 and 2001), there was clear support from major trade bodies such as the FTA and CBI. Indeed the FTA, representing over 13,000 freight transport users in the UK, had actively campaigned for the lorry weight increase for 20 years. There has been no similar, unequivocal support from the main trade associations for LHVs. This may partly reflect the diversity of opinion on the subject across the FTA's broad membership. The FTA has also argued that the LHV proposal which is being investigated is *'complex…vague and unspecific'* and that this has made the *'supporting case difficult to articulate convincingly'*. It stresses, however, that *'this should not be taken as a lack of support for the principle… of increasing the capacity of goods vehicles as a means of reducing the numbers of vehicles required and reducing emissions.'*

The focus group discussions provided a stronger empirical base upon which to estimate the likely uptake of LHVs, if they were permitted, though this assessment is based on qualitative rather than quantitative data. They suggested that many companies in particular sectors of the economy would like to have the opportunity to use LHVs but that most of these potential users saw limited applications for LHVs in their logistics systems. There was a broad consensus that LHVs would not become the standard vehicle in the way that 44 tonne 13.6 m articulated vehicles have become over the past six years. The FTA concurs with this view in foreseeing *'niche applications'* for LHVs. These 'niches' will exist both at a sectoral level and within logistics operations of individual companies. In researching the market for LHVs, the challenge is therefore to define these niches and quantify the likely level of usage in each niche. On the basis of the industry fact-finding exercise it has been possible only to identify sectors in which LHVs would probably be widely adopted. The following two sections outline these sectors and give examples of companies that see a role for LHVs in the freight transport operations.

F.7 Key Sectors Likely to Adopt LHVs, if permitted

F.7.1 Pallet-load networks

These are hub-and-spoke networks for the overnight delivery of pallet-loads across the UK. Regional hauliers collect pallets and consolidate them into larger loads for overnight trunking to sortation hubs, most of which are located in the English Midlands. Pallets collected from the hub are trunked back to the regional depot for distribution to local customers, as illustrated in Figure 86, below. The volume of pallet traffic on some of the trunk routes into the hubs would justify the use of LHVs. Much of this trunk movement is currently undertaken by double-deck, curtain-sided artics. Some of this traffic would be likely to switch to LHVs, for ease of handling and / or to take advantage of additional payload weight.

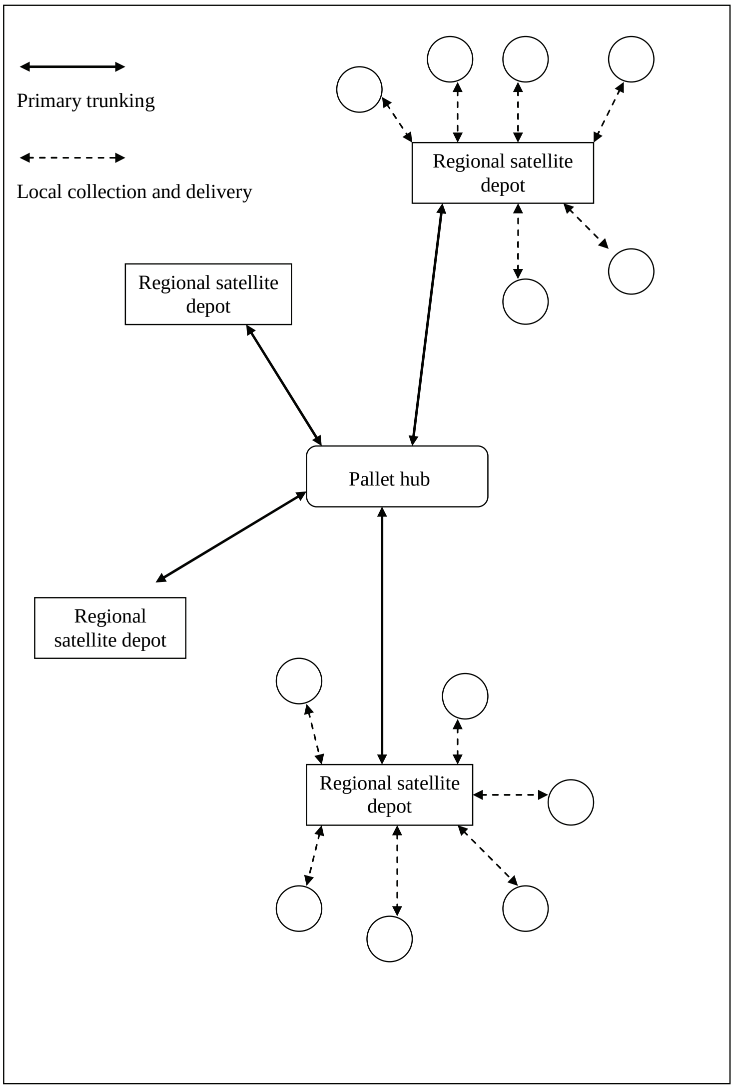

Figure 86: Hub-and-spoke structure of pallet-load and express parcel carriers.

(Adapted from Freight Best Practice Programme, 2005)

There has been a substantial growth in the volume of road freight being channelled through pallet-load networks since the early 1990s. This growth can be partly attributed to a reduction in average consignment size in sectors where the just-in-time principle has been widely applied. When this consignment size falls below a critical value (which varies by commodity and distance travelled), it become more cost-effective to use a pallet-load network than to deliver the order directly between origin and destination in a partly filled vehicle. Pallet-load operators consolidate ‘less-than-truckload’ traffic on the trunk radial routes, achieving economies of scale. On those corridors with the high traffic volumes, the use of LHVs could augment these scale economies. It has been estimated that the main pallet-load networks now handle between 60,000 and 70,000 pallet-loads per night.

Several of the main pallet-load hubs are located in or around the Fradley distribution park, north of Birmingham, which is connected by a dual carriageway link to the M6.

Access is more likely to be a problem at the regional ‘satellite’ depots, many of which are located on single carriageway roads, some distance from the nearest dual carriageway / motorway. The level of use of LHVs, if permitted, would depend at least partly on the access restrictions applied to the vehicles, which would in turn depend on the characteristics of the vehicle types permitted. If the smaller LHV types were permitted and were capable of meeting current manoeuvrability criteria then this would be less of a problem but may be more substantial for the largest vehicles. It was suggested, however, that for the larger vehicle types coupling / decoupling points, strategically located within the radial trunk networks would help to solve this problem. This would obviously depend on the comments reported earlier about the relative length of the trunk haul and feeder journeys.

Almost all trunking to and from these hubs takes place at night, which led stakeholders to believe that the LHV movements in this sector would be relatively inconspicuous and have little effect on other types of traffic. On the other hand, the same rationale led them to consider that the use of LHVs in pallet-load networks would not relieve day-time traffic congestion.

The issue of loading and unloading vehicles with two separate loading units was discussed. Some companies considered that loading would take place from the side using curtain-sided vehicles. Those companies with requirements or facilities for rear loading of box bodied vehicles considered that it would be necessary to uncouple the vehicles and move each trailer into position at the loading dock. While some companies were concerned about the requirements for manoeuvring space to achieve this, most did not see it as a major constraint.

In contrast to the views expressed by the majority, some hauliers involved in pallet-load networks and the retired founder of one of these networks were sceptical about the net benefits of using LHVs. As discussed at greater length in section A.12, their main concern was that these vehicles will depress rates, further commoditise road haulage services and not yield any additional profit for hauliers (i.e. the benefits would accrue mainly to shippers and/or their customers).

F.7.2 Primary Distribution in the Fast Moving Consumer Goods (FMCG) Sector

Primary distribution is defined as the movement of freight at upper levels in the supply chain between factories and between factories and national or regional distribution centres, as shown in Figure 87, below. The FMCG product range roughly equates with the product portfolio found in a typical supermarket and includes grocery items, drinks, household cleaning products and health and beauty items. Approximately one third of the companies represented at the focus groups were from this sector, including major supermarket chains, large manufacturers and logistics providers specialising in FMCG distribution. Most of these companies transport relatively low density products which ‘cube out’ well below the maximum gross weight. Participants generally considered that typical payload weights on fully-laden artics (by cube) would be 7 tonnes (for household paper products), 10 tonnes (for breakfast cereal) and around 12 tonnes (for a mixed range of supermarket products). These companies saw a limited though useful role for LHVs in the primary distribution of these products, even in pay-load neutral versions of the 25.25 m vehicle. Companies in the drinks, canned goods and frozen food sectors, on the other hand, suggested that they would require an increase in the maximum payload weight to derive any economic benefit from the use of LHVs.

The use of LHVs in the FMCG sector would be constrained by several factors:

1. Just-in-time (JIT) and quick response pressures which have been depressing consignment sizes and limiting the extent to which suppliers can fill existing vehicles, let alone longer and heavier ones. Most delegates in the focus groups doubted that the availability of LHVs would cause vendors, particularly the retail chains, to relax these pressures in an effort to improve vehicle loading. JIT replenishment is now deeply embedded into companies’ business processes and would be difficult to reverse.

2. Vehicle manoeuvring and parking space at retailers’ distribution centres: Many of these distribution centres are working at or beyond design capacity and would lack the space for the manoeuvring and decoupling of LHVs prior to off-loading. If the larger LHV types with limited manoeuvrability and consequently limited access were permitted then stakeholders considered that there might then be a need for localised decoupling / coupling of trailers in the vicinity of distribution centres, raising possible environmental and safety concerns. Several companies indicated that the loading bays at their production plants and / or distribution centres would have to be extended to accommodate LHVs. Questions were also raised about the scheduling of LHV deliveries into retailers’ distribution centres. It was assumed that an

LHV would be booked in as a single vehicle. It was considered possible, however, that a 34 m road train comprising two trailers with different companies' products might be given two separate, non-sequential slots. This would make it difficult to schedule the movement of LHVs efficiently and create the need for additional trailer parking space in the vicinity of the distribution centre.

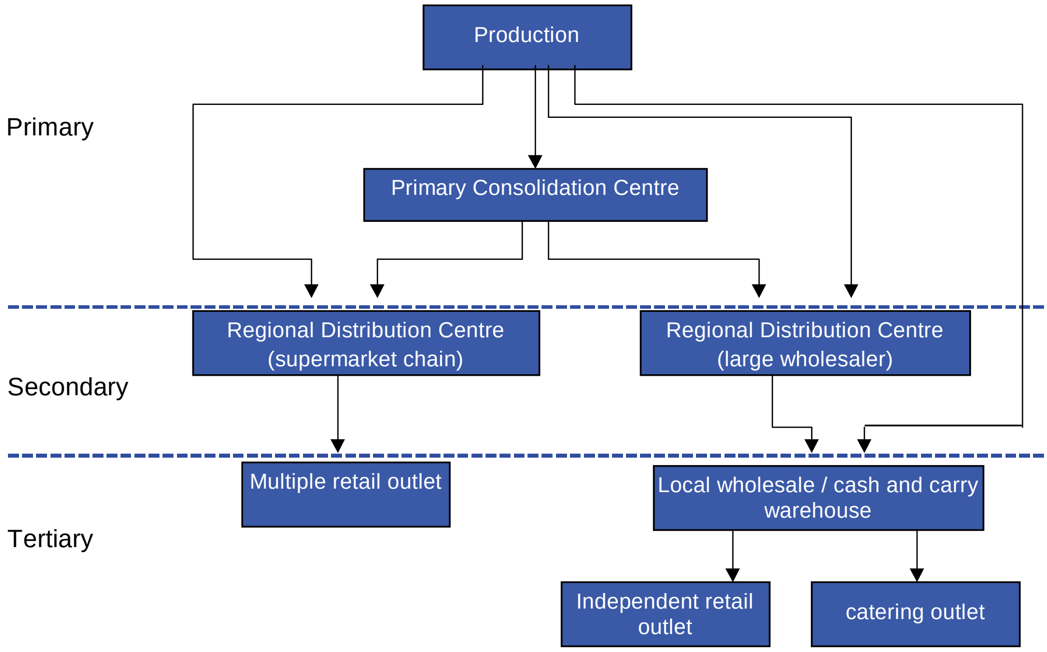

Figure 87: Channels of Distribution the FMCG Sector

3. Integration of primary and secondary distribution: Over the past 15-20 years, retailers and their suppliers have managed to achieve significant improvements in vehicle loading by integrating primary and secondary distribution operations. This can be done mainly in two ways:

   a. Returning shop delivery vehicles can collect loads from suppliers' premises and transport them to retailers' distribution centres.

   b. On their way back to the factory, suppliers' vehicles can deliver supplies from a retailer's distribution centre to a shop on or near the return route.

4. If, because of road network restrictions, LHVs were confined to primary distribution they would be unable to exploit backloading opportunities available at the secondary distribution level. This might discourage their use within the FMCG sector.

5. Widespread use of double-deck vehicles: Many companies in this sector already make extensive use of double-deck vehicles capable of carrying up to 52 pallets / roll cages and can fill them within the current maximum weight limit. The 25.25 m combinations, with a carrying capacity of only 40 pallets, would offer limited benefit to such companies, except those which:

   a. have a significant number of orders in the intermediate range between, say, 35 and 45 pallet-loads.

   b. could take advantage of the ability to split these LHVs into 13.6 m and 7.8 m units.

F.7.3 Deep-sea container traffic to and from ports

The introduction of LHVs would cause a step-change in the economics of moving ISO containers by road. For the first time in the UK, it would allow hauliers to combine a 40ft and 20ft container on a 25.25 m combination or two 40 ft containers, one 40ft and two 20ft containers or four 20 ft containers on the 34 m LHV. As the rail industry acknowledged in its written evidence, many hauliers will, at least initially, lack the necessary infrastructure to consolidate container traffic and hence not be able to exploit the full cost savings. It estimates that, under normal operating conditions, a 25.25 m LHV would cut current operating costs per Twenty-foot Equivalent Unit (TEU) by around 15%. Major road hauliers in the deep-sea container market are, nevertheless, among the strongest supporters of LHVs. They seem less concerned about the fear expressed more generally across the road haulage industry that shippers will capture all the cost savings and net improvements in profitability will be marginal. It is likely that there would be a substantial uptake of LHVs in this sector. To remain competitive all operators would have to acquire them and market shares within this sector of the road freight market might remain reasonably constant. The reductions in inland container transport rates might cause some redrawing of port hinterlands, though this too is likely to be marginal. The main losers are likely to be the railfreight operators carrying deep-sea containers, particularly Freightliner. As discussed more fully in Section F.14.2, road would be likely to expand its current 75% share of the deep-sea container market if LHVs capable of carrying more TEUs than current vehicles were to be allowed.

Port operators are concerned that modal shift to road will exacerbate current congestion problems on access roads and on-site. They considered, however, that it was possible that the consolidation of existing HGV traffic in a smaller number of LHV trips would more than offset any increase in road traffic from modal shift, although they had not undertaken objective analysis to support this view. LHVs might also inhibit the development of ‘port-centric logistics’. This relatively new concept entails a redefinition of the role of a port within the supply chain. Containers are emptied (‘de-stuffed’) at the port and their contents stored / cross-docked at distribution centres on the port site or nearby. Products can then be distributed from there to retailers’ distribution centres or directly to shops, eliminating a link in the supply chain. If LHVs could not be used for secondary distribution, they would tend to favour retention of the current system of inbound container delivery.

F.7.4 Forest products sector

The Timber Transport Forum, representing companies in the forest products industry, has expressed strong support for the use of LHVs in this sector. Road transport typically accounts for 30%-40% of the selling price of the timber (even higher for the ‘co-products’ produced at sawmills) so the reductions in transport cost that LHVs would permit could have a significant impact on the competitiveness and size of the industry. Major competitors in Sweden and Finland currently make heavy use of LHVs and gain significant cost advantages in the movement of timber from forest to mill. Their transport cost advantage is not simply due to their use of larger trucks; their fuel duty is also much lower. Members of the Forum said they would like to be able to use a 25.25 m rigid-artic trailer combination similar to that used in the Scandinavian forest sector plated at a maximum weight of 60 tonnes. All loads in this sector are weight-constrained and could be increased to take full advantage of the 60 tonne gross weight limit. In recent years there has been an increase in the number of timber lorries that are equipped with cranes, weighing 1-2 tonnes, thus eroding weight carrying capacity in current 44 tonne vehicles.

LHV-related reductions in transport costs would make it economic to harvest timber from a wider area and expand the overall size of the UK forest industry. It would also allow the industry to more effectively exploit the growth in demand for biofuels from forest products.

The main constraint on the use of LHVs in this sector would be road access both on the public rural road network and on the 20,000 km network of unsurfaced forest access roads maintained by the Forestry Commission. LHVs have been used on both public and forest roads in Sweden and Finland for many years. The latter roads tend to be wider in these countries than in the UK, though Sweden has more unsurfaced public roads. The Forestry Commission has always tried to accommodate on its network the maximum size and weight of lorry allowed on the public road network. They would like any LHV to meet current turning circle requirements. The effect of LHVs on unsurfaced roads had not yet been extensively researched but it was expected that the heavier gross weight of the LHV type preferred by the forest industry would be more damaging to its unsurfaced roads than the current generation of timber lorries. Although the maximum axle weight was not likely to increase it was argued that the gross weight was also a significant factor in wear and damage to unsurfaced roads. Variable tyre inflation (CTI), which is used by timber trucks in North American, could be used spread the load over a wider tyre surface area on unsurfaced roads. This would add around £3-4 K to the capital cost of an LHV timber lorry, which with a crane, would probably cost around £120 K. There would still be greater damage to the underlying structure of the forest road which would inflate the Forestry Commission's road maintenance costs. No firm judgement had been made as to whether LHVs would be permitted on forestry roads.

The forestry sector has long experience of working with local authorities in rural areas to confine timber movements to approved roads. There are many voluntary agreements with local authorities and regular discussions with highway authorities. It could adjust to a new set of LHV-related restrictions so long as these were not too restrictive. It is likely that accessibility of LHVs would vary significantly between the main timber-producing regions of the UK, with, for example, the West of Scotland offering less scope for LHV usage than southern England. There may, therefore, be some geographical distortion of the UK timber market. Confining LHVs to dual carriageways and motorways would severely constrain their use for timber transport.

The higher capital cost of LHVs would not deter their use, given the magnitude of the potential cost savings. Much of the timber haulage work is currently undertaken on basis of 'gentlemen's agreements'. To be prepared to make the necessary investment in LHVs, hauliers might have to be given the security of a more formal contract.

F.8 Examples of Companies Likely to Use LHVs, if permitted

As discussed earlier, the stakeholders generally considered that the use of LHVs would not become the norm but would fulfil certain niche applications. The following section highlights the individual views of specific companies that suggested they would be likely to use LHVs, if permitted. It illustrates potential applications and does not attempt to show the full range of possible uses of LHVs. No reference is made to the numerous companies that would be unlikely to find a commercial application for LHVs.

F.8.1 Providers of Transport Services

F.8.1.1 Logistics service provider

This company stated that they would use LHVs mainly for overnight trunking between depots, providing network services to a range of industrial clients in sectors such as automotive, engineering and construction. All their depots are located with five minutes drive of the motorway network.

F.8.1.2 Mail and parcel carrier

The mail and parcel carrier stated that they would use the LHVs mainly for the overnight trunking between their regional depots and their main hub in the Midlands. Their preference would be for a longer semi-trailer because this would most easily fit into their existing operations and infrastructure.

F.8.1.3 Haulier specialising in the movement of low density product

Seventy-five percent of this company's loads were volume rather than weight-limited. The company is a major distributor of insulation materials. They reported that they were very interested in using LHVs for overnight trunking from factories to the regional distribution centres (mainly on the motorway network).

F.8.1.4 Haulier belonging to a pallet-load network

This haulier reported that they would be interested primarily in the 34 m road train. If this were permitted, they would gradually replace the current fleet of double-deck vehicles which they use for overnight trunking to and from the sortation hub in the Midlands.

F.8.1.5 Logistics service provider

Only three of this company's 25 depot locations are adjacent to the motorway network. The rest are located an average of 4 to 5 miles away, many of them served by single carriageway roads. Network restrictions could deter their use of LHVs. This company has also developed a substantial intermodal business and were concerned that LHVs could adversely affect its investment in railfreight facilities.

F.8.1.6 Medium-sized haulier

Catering mainly for companies in the FMCG and consumer goods sectors, this company estimates that 80% of its loads, mostly on the primary trunk routes, are volume-constrained. They would be very interested in operating LHVs but are unsure whether in current trading conditions they would be able to earn an adequate rate of return on the related investment.

F.8.1.7 Medium-sized haulier

LHVs could be well suited to several overnight trunking contracts that they have with paper companies, though network restrictions could be a problem.

F.8.1.8 Deep-sea shipping line

If granted access to the ports, LHVs could play a major role in landward distribution of containers. LHVs would significantly cut the cost of container movements to and from the ports and increase road's share of this market. Consolidation of containers in LHVs would help to ease the effect of container traffic growth on congested routes from the ports.

F.8.2 Users of Transport Services

F.8.2.1 Manufacturer of domestic paper products

Given the very low density of their products (average payload weight in an articulated vehicle is 7 tonnes), any increase in available cube would be very welcome. Their preference was for the largest possible LHV, though the company could also use 25.25 m combinations for the primary distribution of medium-sized loads to retailers' distribution centres.

F.8.2.2 Confectionery manufacturer

This company see a potential role for LHVs in primary distribution to retailers's distribution centres, but were concerned that road network restrictions would impair the flexibility of distribution operations.

F.8.2.3 Confectionery manufacturer

This company would like to be able to operate a longer semi-trailer capable of carrying 4-6 more pallets. If the maximum carrying capacity could be raised from 26 to 30 pallets, they estimate that they would save approximately 4,500 truck movements and 450k lorry miles per annum (17% reduction). The LHVs would be used primarily for primary trunking from factories to distribution centres.

F.8.2.4 Brewer

This brewer operates five main production sites, five regional distribution centres and 27 depots. They would use LHVs mainly to transfer beer between their breweries and distribution centres, though some deliveries would go directly to depots. All of the breweries and distribution centres, and many of the depots are close to motorways or dual carriageways. Their loads are always weight-constrained and so would need an increase in the gross weight limit (preferably to 60 tonnes) to take advantage of LHVs. They always have to take back empty kegs and so there would be good backloading of these vehicles.

F.8.2.5 Whisky company

LHVs could be used for carrying lighter products, such as empty bottles and packaging, on inbound deliveries to bottling plants. They would mostly be used on the motorways.

F.8.2.6 Drinks company

This company doubted that they would make much use of LHVs. They have recently increased their use of rail. If a 34 m road train were able to achieve operating cost reductions of 30% or more, and could gain access to customer locations, the case for using rail could be undermined. Given the high value of the loads, security concerns would prevent the use of decoupling facilities.

F.8.2.7 Steel producer

This manufacturer currently moves it’s product from steel works to hubs via rail, with onward distribution by road in 44 tonne artics. A high proportion of the HGV loads are weight-constrained, so the company would make extensive use of LHVs with heavier payloads. Much of the product is moved in rolls weighing 14-18 tonnes. Given this ‘lumpiness’ of the loads, vehicle utilisation benefits would depend on gross weight limit (e.g. 3 x 14 tonne rolls could be carried on a 60 tonne LHV). LHVs would be unlikely to cause any diversion of freight from rail upstream of the hubs mainly because of its cost advantage, the volume of bulk flow and the close integration of the rail trunk haul with the production and logistics operation.

F.8.2.8 Food wholesaler and retailer

This company stated that they would use 25.25 m LHVs for grocery deliveries in preference to the smaller drawbar combinations which they currently use. Confining these LHVs to dual carriageways would tightly restrict the number of routes on which they could be deployed.

F.8.2.9 Non-food retail chain

This retailer could see a role for a longer double-deck semi-trailer on the fixed point-to-point routes between distribution centres.

F.8.2.10 Non-food retail chain

This company is a major importer of consumer goods and sees an important role for LHVs in moving containers to its distribution centres, so long as they can gain access to the deep-sea ports. It could also use them for primary trunking between distribution centres and regional depots.

F.8.2.11 Supermarket chain

This chain reported that they could use LHVs for primary trunking between distribution centres and between ports and distribution centres (mainly for imported clothing products). LHVs would have to offer large savings to cause diversion of current railfreight traffic back to road.

F.8.2.12 Supermarket chain

Another supermarket chain reported that they could use LHVs for moving high-cube products, such as bicycles and clothing, mostly at the primary distribution level. They could see no role for LHVs in secondary distribution to shops. They also stated that a detailed analysis of all aspects of LHV operation would be required to be able to identify those applications likely to yield the greatest benefit.

F.9 Constraints on the Use of LHVs

Four types of constraint were discussed in the focus groups: financial, operational, infrastructural and driver-related.

F.9.1 Financial constraints

Unlike the upgrade to the 44 tonne weight after 2001 which, for most hauliers, required minimal additional capital investment, LHVs will have a significantly higher capital cost. Most of this additional cost will be in the purchase of the trailer, dollies and linking equipment, rather than the tractor unit. The general view expressed in the focus groups was that there would be little need for companies operating LHVs to acquire new tractors with higher power ratings. It was felt that much of the tractor fleet is currently over-powered relative to the loads carried and could comfortably haul all the LHV combinations with the exception of the heaviest of the proposed combinations running at 82 tonnes. For the 25.25 m and the 34 m LHVs with gross weights of 60 tonnes or less, 450-500 bhp would suffice, while 600 bhp would be desirable for the 82 tonne vehicle, particularly in parts of the country with hilly terrain.

The largest capital cost increment would have to be paid on the B-double version of the 25.25 m combination because it requires a special inter-link trailer unit. The cost of this equipment would partly depend on the level of demand for such vehicles and economies of scale in manufacturing. An average figure of £15,000 to £20,000 was quoted by several firms. Other LHVs would use standard trailers and vehicle chassis, but require extra dollies and drawbars, each adding several thousand pounds to the capital cost. It was felt that these latter expenses were modest and would deter very few companies from using LHVs, particularly as they would ‘buy’ substantial increases in carrying capacity. Some hauliers would, nevertheless, have to be convinced that they would be adequately compensated for this additional investment before running these LHVs. This assurance would have to be much stronger in the case of the B-double vehicle. Its much higher capital cost would limit its use to applications offering regular flows and high utilisation.

F.9.2 Operational constraints

The main operational constraint was deemed to be average consignment size. The just-in-time principle is now widely applied across UK production and distribution systems and has the effect of depressing average consignment size. This has reduced the proportion of loads requiring the greater capacity available in LHVs. In some sectors, such as grocery and automotive for example, companies have introduced systems of primary consolidation to try to maintain high vehicle load factors even within a JIT regime. CSRGT statistics also indicate that, despite JIT pressures, a large proportion of loads in 44 tonne articulated vehicles are volume or weight-constrained. Even within current low-inventory replenishment systems, therefore, it appears that there would be a healthy demand for additional carrying capacity.

F.9.3 Infrastructure constraints

Companies were asked if they would be able to accommodate LHVs at collection and delivery points. A common response from delegates was that their own company had sufficient space but that some other companies would not. It was generally felt that a 25.25 m LHV capable of meeting current turning circle restrictions would present no problem, whereas manoeuvring the 34 m road train would be very difficult at many industrial and commercial sites. Most delegates were much less concerned about space limitations at company premises than about the lack of capacity for LHVs at truck-stops, motorway service stations and lay-bys. There was a general consensus that these facilities are currently inadequate and that substantial investment would be required to upgrade them for a new generation of LHVs, especially if the larger LHV types were permitted and coupling / decoupling of LHV units became a common practice. (Reactions to the imposition of network restrictions on LHVs are discussed below).

F.9.4 Human-resource constraints

Companies were generally confident that they would be able to find sufficient drivers willing and able to drive LHVs. They typically considered that little extra training would be required for an experienced HGV driver, particularly on the 25.25 m combinations. They believed that there would be no need for the introduction of a special LHV driver’s license. It was anticipated that many LHV deliveries would be along fixed routes on a regular basis. If there were particular LHV ‘hazards’ along these routes, drivers could be given specialist route training similar to that given to train drivers.

Some delegates suggested that they would only allow better drivers with more than five years experience to drive LHVs. It was felt that drivers would gain extra prestige from driving them and that a new ‘elite’ group of LHV drivers might emerge. The driver unions might demand higher payment for LHV drivers given the extra skill and responsibility involved. Many delegates saw the HR issue as an opportunity rather than a constraint in the sense that LHVs would reduce the demand for drivers and help to ease the current driver shortage.

F.10 Effects of Network Restrictions

There was general acceptance that it would be inappropriate to run LHVs on urban roads or smaller rural roads. The majority of delegates also conceded that the 34 m road train might have to be confined to motorways and dual carriageways. Opinion’s varied on whether 25.25 m combinations that met current turning circle requirements should be similarly restricted. Many delegates argued that they should be allowed on most single carriageway “A” roads. Reference was made to Sweden and New Zealand where stakeholders believed that LHVs have been allowed to use such roads for many years without any serious problems.

Several delegates suggested that LHV networks (comprising motorway, dual and single-carriageway roads) could be customised to particular companies. This was based on the assumption that much LHV usage would be for regular flows between a fixed set of origins and destinations. Once a specific set of LHV routes had been approved for a company, telematics could be used to ensure that its vehicles did not stray from this network. It was conceded that this could involve a good deal of bureaucracy and introduce ‘rigidities’ into companies’ logistics systems.

Some delegates expressed concern that network restrictions could be considered discriminatory. If LHVs were confined to narrow motorway / dual carriageway corridors, only companies with premises and customers in these corridors would be able to use them. Competing companies with premises outside these corridors would be put at a comparative disadvantage. This discrimination could also have a regional dimension, with more peripheral parts of the country denied the benefits of LHVs.

A few delegates raised concerns about what would happen if LHVs were restricted to certain routes when an accident or roadworks required the vehicles to take a diversionary route. However, they considered that this was a problem for the highways authorities to address.

F.11 Coupling / Decoupling of LHVs

The majority view of participants in the focus groups was that LHVs would be used mainly for point-to-point deliveries with only a minority of trips involving coupling and decoupling. This extent of coupling / decoupling would be determined mainly by:

- The type of vehicle permitted – more likely for 34m combinations
- The extent of road network restrictions – restrictions to motorway only would increase the likelihood
- Nature of the logistics operation
- Consignment sizes
- Availability of capacity at truck-stops / motorway service stations
- Security concerns – for higher value products.

It was argued that it might be comparatively rare for the 25.25 m combinations to be split on a journey, for several reasons:

- Because they would be relatively manoeuvrable, they should be subject to fewer network restrictions giving them greater access, as an integrated unit, to industrial premises.
- They would tend only to be deployed where the consignment size / weight filled the vehicle on a point-to-point journey.
- Few distribution operations would require breaking-of-bulk on a 1/3 : 2/3 basis, as would occur with the splitting of a 7.8 m rigid unit and 13.6 m trailer. It was noted that within the 25.25 m 'modular' type vehicles (i.e. vehicles 5 and 7) it would be possible to have a rigid vehicle hauling two 7.8 m trailers, offering more flexibility in terms of breaking-of-bulk and consolidation. This vehicle proved popular in the Dutch trial, but was not selected for assessment as part of the present study, partly because it was considered likely to have a lower safety performance in terms of rearward amplification and partly because of the relatively low use of drawbar trailers in the UK.
- Coupling / decoupling would only be economically justifiable where the trunk haul was relatively long. In most of the likely applications of LHVs (as confirmed by the logistics modelling work undertaken on CSRGT data) the average length of haul would relatively short (under 100km). During the focus group discussions, companies were asked to indicate how long the LHV trunk haul would have to be and how short the 'uncoupled' feeder movements at either end would have to be to make the coupling / uncoupling operation viable. None of them were able to quote a figure on the basis of the available data.
- A lack of suitable facilities for coupling / decoupling.

Participants considered that coupling and decoupling would be likely to occur more frequently in the case of 34 m LHVs because of tighter network restrictions that they expected, the smaller proportion of loads likely to fill these vehicles and the greater demand for splitting two standard 13.6 trailer units. However, it was acknowledged that the physical constraints on parking and manoeuvring space at truck-stops and motorway service areas would be greater. One delegate envisaged the longer term development of 'trailer pooling' in the UK, based on the analogy of pallet pooling. Trailers belonging to the pool would be moved through a network based on a series of trailer parks strategically located on the trunk road network. These would be the road equivalent of railway marshalling yards. Trailers could be parked and 'marshalled' according to their destination, with some combined to form LHVs for motorway running and other despatched as single-trailer HGVs across the wider road network.

F.12 Choice of Double-deck / High-cube Vehicle or LHV

In assessing the likely demand for LHVs it is important to weigh up the relative merits of these vehicles against those of double-deck / high cube vehicles currently operating in the UK. The British road infrastructure is unusual in being able to accommodate taller vehicles with heights of up to 5 metres possible on the vast majority of routes. This is partly a consequence of the widespread use of double-deck buses in the UK. Elsewhere in Europe where heights are generally limited to 4.2 metres, companies have gained extra cubic capacity horizontally by using vehicles with extended length. This largely explains why drawbar trailer combinations up to a length of 18.75 m represent a much larger proportion of the truck fleet in mainland Europe than they do here in the UK. In Britain companies moving low density product and requiring extra space have generally gained cube vertically.

Over the past 15 years there has been a substantial growth in the number of double-deck vehicles on Britain's roads. One of the main manufacturer's of double deck trailers has indicated, however, that this growth has slackened over the past year. Double deck vehicles have only been separately identified in the Continuing Survey of Road Goods Transport since 2005. In that year double-deck lorries accounted for 3.2% of all kilometres travelled by articulated vehicles.

Many of the companies attending the focus groups currently operate double-deck vehicles. In the course of the discussion they were asked about the relative advantages and disadvantages of double-decks and likelihood of them being replaced by various types of LHV.

Table 88 summarises the relative strengths and weaknesses of double-decks, 25.25 m LHVs and 34 m LHVs.

Table 88: Relative Strengths and Weaknesses of Double-deck Trailers and LHVs.

	Double deck	**25.25m LHV**	**34m LHV**
Strengths	Highest capacity (up to 52 pallets) Established equipment Wide access Lower capital cost than the larger LHV options New loading systems Easier to drive and manoeuvre	Load splitting flexibility No special loading needs Standard Modules Good for mid-range loads Modules can cross borders (individually)	Equivalent volume capacity to double deck Load splitting flexibility No special loading needs Standard Modules Good for mid-range loads Modules can cross borders (individually) Very cost effective
Weaknesses	Need special reception facilities No splitting of loads Need high volume to justify use Payload reduced compared with standard artic Confined to UK	Less capacity than DD (40 Pallets) Potentially more restricted access Higher capital cost than DD Rigid/artic combination less operational flexibility than 34m LHV	Potentially very restricted access Needs greater manoeuvring space Manoeuvring and parking difficult

The main advantages of double-decks over 25.25 m LHVs were seen by participants as their higher cubic capacity (accommodating up to 52 pallets), network accessibility and manoeuvrability / ease of reversing. Only 34 m LHVs offer similar carrying capacity for pallet-loads, though their movements were considered likely to be much more restricted and driving and reversing them would require much more skill. The main disadvantage of double-deck vehicles was considered to be the need for specialist handling facilities at collection and delivery points and / or the addition of tail-lifts and hydraulic decks. This increases handling costs and, in the case, of onboard lift equipment, incurs a weight penalty. For many companies the additional tare weight does not constrain loading as the commodities are very light and still ‘cube out’ within the weight limit. In 2005 the average double-deck artic carried a payload of only 12.1 tonnes.

LHVs with only a single deck could be loaded and unloaded more easily, without the need for specialist equipment. Their modular structure would also allow the splitting of loads. Such operational flexibility is already available to companies with drawbar trailer combinations, though relatively few companies actually use it. A common view expressed at the focus groups was that relatively few distribution operations would require the splitting of 7.85 m and 13.6 m units. Only specialist transhipment operations would therefore involve the decoupling of 25.25 m LHVs. The main proponent of this type of combination in the UK sees it running as an integrated unit from point to point. In this respect, it would operate in a similar way to double-deck artics. The 34 m LHV comprising two 13.6 m trailers would, on the other hand, be much more regularly decoupled, partly because of the network restrictions that participants expected but also because of the articulation of trunk hauls and local deliveries. Several delegates envisaged the 34 m road trains using the motorway network and being coupled / decoupled at strategic interchange points in the vicinity of motorway junctions. Although the main role for LHVs is seen to be in primary distribution, it was recognised that some retailers might want to deploy a 34 m vehicle in a secondary distribution role, linking two trailers on the motorway trunkhaul and splitting them for delivery to shops close to a decoupling point. Double-deck vehicles could not offer this flexibility. Some delegates, nevertheless, doubted whether lengths of haul in the UK were long enough to make such an operation commercially attractive.

The relative advantage of LHVs over double-deck artics would also depend on their gross weight limit. If, in the case of 25.25 m LHVs, the limit remained fixed at 44 tonnes or was only raised enough to cover the extra tare weight, the participants expected that there would be limited migration of loads from double-decks (or standard HGVs) to these vehicles. This was confirmed by several commercial vehicle manufacturers attending the SMMT focus group. The 50% increase in pallet capacity a 25.25 m vehicle would achieve over a conventional articulated vehicle would be far exceeded by the doubling of this capacity which can be achieved on double-decks. For some companies an additional 50% capacity would be adequate, given their order profile and pattern of delivery. They might find it more economical to operate 25.25 m LHVs for these ‘mid-range’ loads than full-size double deck trailers. On the basis of available data, it is not possible to estimate the proportion of road freight operations that would fall into this category.

If the maximum weight of the LHV rose above the payload neutral limit (of 48-49 tonnes) and offered extra weight-carrying capacity as well as cube, the uptake would be significantly greater. The degree of load migration to these vehicles would depend on the statistical distribution of load densities. For medium-density loads that weigh out on double-deck vehicles before they occupy all the available space, heavier LHVs would offer load consolidation benefits. When combined with additional ease of handling, this would give some companies an incentive to switch from double decks to LHVs. The same argument would apply with even greater force to 34 m LHVs plated at 60 tonnes or more.

In some sectors, such as steel and plastic piping, an increase in vehicle length would permit the carriage of products in longer sections, reducing production and transport costs. The longer semi-trailer option would be most appropriate here. This would confer another advantage over double-deck artics of standard length, though one of interest to only a small group of companies.

Finally, at almost all the focus groups, at least one delegate advocated the legalisation of double-deck versions of LHVs. It was suggested that rather then choosing between double-decks and LHVs, companies should be able to expand vehicle capacity in two dimensions, carrying up to 104 pallet loads on a single trip. Companies carrying very low density product with transport costs in excess of 10% of the product value were particularly keen on the option.

F.13 Attitudes of the Road Haulage Industry

The industry fact-finding exercise uncovered varying levels of support for LHVs across the UK road haulage industry. Broadly speaking, road hauliers can be divided in five categories:

- **Proponents**: The two main proponents of LHVs in the UK are both road hauliers. In both cases, they observed LHVs being successfully operated in other countries and developed types of vehicle which they believed would be adapted to UK freight market conditions. They have a core group of supporters within the haulage industry.
- **Prime-movers**: These are carriers who see LHVs as offering large potential savings in their particular sectors of the haulage market. Early uptake of LHVs could help them gain competitive differentiation. These companies tend to specialise in particular sectors such as, pallet-load, low density / high cube products, ISO containers and timber.
- **Innovators:** These companies are open-minded about the potential benefits and are prepared to trial them, even in the absence of a specific haulage contract. These tend to be larger operators with a varied portfolio of clients and traffic.
- **Contract-bound operators:** These hauliers would only acquire and operate LHVs on a contractual basis on the assurance that they would earn an adequate return for their use.
- **Sceptics:** Many hauliers doubt that the introduction of LHVs would be beneficial to the haulage industry. This large group, which includes prominent members of the Road Haulage Association (RHA), has expressed serious reservations about the legalisation of LHVs. Among this group are several large intermodal operators who have aligned their operations with rail and are, therefore, concerned that they may be disadvantaged by any erosion of railfreight traffic to LHVs.

In the absence of a large-scale survey, it is not possible to estimate the proportions of hauliers falling into these categories. The vast majority of the hauliers completing the online questionnaire and attending the focus group support the case for LHVs. Those companies that see commercial benefit in operating LHVs have a stronger interest in participating and therefore are likely to give a biased view of the level of support across the industry. The fact that the RHA has retained a neutral stance on LHVs reflects the wider division of opinion across the industry.

The lack of support for LHVs in certain sections of the haulage industry can be attributed to several factors:

- ***Uncertainty about the financial rewards:*** Past experience has shown that when lorry weight and/or size limits were raised, hauliers carried more freight for similar rates. Given the intensely competitive conditions in the haulage industry, most, if not all, the economic benefits from increases in carrying capacity are captured by shippers. There is little confidence, therefore, that the use of LHVs will translate into higher profits. On the contrary, there is a widely-held view that LHVs would further 'commoditise' the road freight market. Also, unlike in 1999 and 2001 when the re-plating of artics to the higher weight limits entailed no additional investment, operating LHVs will carry a significant capital cost, particularly if they are 25.25 m combinations. Hauliers are uncertain that they would earn an adequate return on these vehicles.
- ***Differential impact on the haulage industry***: It is also argued that LHVs will tend to discriminate against smaller operators with less access to capital and with fleets that are too small to exploit the benefits of LHVs. Roughly half of Britain's hauliers are owner-drivers

with a single vehicle. It is very unlikely that many of them will replace the standard 44 tonne artic with an LHV. Most also lack the contractual relationships with clients that could guarantee the necessary traffic volumes to ensure efficient use of LHVs. Many of their local operating centres will be unable to accommodate LHVs. At the other end of the spectrum, larger logistics service providers are, on the whole, positive about LHVs.

- ***Worsening public image:*** The participants generally felt that LHVs will be unpopular with the public and that the haulage industry will be blamed for wanting them, despite the fact that there has been no co-ordinated campaign for them and many hauliers are themselves sceptical. It would make it harder for industry to improve its poor public image if LHVs are permitted.
- ***Operational restrictions***: It is expected that LHV movements will be tightly restricted, particularly the 34 m road train which would have the lowest capital cost and greatest operational flexibility. The imposition of network restrictions and other specific regulations would make LHVs relatively unattractive to hauliers and make it harder to operate them profitably.

It is worth noting that, despite these reservations, a poll of delegates at the Road Haulage Association annual conference in May 2007 recorded a 5 to 1 vote in favour of LHVs being trialled in the UK.

F.14 Impact on the Railfreight Market

By improving the relative cost competitiveness of road freight transport, the introduction of LHVs would be likely to erode freight traffic from the rail network. The study has tried to assess the extent of this negative impact on the railfreight market. Discussions have been held with the main railfreight operating companies, relevant trade bodies and pressure groups and current railfreight users. The two main railfreight companies have undertaken quantitative analyses of the potential loss of railfreight traffic and have voluntarily submitted written documents describing their analysis for use by the project team. These analyses have been critically reviewed and considered in the estimation process. On the basis of all the available evidence, an independent assessment has been made of the potential loss of railfreight traffic that would result from the adoption of the various LHV scenarios. Documents submitted by railfreight organisations have included wider reviews of the adverse environmental effects of lorries and discussion of the possibility that LHVs will generate additional freight movement. These issues are dealt with separately in this report. This section focuses on the freight modal split issue.

The railfreight market can be divided into five parts:

- bulk commodities (principally coal and aggregates, which have very different commercial characteristics)
- deep-sea containers
- domestic intermodal
- wagonload
- rail-infrastructure traffic

Currently, approximately 88% of total rail tonnage falls into the first two categories (see Table 4). Domestic intermodal accounts for a relatively small, but substantially growing, quantity of railfreight. Wagonload is a very small and declining sector, while the internal infrastructure traffic carried for Network Rail, though accounting for a substantial tonnage, is not considered to be at risk of diversion to LHVs. Attention has, therefore, focused on the likely impact of LHVs on the movement of bulk commodities and deep-sea containers by rail, although stakeholders involved in all sectors were invited to contribute their views and a basic econometric analysis has been undertaken for the domestic intermodal market.

F.14.1 Bulk Commodities:

These commodities, comprising mainly coal, metals, construction materials and oil, accounted for around two-thirds of all tonne-kms carried by rail in 2005. These are dense products which rail can carry more cost-effectively given its ability to carry heavier weights. LHVs would only capture bulk railfreight traffic if their gross weight increased to to a level such that the maximum payload weight was greater than for an existing 44 tonne vehicle by an amount sufficient to result in reduced transport cost despite any additional vehicle operating costs. In their report for EWS, Oxera assume that the maximum payload weight would increase to 39 tonnes (on a 60 tonne 25.25 m LHV) and to 60 tonnes (on an 82 tonne 34 m LHV). Their analysis is confined to four categories of bulk product:

- solid mineral fuels (i.e. coal)
- petroleum products
- metal products
- minerals / building products

For each category they derive 'cross-price elasticities' (i.e. ratios of the likely amount of rail freight that will shift to LHVs at different levels of cost reduction on road). Applying these elasticities to estimated reductions in road operating costs, Oxera calculate that, for bulk traffic, around 11% of tonne-kms will transfer to LHVs plated at 60 tonnes and 17% to 82 tonne LHVs. No consideration was given to 'payload neutral' versions of these vehicles in the Oxera analysis. Cost data were also provided for two 'case studies' of bulk movements: a steel (strip coil) movement from Newport to the West Midlands and aggregates flow from Dove Holes (Derbyshire) and Peterborough. The analysis showed that for both freight movements, the introduction of 60 tonne or 82 tonne LHVs would eliminate rail's cost advantage and make it significantly cheaper to move the goods by road.

The outcome of any such econometric analysis is very strongly dependant on the cross-elasticity values used. Oxera appears to have used the same methodology to calculate these elasticities as in the study undertaken for EWS in 1999 on the potential impact of a maximum lorry weight increase to 44 tonnes. It essentially involves multiplying internal demand elasticity values for road by the road / rail modal split ratio. This approximation has to be used because there are no empirical data on the actual sensitivity of railfreight demand to variations in road freight prices. It still requires empirically-derived demand elasticity values for road freight, however. According to the 1999 report these elasticity values come from a study by Oum, Waters and Young undertaken for the World Bank in 1989. The elasticity values recommended by this study relate to the North American freight market of the 1970s and 1980s. It is very doubtful that they will accurately reflect modal choice behaviour in the current UK freight market. The lack of empirically derived cross-elasticity values and the subsequent reliance on old data from other countries is a factor that limits the confidence with which the results of the analysis can be considered.

Discussions with current railfreight users and a wider group of freight and logistics specialists suggested that there was a general consensus that little, if any, coal traffic would transfer from rail to LHVs, even at the heaviest weight limit. The main reason given for this was that rail currently has a very large cost advantage in moving coal in 1,500 tonne trains. This conclusion also seems reasonably consistent with the EWS report, which focuses on the threat to other bulk commodities. It is also consistent with data contained in a report on track access charges (ORR, 2006) which cites a cross-elasticity of just 0.1 for power station coal and 0.3 for other coal, although it is not known how these values were derived.

A major steel company which currently makes substantial use of rail and has significantly increased its use of rail over the past few years has indicated that it will remain committed to rail for trunk movement between its steel plants and distribution hubs. The reason given was that rail transport is well integrated into its production operations and offers fast and effective loading and unloading of product in addition to cost effective transport. The company stated that they would use LHVs with higher weight limits, but only on secondary distribution outbound from distribution hubs, replacing 44 tonne artics on these routes. These views at least partly contradict those expressed in the EWS report, which suggests that nearly 17% of rail business in the bulk metals market would shift to road if LHVs (60 or 82 tonne) were to be permitted. EWS also cite the heavy and indivisible nature of steel coils as a factor. Currently, road vehicles might take only one or two steel coils but a relatively small increase in payload could “tip the balance” to allow a further coil to be carried, thus giving a step change in road transport cost not in proportion to the increased payload weight. Elasticity values from ORR (2006) suggest that steel is a more price sensitive commodity than coal with an elasticity of 0.7 but this remains lower than for many other commodities.

The EWS report suggests that construction materials is the bulk market most vulnerable to LHVs, if they were to be permitted, and estimate that 20% of current rail business would transfer to LHVs at 60 tonnes and 40% to those at 82 tonnes. The elasticity value of 4.1 in the ORR report (2006) also suggests that this is rail’s most price sensitive market. However, neither of these sources appears to have considered the possibility that LHVs could be subject to additional constraints that do not apply to existing HGVs and that these could prove to influence mode shift independently to changes in operating cost. One of the largest companies in the aggregates sector, which makes substantial use of rail, stated that they would anticipate little if any modal switch if LHVs were permitted. The reason given was that of the 23 depots that they operate across the UK, only three would be likely to be accessible to LHVs given the route restrictions that they considered likely. Restricting LHVs to the trunk or primary road network would be likely to deny them access to many of the sources and / or destinations of bulk construction traffic currently moving by rail. In addition to this, existing articulated vehicles are not permitted at many sites because of safety concerns over their stability when tipping. An LHV comprising two trailers would be no more stable than an existing articulated vehicle and would almost certainly have to uncouple the combination before tipping could take place, making loading and unloading more time consuming and costly. It is possible that these factors will influence the competitiveness of road and rail in these markets.

F.14.2 Deep-sea Containers

The rail network carries 25% of deep-sea containers to and from UK ports. This share has risen from 17% in 1996. Following the Hatfield rail crash and disruption caused by the subsequent track maintenance work, rail’s share of the container market contracted. This trend has since been reversed. Freightliner has an 80% share of the rail deep-sea container market.

It was generally acknowledged by stakeholders that the movement of deep-sea containers to and from ports, particularly Felixstowe and Southampton, is likely to be the sector of the rail freight market most vulnerable if LHVs were permitted. At present it is possible for one 40 ft or two 20 ft containers to be carried on a 13.6 m trailer. A 25.25 m combination would allow the combination of one 40ft and one 20ft container on a single vehicle, while the 34 m LHV could carry two 40 ft containers. These would represent step changes in the container carrying capabilities of road, substantially reducing operating costs per container and on many routes allowing road to undercut the prevailing rail freight rates.

Freightliner has provided the project team with the results of an internal analysis of the potential impact of LHVs on their business. This analysis relates solely to the 25.25 m LHV. The company believes that lengthening a semi-trailer to 16 m would have no impact on the modal share in the deep sea container market, while, in its opinion, the 34 m LHV is *‘not a practical proposition’*. It estimates that the mid-range 25.25 LHV will reduce average vehicle operating costs per container by 15%. Freightliner considered that , not all the available container carrying capacity on LHVs would be fully utilised, however, because most road hauliers would lack the ability to consolidate containers. Freightliner assumes therefore that LHVs would carry 1.5 import containers per trip and 1 export container per trip. The relative price competitiveness of road was adjusted accordingly. Like Oxera, Freightliner apply cross-elasticity values to the reduction in road freight rates to estimate the likely modal shift. They apply two values:

- the figure of 2.5 which was adopted by MDS Transmodal in work for the ORR (suggesting that for every 1% reduction in road haulage costs, 2.5% of container traffic would transfer to road)
- a *'more realistic'* elasticity value of 6 based on Freightliners commercial experience and judgement.

Table 89 shows the resultant predictions of traffic loss:

Table 89. Freightliners estimate of traffic loss if 25.25m LHVs were to be permitted

Elasticity value	*2.5*	*6*
Traffic loss	27%	66%

Even the lower of these two estimates would have a substantial negative effect on Freightliner's business. As the company notes in its report, the effects on its network could be even more damaging because the erosion of traffic would undermine the viability of terminals and multi-shift working. It is estimated that terminal overheads represent around 45% of total operating costs. They therefore require a large throughput to keep the rail container operation cost competitive. If throughput were to drop sharply, the service network would shrink in a "vicious circle of decline".

The container haulage market is very price-sensitive. Eighty percent of this transport is bought by container shipping lines and their purchase decisions are essentially price-based. A variation in the freight rate of as little of £5-£10 per container can result in traffic switching mode. Road commands a 75% share of the deep-sea container market because it is the price leader.

In the case of bulk rail traffic, the adoption of 'payload neutral' gross weight limits would very tightly restrict any modal shift to LHVs. The same cannot be said of the deep-sea container market. According to Freightliner, the average loaded container has a gross weight of 16.6 tonnes. However, it is not clear whether this average applies only to 40 foot containers or is an average for all containers, including both 40 foot and 20 foot. This is because Freightliner state that two 20 foot containers can be carried on an existing HGV with a 13.6m semi-trailer but only if they weigh less than about 14 tonnes each. They go on to state that this means that only containers of below average weight are available for this particular operation.

The same argument can be applied to the LHVs with a GVW below 60 tonnes. Even if the GVW of an LHV was restricted to the current 44 tonne limit, it would still be possible for it to carry two slightly below average-weight containers. However, if it is assumed that container weights are normally distributed around the mean then this would mean that only in the region of half of all container traffic could be carried by a 44 tonne 25m LHV.

Freightliner operates a fleet of around 350 HGVs for local collection and delivery of containers. In terms of HGV fleet size, it is actually the fifth largest road haulier in the country. Part of the discussions with the company explored the possibility that they might be able to use LHVs in a local feeder role to reduce the road haulage component in the door-to-door cost. Freightliner doubted that this would be possible partly because the road feeder movements are short, averaging only around 30 miles on a round trip, but also because the anticipated network restrictions on LHVs would make it difficult to gain access to many of the necessary industrial and distribution premises. It should be noted, however, that the effects of route restrictions would apply equally to the competing road sector.

In general, it is considered that Freightliner has presented fairly robust evidence to show that the introduction of LHVs would cause significant contraction of the rail container market. This evidence requires several qualifications, however:

- Estimates of the potential traffic loss are highly sensitive to cross-elasticity values. It has not been possible in the course of the present study to derive new cross-elasticity values or to provide independent validation of the estimates used by Freightliner. Existing cross-elasticity values, even if empirically based, consider only the constraints of current road vehicles. If LHVs were subject to greater constraints, particularly route restrictions, then this could affect the validity of the price elasticity.

- The rail infrastructure serving the major ports of Felixstowe and Southampton currently lacks capacity. For example, infrastructure constraints mean that a maximum number of 25 container trains per day can use the Ipswich-Felixstowe line. Several stakeholders have expressed concern that with deep-sea container traffic currently growing at around 6% per annum, capacity restrictions will make it difficult for rail to maintain its share of this market. However, the Government paper "delivering a sustainable railway" (DfT, 2007) states that rail infrastructure improvements are currently under consideration that would relieve these congestion concerns and enable rail to meet the projected increased demand. It further states that Network Rail has set aside £200million of investment to enable these improvements which would be expected to be recovered from users over time. Since the publication of the 2007 document, the Government has also announced that approximately £150million would be made available from the Transport Innovation Fund to support rail infrastructure improvements.

- In the later analysis of costs and benefits it has been assumed that rail will not suffer capacity restrictions. The investments in rail infrastructure described above have not been specifically included. If the network rail investment is recovered from increased use of the line and thus increased track access charge revenue then the capital cost is covered by the inclusion of running costs for rail, providing track access charges do not increase as a result of the investment. However, if the additional government investment is not recovered from the track access charges then this would represent an additional cost of the business as usual case that is not currently incorporated in the model. In addition to this, the financial value of the REPS has not been included in the model.

- The proportion of 20ft containers is steadily declining. Through time this will reduce the opportunities for combining 20ft and 40ft containers on a 25.25 m LHV and weaken road competition from this type of vehicle. The threat from a 34 m LHV capable of carrying two 40 ft containers would remain intense, however.

- The major container ports have a preference for the surface movement of containers by rail because this helps to relieve their current congestion problems. A single container train can replace up to 50 separate road movements to and from a port, each of which has to be separately scheduled and registered. The use of LHVs could reduce this ratio of lorry movement to train movements by around 20-30%, however. The introduction of LHVs would also rationalise the road movement of containers to and from the ports potentially reducing the number of trips by a similar margin. Road has a 75% share of the deep-sea container market, so this consolidation of container movements <u>within</u> the road freight sector may potentially offset any additional road trips resulting from a switch from rail. However, concerns were also expressed that LHVs may effectively have to be loaded at two different points within the port in order to pick up both a 20' and a 40' container, thus causing additional congestion and/or scheduling problems.

- Road congestion in and around ports may represent a substantial constraint on the use of existing HGVs in port operations. A report by MDS Transmodal examined port demand and suggested that, in the absence of capacity constraints, rail traffic from ports will increase by 140% by 2030 and road traffic from ports will increase by 106% in the same time period. If, as many stakeholders have suggested, the ports are currently suffering substantial road congestion problems then major changes may be required to accommodate the predicted 106% growth in road traffic. The substantial investment that would be required to make these road infrastructure changes has not been quantified in the model of costs and benefits.

- These road congestion constraints could substantially increase the modal preference for rail. If it were assumed that capacity constrained HGV traffic to its current level and all of the future increase in container traffic were to be carried by rail then this would represent an increase in deep-sea container rail freight of almost 1,500% by 2030. Even with the planned rail infrastructure improvements this would be difficult to accommodate. Under these circumstances, it is possible that the use of LHVs could help to mitigate the congestion problems around ports without inducing the mode shift predicted by a purely econometric analysis.

F.15 Possible Generation of Additional Road Freight Movement

The two main railfreight companies, the Rail Freight Group and environmental organisations have argued that, by reducing the cost of moving freight by road, LHVs would have the effect of generating additional freight movement. This is based on the simple economic principle that if something gets cheaper, demand for it will increase. It is claimed that the environmental cost associated with this ‘induced’ freight traffic growth would offset, and possibly far exceed, the environmental benefit of load consolidation.

Only one attempt has been made to quantify this so-called ‘rebound’ effect. Oxera in its study for EWS calculate that if a 60 tonne 25.25 m LHV were permitted on UK roads an additional 25 billion tonne-kms of freight movement would be generated, equivalent to 16% of all the freight movement by all lorries (>3.5 tonnes GVW) in 2005 or 22% of all freight movement by articulated vehicles in 2005. They estimate that the adverse environmental effects of this extra freight movement would have an annual monetary value of £863 million, almost twenty times larger than the environmental benefit that they calculate would accrue from the consolidation of loads in this category of LHV.

Oxera’s estimate of induced traffic can be challenged on several grounds:

- ***Estimate of demand elasticity****:* The Oxera calculation is based on a high price elasticity of demand ratio of 1.2. Although not made explicit in the report, this ratio appears to originate from a World Bank study (Oum *et al*, 1990). It reviewed estimates of demand elasticities for road and rail freight made mainly in North America in the 1970s and 1980s. As the North American freight market of 20-30 years ago was quite different from the current British freight market, there is little empirical justification for using the 1.2 elasticity value.
    - Oxera used the same elasticity value in 1999 in its study of the likely impact of the 44 tonne weight increase. The Commission for Integrated Transport (CfIT) cost-benefit analysis for the 44 tonne lorry weight employed an elasticity value of 1.1 to allow for traffic generation. This was justified on the grounds that a similar value had been factored into the government’s 1997 road freight traffic forecasts. Both the Oxera and CfIT studies appear to have substantially over-estimated the level of traffic generation following the 44 tonne lorry weight increase (see Figure 9 comparing the governments 1997 prediction using a value of 1.1 and actual subsequent traffic). Reviewing its impact after three years, McKinnon (2005) concluded:

      ‘Between 2001 and 2003, road tonne-kms did increase slightly from 149 to 152 billion (Department for Transport, 2004), but this 0.7% per annum growth was well below the historic average growth rate of 2.7% experienced between 1980 and 2001. Tonne-kms carried by the heaviest vehicles (38 tonnes and above) increased by 2%, but this too was below the historic average rate of 3.2%. Between 2001 and 2003, annual tonne-kms handled by these vehicles increased by 2 billion per annum. The Commission’s mid-range estimate was that, by reducing the cost of road haulage, the uplift in maximum weight to 44 tonnes would generate around 168 million tonne-kms per annum. This would have represented only 8% of the actual growth. There is little evidence, however, that the truck weight increase has, as yet, generated much additional demand for road freight movement.’

    - No attempt has been made since 1999 to derive price elasticity indices for the UK road freight market. In a review of estimates of road traffic demand elasticities

Graham and Glaister (2004) argued that *'it would be imprudent to offer a firm conclusion even about the order of magnitude of the price elasticity of demand for road freight movement'*. Beuthe et al (2001) developed a series of 'freight transportation demand elasticities' using Belgian data. Their study inferred cross-modal elasticities from an analysis of the costs of operating different types of transport service within origin and destination matrices on the assumption that companies would always aim to minimise 'generalised cost'. Their analysis did '*not take account of any demand induced by the cost changes*' so the elasticity values they derived cannot be used to estimate traffic generation.

- Analysis of the relationship between changes in the real cost of road haulage services and total road tonne-kms over the past ten years casts doubt on the use of a single elasticity factor to predict any traffic generation effect (Figure 5). No significant relationship was observed between these variables.

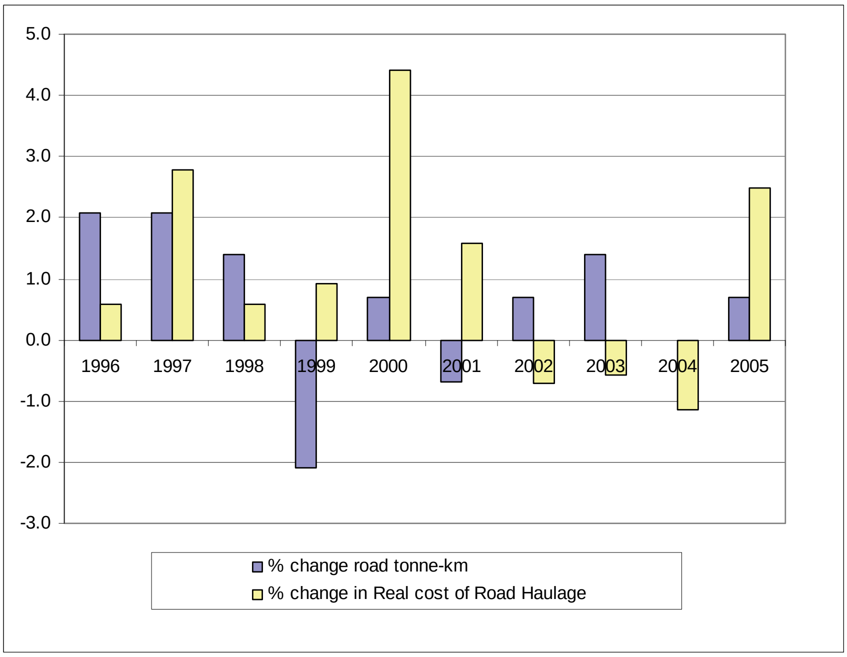

Figure 88: Trends in road tonne-kms and the real cost of road haulage: 1996-2005

(Sources: DfT Continuing Survey of Road Goods Transport; ONS Corporate Services Price Index)

- ***Load migration by vehicle type:*** the demand elasticity value must be applied to the sector of the road freight market likely to be affected by the introduction of LHVs. The Oxera study identifies this market segment as comprising all the tonne-kms carried by HGVs with a gross weight in excess of 25 tonnes. No allowance is made for the fact that only volume- and / or weight-constrained loads moved in these vehicles would be likely to migrate to LHVs. Moreover, not all of these constrained loads would be likely to transfer – only those from which an economic benefit would accrue. Some may also be constrained by other factors. Also, as Oxera acknowledge, the migrating loads would have to be large and/or heavy enough to fill enough of the LHV's available capacity to make it economically advantageous to use them. On the basis of the available data, it is not possible to predict the likely level of load migration. It is possible, however, to estimate what the levels of traffic generation would be at different degrees of constrained-load migration with different demand elasticity values. Even with an elasticity value of 1.1 and a 30% migration of constrained-loads to the 60 tonne

25.25 m LHV, the estimated amount of induced traffic is only 17.7% of that predicted by Oxera.

- ***Process of traffic generation:*** Oxera offer no explanation of where the induced road freight traffic will come from. Their econometric analysis is detached from the real world of logistics and supply chain management. Previous research has highlighted the importance of centralisation and wider sourcing of supplies, essentially geographical processes, as major drivers of road freight traffic growth. To what extent, therefore, are transport cost reductions from the use of LHVs likely to reinforce these trends? This question was posed at the series of focus group meetings. Fewer than 5% of the company representatives believed that the use of LHVs would promote structural change resulting in higher freight transport demand. It was expected that this would occur in the forestry sector because the geographical extent of harvesting was currently being constrained by the high cost of road transport (accounting on average for 40% of the sale price). LHVs operating a significantly higher weight limit would permit an expansion of the overall forest products market. A company in the drinks industry also indicated that it might source some inbound materials from further afield if road transport costs dropped by 25-30%. A much more common response, however, was that companies' production and logistics systems were already highly centralised and their patterns of sourcing and distribution already very extensive (both within the UK and internationally), leaving little scope for further geographical reorganisation. Many companies also argued that their use of LHVs would be confined to particular routes and operations and so unlikely to induce much system-wide restructuring.
- ***Level of cost reduction:*** the demand elasticity value is multiplied by the anticipated reduction in vehicle operating costs. The cost reduction that Oxera use in their analysis (of 15%) is measured relative to a fully-laden 44 tonne articulated lorry. As explained above, however, they model the traffic generation effect with reference to all lorries with a gross weight above 25 tonnes. The average operating cost per tonne-km for this much larger lorry population would to be higher. Relative to this baseline value, the potential LHV savings would be larger. This would tend to strengthen any traffic generating effect, though as discussed under the previous three headings Oxera's modelling of this effect is highly questionable.

F.16 Estimation of Key Parameter Values

One purpose of the industry fact-finding exercise was to provide guidance on the choice of values for four key parameters in the LHV cost model:

- Level of use of LHVs if permitted
- Utilisation of LHV capacity
- Freight modal shift
- Traffic generation effect

For the first two parameters only qualitative data is available from the focus group discussions. Quantitative estimates have been made of the third and fourth parameters by railfreight companies, though as discussed above, some of these estimates appear to lack credibility. Full account has, nevertheless, been taken of these estimates in the choice of parameter values as well as consideration of the effects observed in other countries.

F.16.1 Level of use of LHVs if permitted.

The level of use of LHVs, if permitted, was defined as the proportion of volume and / or weight-constrained loads likely to migrate from HGVs of the current maximum size and weight to LHVs. The extent to which loads migrate will vary with the LHV scenario, the level of network restrictions imposed in each scenario and the industry sector. It is not a matter therefore of determining a single adoption value. Instead a multi-dimensional analysis would have to be undertaken to establish update values for around 240 permutations of scenario, network restriction and sector, as illustrated in Figure 89, below. It was found to be impossible to estimate all cells of this matrix with any degree of confidence given the data available and the lack of quantitative estimates from a large, representative sample of hauliers and shippers.

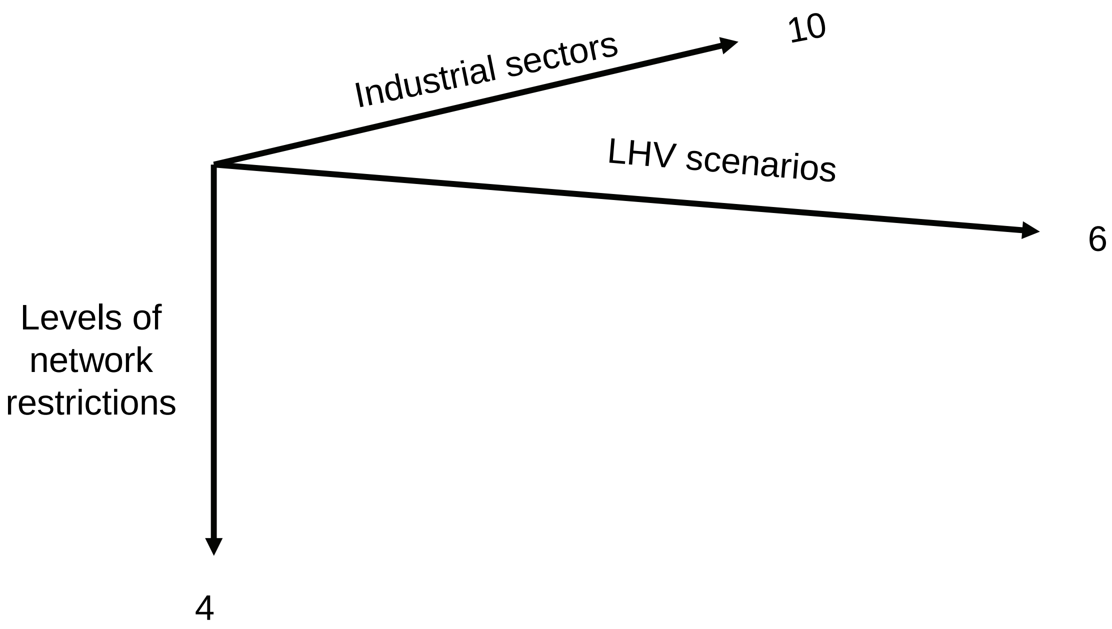

Figure 89: Illustration of the matrix of values required for full analysis of LHV affects

The best that can be achieved at this stage is to estimate subjectively a range of possible uptake percentages for different industrial sectors, distinguishing between 44 tonne, payload-neutral and payload-positive options. No distinction has made between the 25.25 m and 34 m LHVs in this estimation process. The 34 m combinations were the most popular though likely to be subject to the tightest network restrictions. Although the 25.25 m vehicles provide only half as much additional carrying capacity, they were perceived to be likely to have much greater freedom of movement. It is assumed for the purposes of this estimation that these differences in capacity and network access would cancel out. In the absence of detailed guidance on route restrictions and gross weight limits, the estimation is inevitably fairly crude.

The experience of operating LHVs in other countries can provide important contextual information. In Sweden, Vierth *et al* (2008) showed that 74% of tonne kms were transported by LHVs (defined as vehicles in excess of 40 tonnes and with 7 or more axles). In Australia, Moore (2007) shows that more than half of all tonne kms are transported by B-doubles and road trains. These are both very high proportions of road freight that are carried by LHVs. However, this is likely to reflect the fact that the use of very large vehicles is quite mature in both countries and both will have freight routes travelling long distances through sparsely populated areas. Arcadis (2006) describes the result of the recent trials in the Netherlands, which led to an estimate that between 7% and 31% of those tonne kms currently carried by vehicles with a GVW in excess of 20 tonnes would transfer to 25.25m vehicles at 60 tonnes. In the USA, Craft (undated) reports that in 1994 just 2% of articulated vehicle-kms (which will translate into a higher proportion of tonne-kms) were transported by what they define as ‘longer combination vehicles'. The restrictions applied in terms of access to the road network were cited as one of the reasons for the relatively low distance travelled by such vehicles, although it is worth noting that the standard combination vehicle in the USA is permitted to be longer than those in the UK. The proportion may also have grown since 1994.

Appendix G analyses trip data from the CSRGT and suggests that a maximum of approximately one-third of current trips would be suitable for transfer to LHVs. This suggests that LHV use in the UK would be towards the lower end of that seen in other countries. Analysis of CSRGT statistics identifies commodity classes subject to high levels of load weight- and volume- constraint. These commodity classes most likely to benefit from the 44 tonne LHV scenarios correspond quite closely to sectors identified by the industry fact-finding exercise as being likely to adopt LHVs. Only five commodity groups have 40% or more of their laden-kms constrained by volume but less than 20% constrained partly or wholly by weight:

- *Miscellaneous articles*: this category contains parcel and pallet-load movements as well as mixed retail supplies in the FMCG sector.
- *Other foodstuffs*: including grocery products
- *Miscellaneous manufacturers*
- *Machinery and transport equipment*
- *Other metal products*

Collectively these five commodity groups account for 55% of all laden kms and 74% of laden kms subject to a volume constraint.

In keeping with the general view that LHVs will have niche applications, the analysis suggesting a maximum of about a third of trips could be candidates for transfer and the likelihood that some level of route restrictions would be applied, it is proposed that the degree of volume-constrained load migration to LHVs in these commodity groups would vary between 5% and 10%.

Partly on the basis of the fact-finding exercise, five sectors have been identified as the potential beneficiaries of an increase in weight and volume carrying capacity:

- beverages;
- wood, timber and cork;
- iron and steel products;
- other building materials;
- agricultural products.

A similar range of 5-10% constrained-load migration to LHV is suggested for these commodity groups.

It will, therefore, be assumed that for vehicles with a GVW of 60 tonnes or more then 5%-10% of all articulated vehicle tonne kms would transfer from standard articulated vehicles to LHVs. Similarly, it will be assumed that 5%-10% of all volume constrained articulated vehicle tonne kms would transfer from standard articulated vehicles to the 25.25m 44 tonne LHV. This translates to an estimate of approximately 2.75% to 5% of ALL articulated vehicle tonne kms. The industry indicated that fewer companies would benefit from an 18.75m articulated vehicle at 44 tonnes, although some still suggested that such a vehicle would be very useful. It will, therefore, be assumed that the take-up of such a vehicle will be half that of the 25.25m 44 tonne LHV, a total migration of between 1.38% and 2.75%, which is comparable to the current level of use for drawbar vehicles and double decks.

The above estimates of LHV usage fall at the lower end of the range found or predicted in other countries However, it is considered that given the various constraints discussed by the focus groups, and the different road networks available in other countries, the lower prediction for the UK uptake of LHVs is justified.

F.16.2 Vehicle Utilisation

A general view expressed at the focus groups was that the load factor on laden LHV trips would be higher than on maximum-weight HGVs, and the level of empty running lower. This was based on the reasoning that, given their higher capital cost and tighter route restrictions, LHVs would tend only to be used on routes offering good loading potential in both directions. A conflicting view was that the network restrictions imposed on LHVs would limit their ability to deviate from approved routes to collect backloads. In addition to this, the backloads available may not be of sufficient size to fill the additional capacity of an LHV. These factors could have the effect of increasing their level of empty running and/or reducing the load factors.

Weight-based lading factors can be obtained from CSRGT but there are no equivalent measures for volume utilisation. The only available volumetric statistics (relating to deck area / pallet slot utilisation) come from the transport KPI surveys (DfT, 2005, 2006a, 2006b, 2006c) undertaken in the food, non-food retailing, pallet-load and parcel sectors. For articulated vehicles, the average deck area utilisation figures for these sectors are, respectively 69%, 74%, 80% and 69%, significantly above the comparable weight-based utilisation factors. These sectors, however, are characterised by lower density products and tend to 'cube-out' before they 'weigh out'. Their average deck area utilisation is therefore likely to be above the average for all road freight, though it is not known by how much.

Deriving predictions of the vehicle utilisation for a range of vehicles which offer either increases in volume and a decrease in payload, an increase in volume only, or an increase in both volume and payload while introducing new, untested, route restrictions is, therefore, very complex. The views from the stakeholders suggested that the fact that route restrictions might limit backloading opportunities was likely to contribute to a lower take up rate rather than an increased level of empty running. It is also likely that, although stakeholders suggested that LHVs would tend to be used on trips with higher than average utilisation, many of those trips would be replacing trips with standard articulated vehicles with higher than average utilisation. Thus, it would be expected that the average load of those trips that were still carried out by standard articulated vehicles would decrease. However, this would not always be the case.

The stakeholders have also expressed the view that many loads are not constrained by volume or weight directly but by the size of the consignment. This can be related to the concept of just-in-time delivery where it is possible, for example, that there is a need to deliver 39 pallet loads of goods at a specified time. Currently, this would require two articulated vehicles or one double decked articulated vehicle, each of which would be 75% full. The same load could be carried on a single 25.25m LHV, which would be 98% full, a 30% increase in load factor. Equally, the size of the consignment can relate to the physical size and mass of each unit of load. For example, steel is often shipped in large coils. If a steel coil weighs 19 tonnes it may be carried on a 38 tonne articulated vehicle, which would be approximately 73% of its maximum payload weight. However, if 60 tonne LHVs were permitted it is likely that two coils could be shipped on the same vehicle, which would mean that the LHV was 96% full, a 32% increase in load factor. Thus it could be argued that having a greater selection of vehicle types available would improve the ability of the road haulage industry to use the right sized vehicle for each load, thus increasing load factors.

However, it has also been noted that backloads can be difficult to source and are often only partial loads that do not fill the vehicle. It is possible that an LHV could be used on a route where the outbound load factor is very good but the return load is no bigger than it would have been if a standard articulated vehicle was used. This would have the effect of reducing the average load.

For the reasons described above, the later analysis of costs and benefits (see Appendix H) will assume that empty running and average load will be the same in percentage terms as for current single decked articulated vehicles.

The lack of volumetric utilisation data has meant that the final analysis of the projected impacts of LHVs (see section 7) had to use a complex method to translate this assumption for types of LHV with equal or reduced payload weight. This was based on average load expressed in terms of average weight, maximum payload weight and maximum pallet capacity. This method predicted the average load based on extrapolating actual average loads recorded by CSRGT for single decked and double decked articulated vehicles with different maximum payloads, based on the payload weight of the LHV type under consideration. This results in an absolute value of average load lower than the baseline figure. The reason for this is that only the lowest density loads will transfer (as shown by actual data on double decked vehicles). An average density of load can be estimated from the average load and the pallet capacity ratio between the baseline vehicle and the LHV under consideration. From this, the average load of goods taken away from standard articulated vehicles can be calculated and a new value of average load (post transfer to LHVs) can be calculated for the standard articulated vehicles. Based on current data this is always higher than it was previously. In this way, the distance travelled by standard articulated vehicles reduces by a greater amount than the increase in distance travelled by the LHV under consideration.

F.16.3 Freight Modal Shift

On the basis of the earlier discussion of the possible impact of LHVs on the railfreight market, estimates of the potential modal shift from rail have been produced as described in the following sections.

F.16.3.1 Deep-sea container traffic:

The prediction of modal shift in this sector has been based on an econometric analysis using cross-elasticity values of 2 and 5. This is a slightly lower range than that provided by the estimate of 2.5 from the ORR (2006) report and the estimate of 6 provided to the project by the rail industry. However, these higher values have been moderated slightly to represent the fact that they will have related to the price sensitivity of the market given the constraints of standard articulated vehicles and that greater constraints will apply to LHVs. These are applied to the estimated reduction in road vehicle operating costs per TEU from replacing an HGV with a 25.25 m LHV operating at 60 tonnes. This suggests a potential loss of rail container traffic of between 22% and 54%.

Freightliner has also provided evidence that the average weight of a loaded 40’ container is 16.6 tonnes. Although not clear in freightliners report, it has been assumed that this applies to 40’ containers and the average weight of a loaded 20’ container will be 8.3 tonnes, giving a total of 24.9 tonnes in combination. The payload capacity of a 44 tonne 25.25m LHV would be approximately 23.5 tonnes. Although the distribution of container weights around the average is not known it is reasonable to assume that there will be a normal distribution. This would mean, therefore, that just less than half of all loaded containers could be carried by a 44 tonne 25.25m LHV. It has, therefore, been estimated that a 44 tonne 25.25m vehicle would result in a mode shift of half of that caused by a 60 tonne vehicle.

None of the stakeholders considered that a longer articulated vehicle would present a substantial risk of mode shift in the deep sea container market.

The values of mode shift that have been estimated for the deep sea container market on the basis of the information, both analytical and subjective, provided by stakeholders are shown in Table 90, below.

Table 90. Estimates of mode shift in the deep sea container market

Scenario	Proportion of container tonne kms moving to road (%)	Deep sea container tonne kms as a proportion of all rail tonne kms (%)	Proportion of all rail tonne kms moving to road (%)
18.75m articulated vehicle (44t)	0	21	0
25.25m (44t)	11-27	21	2.5-5.5
60+ tonne	22-54	21	5-11

It should be noted that these estimates effectively assume that all competing road traffic transfers to LHVs. As acknowledged by Freightliner in its' written evidence, accessibility difficulties are likely to mean that a number of destinations are not accessible to LHVs, meaning that either containers must be trans-shipped or that not all containers transported by road would be carried by LHVs. Freightliner also modify their price reduction for LHVs based on the fact that they considered it unlikely that road operations would be able to fully utilise the additional capacity in both directions.

Other sections of this research examined these issues in the context of the road operations and concluded that, across all markets, LHVs of 60+ tonnes would only be able to be used for between 5% and 10% of all road tonne-kms currently carried by articulated vehicles. However, it is possible that the take up could be higher than this in a specific sector such as the deep sea container market. In order to check the above findings a simple econometric analysis was carried out based on a range of elasticity values and applying the cost reductions estimated in section 5.4 to only the proportions of all road traffic estimated by other parts of this research to use LHVs. The results are shown in Table 91, below. It should be noted that this calculation assumes that all of the cost reduction enabled by LHVs would be passed on to the consignor of the goods, that is, the haulier does not increase their profits. In terms of mode shift analysis, this is a conservative assumption and represents a larger cost reduction that either of the major rail freight companies considered likely.

Table 91. Alternative mode shift analysis

Vehicle type	Estimate	Cost reduction per unit of goods moved*	Take-up rate	Mode shift predicted by elasticity value			
				2	2.5	5	6
44 tonne - 25.25m	Upper	28.00%	5.50%	3.08%	3.85%	7.70%	9.24%
	Lower	27.00%	2.75%	1.49%	1.86%	3.71%	4.46%
60tonne - 25.25m	Upper	27.00%	10.00%	5.40%	6.75%	13.50%	16.20%
	Lower	25.00%	5.00%	2.50%	3.13%	6.25%	7.50%

* per pallet km assuming 100% full load for 44 tonne vehicle/ per tonne-km assuming average load for 60 tonne vehicle

It can be seen that if the take up rate of LHVs by road hauliers in the deep-sea container market was equal to the average for all road freight, because of constraints on available routes, capital investment, facilities at destinations etc., then the analysis suggests that the mode shift would be much lower than predicted in Table 90. In order to fully explore the issues, the main cases considered in the later analysis of costs and benefits were based on the mode shift values shown in Table 90. However, additional input values were analysed in the model to assess the mode shift values in Table 90 in combination with a 100% take up in the competing road sector (i.e. in the deep sea container market only) and to assess the higher end of the mode shift values in Table 91 in combination with the average take up rates.

F.16.3.2 Bulk traffic:

Many of the stakeholders involved in the focus groups suggested that bulk rail traffic would be at considerably less risk than deep sea container traffic. However, the Oxera analysis did provide some evidence to suggest some erosion of bulk rail freight traffic to LHVs. In recognition of this possible modal transfer, expert judgment was used to arrive at the modal shift percentages to be applied for bulk traffic shown in Table 92, below.

Table 92. Estimates of mode shift in the bulk rail market

Scenario	Proportion of bulk rail tonnekms moving to road (%)	Bulk rail as a proportion of all rail tonnekms (%)	Proportion of all rail tonne kms moving to road (%)
44 tonne and payload neutral	0	67	0
60+ tonne	5-10	67	3-7

Again, it is possible to independently check these estimates using the road transport cost reductions estimated in this research in combination with the elasticity values used in ORR (2006). However, the ORR report (2006) publishes values for specific commodities whereas the later analysis of costs and benefits does not separate individual commodities. A weighted mean elasticity for bulk traffic has, therefore, been derived on the basis of the published information, as shown in Table 93 below.

Table 93. Elasticity values derived for bulk rail.

	Million TKMs (2005)	Elasticity (ORR, 2006)
Coal	7,753	0.2
Other minerals	3,478	4.1
Metals	2,037	0.7
Petro-chemical	1,388	1.2
Ore	256	0
Weighted mean bulk elasticity		1.27

The other key part of an econometric analysis is identifying the average price reduction in the road sector directly competing with rail. On average, across all sectors, the take up of 60+ tonne LHVs in the road sector has been estimated to be between 5% and 10%. If the take up was the same as the average in the sectors competing with bulk rail the average price reduction that should be applied in the estimate is only 5% to 10% of that calculated on a per vehicle basis. However, LHVs, if permitted, would be likely to be used on longer trunk hauls, many of which could be in direct competition with rail. If the 5% to 10% of existing road trips that would be replaced by LHVs, if permitted, were all to be in direct competition with rail then the full price reduction should be used in the calculation.

Evidence from stakeholders and from the modelling of CSRGT trip data for origins and destinations suggests that LHVs may not be able to access many of the necessary sites for bulk traffic, subject to any policy decision regarding route restrictions. In addition to this, there could be difficulties with site safety and more complex and time consuming unloading procedures. Thus, in reality, there is likely to be a substantial proportion of bulk rail flows that would still compete with standard HGVs rather than LHVs if they were permitted. It is not, therefore, possible to accurately assess at this stage exactly what price reduction would be appropriate for an objective econometric analysis of mode shift. For this reason, a check on the figures derived in Table 92 has been made on the basis of 5%, 10% and 100% take up of the relevant LHV for the trips directly competing with rail. The results are shown in Table 94 and represent boundary conditions within which the true answer would be expected to lie. It should be noted that this calculation assumes that all of the cost reduction enabled by LHVs would be passed on to the consignor of the goods, that is, the haulier does not increase their profit. In terms of mode shift analysis, this is a conservative assumption and represents a larger cost reduction than either of the major rail freight companies considered likely.

Table 94. Alternative analysis of mode shift in the bulk rail sector

		Mode shift predicted			
		25.25m 60tonne		34m 82 tonne	
	Cost reduction	25%	27%	27%	43%
Take up in competing road sector	5%	1.58%	1.71%	1.71%	2.73%
	10%	3.17%	3.42%	3.42%	5.45%
	100%	31.69%	34.22%	34.22%	54.51%

It can be seen that the estimate of which part of the markets will actually be using LHVs is critical and the full range of estimates span a wide range of possibility. Given this wide range of possibility it is considered that the factors proposed in Table 92 are a fair compromise between the extreme values derived in Table 94, the analysis provided by the rail freight industry and the subjective views of other stakeholders in the wider freight industry. The proposed values are consistent with the relatively low take up in the road freight industry and the fact that the take-up will tend to be biased towards those journeys directly competing with rail but still substantially less than 100% because of other constraints.

F.16.3.3 Domestic Intermodal traffic

The domestic intermodal rail freight market is currently very small, representing 251 million tonne-kms in 2005, compared with 22,304 million tonne-kms by rail in total and approximately 163,000 million tonne-kms by road (116,000 million of which by articulated vehicles). Thus, for the larger vehicles assessed in this research (25.25m+) calculation of mode shift from rail to road is likely to be dominated by effects in the bulk and deep-sea container markets. The 18.75m vehicle is likely to have lower benefits in terms of consolidation of existing road freight and is not considered likely to have any effect on the other rail markets and thus, effects on the domestic intermodal market may have an influence on the overall results of the model and require further consideration.

Stakeholders from the rail freight operating companies expressed concern that LHVs would, if permitted, have a serious adverse effect on the domestic intermodal market. However, in this case, no analytical evidence was provided to support these conclusions. The only analytical approach to estimating the potential effects that was available was, therefore, to combine the elasticity values cited by the ORR (2006) with the cost reductions calculated in this research, again assuming that all such reduction was passed on to the consignor of the goods. The ORR report cites an elasticity value for the domestic intermodal market of 1.8, although it is not clear how this was derived. Again, the most difficult part of the analysis is to estimate what proportion of the vehicle fleet competing with rail would adopt an LHV, if available, and thus, what level of price competitiveness road gains from such a move.

For the 18.75m articulated vehicle, other parts of this research estimated that across all road freight sectors the average take-up rate would be between 1.37% and 2.75% of all articulated vehicle tonne-kms. This was estimated to be lower than for other 44 tonne options because the increase in volume capacity was smaller and the option was less popular with the road freight industry. The 18.75m articulated vehicle would have a lower payload capacity than an existing 44 tonne vehicle, thus meaning that the cost per tonne km would be higher. However, the increased volume capacity would mean that the price per pallet km for volume constrained goods would be reduced, by an estimated 18%. It should be noted that the national lack of data on the average load on vehicles expressed in volumetric terms meant that this price reduction was estimated based on a full vehicle, which is highly unlikely to occur, on average, in service and thus over-estimates the price reduction. Estimates of mode shift based on this reduction will, therefore, tend to over-estimate the effect. If this price reduction was factored by the average predicted take up in the industry then the overall price reduction for all road freight in comparison to rail freight would be very small.

As with other LHV types assessed there is a likelihood that an 18.75m articulated vehicle would predominantly be used on longer trunk hauls, which are those most likely to be competing with rail. For these specific freight flows the proportion of LHVs would be likely to be higher than the average take up would suggest. However, in this case the upper boundary would not be that all rail freight flows could be competing with an LHV because the longer articulated vehicle could only be used to roads advantage for low density goods that are currently constrained by volume rather than weight. Rail freight is able to compete for domestic intermodal transport of goods of all densities. Thus the maximum proportion of rail freight competition that would be carried by a longer articulated vehicle at 44 tonnes is the approximately 55% of the market that involves commodities which have very high levels of volume constraints. In reality it would be lower than this because some goods that are volume constrained on a standard 44 tonne HGV would be weight constrained on an 18.75m articulated vehicle at 44 tonnes.

Each of these competitive positions has been assessed based on the 18% price reduction and the elasticity value of 1.8 and the results are shown in Table 95, below.

Table 95. Range of mode shift estimates for an 18.75m articulated vehicle at 44 tonnes.

Proportion of LHVs used on trips in competition with domestic intermodal railfreight	1.37%	2.75%	55%
Predicted Mode Shift (% current domestic intermodal market)	0.44%	0.89%	17.82%
Predicted mode shift (% of all current rail freight)	0.005%	0.010%	0.201%

It can be seen that this analysis leaves quite a wide range of uncertainty in the likely mode shift effects. For the domestic intermodal market stakeholders contributed much less information on the likely effects. It was considered, therefore, that the estimate of mode shift to be used should span a relatively wide range, be higher than implied by the average take up rate to cover the likelihood that the vehicles would be more likely to be used on routes competing with rail (i.e. long haul) than on other routes, but be less than the maximum boundary to reflect the lower popularity of these vehicles. This is considered to be a cautious approach because recent rail successes in the domestic intermodal market have been achieved despite the rapid increase in the use of drawbar combinations (offering the similar volume to an 18.75m articulated vehicle) and double decked articulated vehicles (offering considerably more pallet capacity than a single decked 18.75m articulated vehicle). A range of between approximately 0.05% and 0.15% of all rail tonne kms was selected.

F.16.3.4 Consideration of differential growth of rail freight markets

The analysis of costs and benefits carried out in this research was based on an aggregate model of GB freight. Growth was, therefore, accounted for at a high level in terms of the total tonne kms transported by road and rail. The predictions on which the model is based were shown in Figure 9 and Figure 10. For road, the prediction used was the lowest available whereas for rail the highest available was used in order to form a cautious analysis. If actual future growth reflects other predictions more closely then this analysis will tend to under-estimate the benefits of consolidation within the road industry and over-estimate the effects of mode shift. Neither of the modes were further divided to consider changes in the distribution or size of specific commodities or markets, so that decline in coal freight on rail was not considered but nor was the decline in the average density of goods carried by road, making volume a more important consideration in future.

Table 6 clearly shows that within the overall estimates of rail freight growth, individual commodities are expected to change substantially. The mode shift estimates to be applied in the cost benefit model (based on total rail tonne-kms) derived in the preceding sections are based on the proportions of the total that each market currently represents. This has the potential to distort the mode shift findings.

However, a comparison of the actual shift in tonne-kms predicted by mode shift percentages in the bulk and deep-sea container markets has shown that the predicted decline in coal traffic and increase in deep-sea container markets approximately cancel out such that the overall percentage changes applied to the total in the cost-benefit model remain approximately correct. There will be a tendency for the 44 tonne vehicles to slightly under-estimate mode shift because they do not include the bulk market. However, given that the overall growth in rail tonne-kms used in the model is the highest of all available estimates and the fact that the high level of growth also predicted for the carriage of deep-sea containers by road was also not specifically accounted for it was considered unnecessary to modify the estimates further.

The domestic intermodal market is forecast to see very large growth over the years considered by this study and this is not balanced by declines elsewhere. It was, therefore, considered necessary to consider this market in more detail. The two available forecasts from the Freight Route Utilisation Strategy (Network Rail, 2007) suggest growth of either 225% or 747%, depending on the forecasting method used. The same document reports that *"Domestic intermodal is forecast to see continued growth in line with the last few years, with supermarkets and other retail distributors increasingly making regular use of rail. The West Coast Main Line London-Midlands-Scotland corridor is highlighted as the key route for this traffic, with traffic between Scottish terminals at Mossend, Coatbridge and Grangemouth and intermodal terminals in the Midlands expected to show continued growth."* The highlighted routes between the Midlands and Scotland are consistent with the high average length of haul of 327km calculated in Table 6 and the fact that the distance between Birmingham and Glasgow is approximately 300km. It is also consistent with the general view expressed that the competitiveness of rail increases on longer hauls.

The growth in this market is not expected to be as a result of growth in the underlying amount of freight requiring shipment on this route but is expected to come as a result of increased competitiveness leading to mode shift from road to rail. Road freight statistics (DfT, 2007a) shows that 82 (4.5%) million tonnes of goods were transported on hauls of more than 300km out of a total of 1,810 million tonnes. This reflects the fact that most goods transport is over shorter distances where rail tends to be less competitive, unless there is a direct rail link from origin to destination. Of this total, 24 million tonnes were classified as bulk products or chemicals, leaving a maximum of 58 million tonnes that could be classified as potential traffic for the domestic intermodal market, although this will also include some deep-sea container traffic which also has long average lengths of haul. By definition, the long distances involved mean that these long haul goods represent a much larger (21%) proportion of total road tonne-kms, with 23,451 million tonne-kms that could be considered to be long-haul traffic within the remit of the domestic intermodal market (i.e. excluding bulk and chemicals from a total of 32,974 million tonne-kms on hauls > 300km).

Network Rail (2007) states that the main growth in domestic intermodal is expected on routes between the Midlands and Scotland. This rail route could sensibly form part of any journey with either an origin or destination in Scotland and the other end of the journey anywhere except Scotland, the north of England or Northern Ireland. DfT (2007a) shows that 9 million tonnes of goods lifted fall into the relevant origin and destination categories, which represents 0.5% of a total 1, 810 million tonnes lifted in the UK. Table 5 showed that using two separate methods, Network Rail (2007) predicted that domestic intermodal traffic would account for either 2.5tonnes or 6.5 tonnes of traffic in 2014/15. If based predominantly on growth of the west coast main line traffic this would represent a mode shift of up to approximately 28% or 72% of current road traffic on compatible routes to rail, for at least part of its journey. For the top down estimate (resulting in the market share of up to 72%), this high proportion is likely to explain the much slower growth predicted between 2014 and 2030 as rail begins to saturate the available market.

This represents a substantial mode shift from road to rail so it is important to consider whether permitting LHVs would be likely to prevent this mode shift. This can only be achieved by assuming that this rail growth will happen and assessing the effect as if it were a mode shift from rail to road. It was, therefore, necessary to adapt the mode shift percentage for the domestic intermodal market to account not only for its share of the 2005 rail market but also for its increasing share of the growing total rail market for each year considered in the later analysis of costs and benefits (2006-2020). There was insufficient information in the Network Rail (2007) report to use only data published therein, so simple linear interpolation and extrapolation was used to estimate the data for years not published by Network Rail (2007). The results are shown in Table 96, below.

Table 96. Comparison of Network rail predictions of domestic intermodal growth and TRL predictions of total rail growth and market share

Year	Million tonne kms			Domestic intermodal share of rail total	
	Network rail (2007) Domestic Intermodal (top down)*	Network rail (2007) Domestic Intermodal (bottom up)**	TRL cost benefit model (all rail)	Top down	Bottom up
2005	251	251	N/A	N/A	N/A
2006	459	314	22,000	2.09%	1.43%
2007	667	377	22,636	2.95%	1.66%
2008	875	440	23,273	3.76%	1.89%
2009	1,083	503	23,909	4.53%	2.10%
2010	1,292	565	24,545	5.26%	2.30%
2011	1,500	628	25,182	5.96%	2.50%
2012	1,708	691	25,818	6.61%	2.68%
2013	1,916	754	26,455	7.24%	2.85%
2014	2,124	817	27,091	7.84%	3.02%
2015	2,139	880	27,727	7.71%	3.17%
2016	2,154	943	28,364	7.59%	3.32%
2017	2,169	1,006	29,000	7.48%	3.47%
2018	2,183	1,069	29,636	7.37%	3.61%
2019	2,198	1,131	30,273	7.26%	3.74%
2020	2,213	1,194	30,909	7.16%	3.86%
Total (2006 - 2020	**24,680**	**11,312**	**396,818**	**6.22%**	**2.85%**

* - Linear interpolation between actual data for 2005, 2014 and 2030

** - Linear interpolation for years between actual data in 2005 and 2014 with linear extrapolation for years after 2014

In order to produce an estimate of mode shift from TRLs model of costs and benefits that reflects the potential growth in the domestic intermodal market, it is necessary to apply the estimates of the percentage effect within the market (Table 95) to the total market share (2006 – 2020) shown in Table 96. This produces the results shown in Table 97, below.

Table 97. Modified mode shift percentages for the 18.75m articulated vehicle, accounting for growth in the domestic intermodal market.

Proportion of LHVs used on trips in competition with domestic intermodal railfreight	1.37%	2.75%	55%
Predicted Mode Shift (% current domestic intermodal market)	0.44%	0.89%	17.82%
Predicted mode shift (% of total rail freight including growth) - bottom up	0.013%	0.025%	0.508%
Predicted mode shift (% of total rail freight including growth) - top down	0.028%	0.055%	1.108%

Again, a lack of information from stakeholders on the likely competition offered by the 18.75m vehicle makes it difficult to resolve the uncertainty in the range of predictions with confidence. Based on the same logic as used in the preceding section it seems reasonable to select a mode shift of between 0.25% and 0.75% of all rail tonne kms in the later analysis of costs and benefits.

F.16.3.5 Overall effect on rail traffic

To estimate the overall effect on rail traffic is a simple addition of the effects in the different markets. On this basis, the overall impact of the LHV scenarios on railfreight tonne-kms, to be used in the analysis of costs and benefits are estimated to be:

- 18.75m articulated vehicles with 44 tonne GVW: 0.25%-0.75%tonne-km shift
- 25.25m, 44 tonne LHV scenarios: 2.5%-5.5% tonne-km shift
- 60 tonne+ LHV scenarios: 8%-18% tonne-km shift

It must be emphasised that these estimates are based on the best evidence that could be generated within the scope of this project. However, they do include substantial elements of subjective judgement to resolve the uncertainties remaining when the econometric analyses provided to the project by the rail industry, the views of other stakeholders, the independent econometric analyses and the potential additional constraints on LHV use, if permitted, are considered.

The recent trial of LHVs in Holland, where 25.25m LHVs were permitted to operate on selected routes at 60 tonnes GVW, led to a prediction that a more widespread introduction of LHVs would result in a mode shift from rail of between 1.4% and 2.7%. It can be seen that this is considerably lower than the estimates for the UK. While the trial meant that the Netherlands had considerably more objective evidence available with which to quantify the effects, it is also likely that fundamental differences in the freight markets in each country, for example the large proportion of international rail freight in the Netherlands, have contributed to the difference in the magnitude of effects predicted.

The discussions with organisations in the maritime shipping and ports sectors strongly suggested that they did not see LHVs as a threat to their business. This is consistent with the analysis of freight data which shows that the average length of haul on waterborne transport is 744km, far greater than either road or rail, and that the commodities carried are dominated by bulk liquids. This difference in the market between water and road suggests that there is little competition between the two and it has, therefore, been assumed that there will be no shift of waterborne freight to LHVs.

F.16.3.6 Payload neutral scenarios

The concept of scenarios where the permitted GVW was increased but only by enough to give the vehicle the same payload capacity as a standard 44-tonne articulated vehicle was introduced part way through the project. As such, this concept could not be fully evaluated in the analysis of costs and benefits because the detailed assessments of impacts such as fuel consumption and emissions could not be carried out. The effects expected for such vehicle combinations were, therefore, estimated on the basis of linear interpolation of the results of the model (see section H.2).

However, in order to put the results in context and to assess their plausibility it is possible to apply the same interpolation techniques to the mode shift inputs defined above to give the equivalent mode shift percentages implied by the results for the payload neutral scenarios. These can then be compared with the information from stakeholders to assess their likely validity. The results are shown in Table 98, below, but it must be emphasised that the percentages for the payload neutral scenarios shown were not used as inputs to the cost model.

Table 98. Mode shift percentages including interpolated estimates for payload neutral scenarios.

Scenario	Low	High
18.75m 44 tonnes	0.25%	0.75%
18.75m Payload neutral	1.59%	3.68%
25.25m 44 tonnes	2.50%	5.50%
25.25m Payload neutral	4.40%	9.82%
25.25 60 tonnes	8.00%	18.00%
34m 63 tonnes	8.00%	18.00%
34m 82 tonnes	8.00%	18.00%

The 18.75m payload neutral scenario is an interpolation between the standard 44-tonne articulated vehicle and the 25.25m 44 tonne vehicle, based on the increase in length/volume. It can be seen that the mode shift implied by the interpolation technique is considerably higher than for the 44 tonne version of the same vehicle. This is much higher than would be implied by the effect of the additional weight carrying capacity on the cost and, therefore, on an econometric analysis. This is a function of the fact that it effectively includes a proportion of the mode shift attributed to the 25m vehicle, which was based on its ability to carry two maritime containers. The 18.75m vehicle can only carry one maritime container and as such, it is highly likely that the interpolation over-estimates the mode shift effect.

Similarly, the 25m payload neutral version is an interpolation of the 44 tonne and 60 tonne versions of the same vehicle, based on payload weight capacity. Thus, a proportion of the mode shift in the bulk rail market that is attributed to the 60 tonne vehicle is also attributed to the payload neutral version in addition to a proportion of the deep-sea container mode shift. The deep sea container mode shift is appropriate because a greater proportion of the full range of container weights could be carried on a payload neutral vehicle than on a 44-tonne version. However, the proportion of the bulk rail mode shift that is effectively attributed is not because, by definition, a payload neutral scenario does not offer any economic advantage to the carriage of goods that are already weight constrained on a 16.5m 44-tonne articulated vehicle. Thus, this also slightly over-estimates the mode shift effect.

F.16.4 Traffic Generation Effect

Reducing the cost of moving freight by road could generate additional freight movement. However, the predictions made by previous studies appear to have substantially over-estimated the level of traffic generation. Reviewing the impact of the 44 tonne lorry weight increase, three years after its introduction, McKinnon (2005) concluded that:

“There is little evidence .… that the truck weight increase has, as yet, generated much additional demand for road freight movement”.

The reason for this is that the growth in road freight tonnekms has slowed considerably since around the time of the recent weight increases and is now fairly flat. In the information gathering exercise stakeholders were asked whether transport cost reductions from the use of LHVs would be likely to encourage further centralisation of logistics and / or wider sourcing of supplies. Fewer than 5% of road freight industry representatives believed that the use of LHVs would promote structural change resulting in higher freight transport demand. One sector in which this might occur is forestry where the geographical extent of harvesting is constrained by the high cost of road transport relative to the sale price of the product transported. In most other sectors, companies’ production and logistics systems were felt to be already highly centralised and their patterns of sourcing and distribution are already very extensive (both within the UK and internationally), leaving little scope for further geographical reorganisation. Many companies also argued that use of LHVs would be confined to particular routes and operations and therefore would be unlikely to induce much system-wide restructuring. The vast majority of the focus group delegates also doubted that LHV-related cost reductions would stimulate much additional freight traffic growth.

Nevertheless, allowance was made for some traffic generation in the parametric model described in section H.2.2.4. A range of price elasticity of demand values for road freight between 0.02 and 0.04 was used in the analysis. These were only applied to those market segments that would be likely to use LHVs if they were permitted.

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Appendix G. Analysis of the effects of imposing route restrictions on LHVs

G.1 Introduction

The objective of this part of the study was to identify candidate freight flows for LHVs based on the actual routes used in real haulage operations. This information was considered important because it would help to identify the maximum number of HGV trips that could feasibly be replaced by LHVs and would quantify in economic and environmental terms the impact that imposing route restrictions would be expected to have if LHVs were permitted. This information has been used to inform the estimates of the take-up rate of LHVs, given different route restrictions, that were used as inputs to the parametric cost model to estimate the overall net effect if any decision were to be made to permit such vehicles in the UK.

G.2 Methods

Trip data from the Continuing Survey of Road Goods Transported (CSRGT) was used as the basis for assessing the economic and environmental impact of imposing different route restrictions on LHVs. Details of trips from the CSRGT data set were provided by the Department for Transport (DfT) under four vehicle groupings as follows:

- 32 - 37 tonnes (4 or more axles) for trips that are weight/cube constrained only
- 38 - 40 tonnes (5 or more axles) for trips that are weight/cube constrained only
- 41 - 43 tonnes (6 or more axles) for trips that are weight/cube constrained only
- 44 tonnes (6 or more axles) all trips

Each of the trip records contained:

- An origin and destination (OD) according to a NUTS4 classification
- The type of intermodal location, if applicable (i.e. port, rail interchange, airport)
- The gross vehicle weight and carrying capacity
- Vehicle characteristics such as body type and axle configuration
- Industry sector / type of goods
- Mode of appearance (pallet, bulk, etc)
- The weight moved between the origin and destination

In addition a grossed up value of the weight carried on each trip was also provided. This is done by the DfT to produce a statistically representative sample of all road freight activity. It is split across ten weight bands and eleven government regions. In total, more than 144,000 trip records were provided for the 2 year period 2004/5. The data was provided in SPSS format but was exported into Excel so that macros could be written to analyse the data. Analysis of this data showed that there were 432 unique NUTS4 locations and 29,536 unique origin and destination combinations. NUTS which stands for Nomenclature of Territorial Units for Statistics, is a European Union classification, used for statistical purposes, which divides European countries into areas at different hierarchical levels. Level 3 equates approximately to county and unitary authority boundaries. NUTS4 is a more detailed subdivision of these boundaries.

In order to model the movements of the trip vehicles and possible LHV's, a digitised road network was used to produce routes for each origin and destination pair. This was accomplished by geocoding each of the NUTS4 locations with latitude and longitude coordinates and finding the nearest node on the digitised road network. The road network consists of 9,207 nodes and 11,382 bidirectional links between these nodes. Each link contained a distance and a road category with a speed as follows:

- Motorway 80km/h
- Dual Carriageway 65km/h
- Federal Highway 55km/h
- Regional Road 45km/h
- Local Road 40km/h
- Unimportant Road 35km/h
- Ferry 5km/h

The speeds were used to calculate the travel time on each link and the quickest route between each origin and destination pair was calculated using a shortest path algorithm in an Excel macro. A node by node route was produced for each origin and destination pair with a summary of distance by road category. The additional distance and time between each NUTS4 location and the nearest road node was calculated using the latitude and longitude coordinates, and was taken into account in the routing algorithm by considering it as an off map distance on a local road.

The CSRGT data were then reduced to eliminate any trips for which LHV's were considered unlikely to be used. The trips excluded were:

- Northern Ireland trips
- Trips to or from the Scottish Isles
- For each OD, any trips where the NUTS4 or the road network nodes were the same (i.e. insufficient distance travelled to justify the use of an LHV
- Any trips less than 20 kms
- Trips that only involved empty running (NB allowance has been made for empty running in the parametric cost model)
- Trips classified as Type30 which are multi drop runs
- Livestock carriers
- Car transporters
- Tipper trucks

This reduced the number of trips in the data base to 77,073. Of these trips 16.7% were weight constrained, 33.5% volume constrained, 39.9% weight and volume constrained, and 9.9% (all 44 tonne movements) unconstrained.

There were six LHV types considered in the strategic modelling, the details of which are shown in Table 99. Detailed costs and operating characteristics for a baseline 44 tonne vehicle, and for each LHV, were established from a number of sources including FTA data, Motor Transport cost tables and outputs from other analyses carried out for this project. Costs and operating characteristics for the 35 tonne, 38 tonne and 41 tonne vehicles were synthesised from this data by using pro rata values based on Motor Transport cost tables for February 2007. The fuel consumption represents an average value for each of the vehicles, however it should be noted that these values were based on computer simulation that already assumed certain route restrictions would be applied. Values for the baseline vehicles are, therefore, higher than many published averages because it is based on use outside of urban areas.

Table 99: Vehicle costs and operating parameters

	Fixed cost/hr	Drivers cost/hr	Variable cost/km	Kms per litre	Mls per gall	Annual cost	Total cost/km	Max payload (kgs)	Max pallets
35 tonne	£9.89	£10.65	£0.307	2.987	8.40	£72,765	£0.51	23155	26
38 tonne	£10.41	£10.84	£0.324	2.844	8.00	£75,854	£0.53	25140	26
41 tonne	£11.14	£10.84	£0.350	2.667	7.50	£79,712	£0.55	27124	26
Baseline (44 tonne) - 6 axle articulated vehicle	£11.69	£11.14	£0.365	2.560	7.20	£82,697	£0.57	29109	26
Double -deck	£12.00	£11.14	£0.389	2.322	6.53	£86,295	£0.60	26130	52
Rigid/A dolly/semi/44	£11.55	£11.14	£0.420	2.220	6.24	£90,720	£0.63	23651	40
Rigid/A dolly/semi/60	£11.55	£11.14	£0.467	1.898	5.34	£97,484	£0.68	39651	40
Tractor, Semi+Csemi/82	£13.28	£11.14	£0.557	1.538	4.33	£110,838	£0.77	58380	52
Tractor/Interlinksemi/semi/44	£12.74	£11.14	£0.411	2.224	6.26	£89,676	£0.62	23349	40
Tractor/Interlinksemi/semi/60	£12.74	£11.14	£0.431	2.115	5.95	£92,536	£0.64	39349	40
Tractor, 16m semi	£11.61	£11.14	£0.356	2.570	7.23	£81,394	£0.57	27322	32

In order to assess the implications of replacing some current vehicles with LHVs, a number of assumptions were made. A fundamental assumption was that if the gross tonnes carried in the vehicle population between any pair of origin and destination were divided by the tonnes carried by the current vehicle on the trip, then the result represented the number of trips between the two locations. Increasing the tonnes carried on the trip as a result of using an LHV would therefore reduce the number of trips between the two locations. For example, if a 44-tonne vehicle carried 1,400 tonnes of goods between A and B at an average load of 14 tonnes, then it would take 100 trips. If the 44-tonne vehicle was replaced with a C-train carrying an average load of 28 tonnes then the number of trips required to move the same goods would be reduced to 50.

In order to provide an indication of the effects on the environment, it was assumed that all vehicles used diesel fuel emitting approximately 2.68 kgs of CO_2 per litre. More detailed emissions analysis was used in the final parametric cost model and this is described in Appendix C.

The CSRGT trip details only provided information about the weight carried by vehicles. For those trips which were volume constrained, it was assumed that the amount carried was equivalent to 26 pallets. Thus, if an LHV were to be considered, the weight carried on a trip would be increased by a factor based on the maximum number of pallets on the LHV divided by 26 pallets carried by the current vehicle. However, if this resultant weight exceeded the maximum payload of the LHV, then the volume on the LHV would be reduced accordingly. For example, if the load on a volume constrained trip was 20 tonnes, the load per pallet could be calculated as 20/26, which is 0.77 tonnes per pallet. If this was moved to a 25.25m LHV with a capacity of 40 pallets then filling the available space would result in a load of approximately 30 tonnes. If the LHV being considered was a 60-tonne version then it would be assumed that the load on the vehicle was 30 tonnes. However, if the LHV being considered was the version with the 44 tonne maximum weight then the payload would only be approximately 26 tonnes. In this case the load assumed for this vehicle would be limited to only 26 tonnes, effectively meaning that the LHV was carrying only 7 pallets more than the standard vehicle would have, thus meaning that the number of trips required was less than the standard vehicle but more than a 60 tonne vehicle would require.

For any vehicle trips which were weight constrained, the new weight carried would be increased by a factor of the maximum payload of the LHV being considered divided by the maximum carrying capacity of the current vehicle being used on the trip. For those LHV's which were payload negative (i.e. whose maximum payload weight was reduced because maximum weights were not changed) weight constrained trips were ignored. For those trips which were neither weight nor volume constrained, both options were considered and the greatest weight increase used.

Seven vehicle operating scenarios (referred to here as strategies to avoid confusion with the scenarios discussed elsewhere in the report) were considered. These were intended to represent different possible modes of operation as suggested by various stakeholders and are described below:

1. LHV's permitted on all types of roads. This was intended to represent an unconstrained reference situation for comparison with the other strategies. In this strategy a range of

percentage uptake of LHV’s were measured from 10% up to 100% in order to assess the relationship between uptake and results. This was achieved by randomly selecting trips from those judged to be amenable to transfer. To ensure that such a random selection was justifiable, five different sets of random trips were selected for each of the percentage uptake options, excluding the 100% option, and compared.

2. LHV’s allowed on any road as long as the origin and destination location are less than 20km from a motorway, and that at least 20km of motorway travel is involved. This is intended to approximate the situation in the Dutch trial where short distance access was allowed to reach origins and destinations off the primary road network. This strategy assumes that the motorway leg is uninterrupted and no coupling or decoupling of LHV combinations takes place.
3. LHV’s allowed on motorways only. This represents a possible situation suggested by some road freight hauliers. In this strategy the current vehicles would be used to service motorway coupling / decoupling points, with the LHV’s travelling on the motorway between them. This strategy assumes that as many coupling / decoupling points as required are available, even if it is only for a single origin and destination pair, and that the motorway leg, which has to be at least 20km, is uninterrupted. It is worth noting that at present there are no such coupling / decoupling points on the road network, however it was considered important to understand the effect this strategy could have on the potential use of LHVs, because it was an idea often discussed by representatives of the road freight industry at focus groups and many proposals/studies elsewhere in Europe have referred to the concept. The cost and feasibility of such sites, particularly related to land availability and planning constraints, would of course need to be considered in detail if there were grounds to consider this strategy further.
4. This strategy is similar to strategy 2 in that it assumes that LHV’s would be allowed on any road as long as the origin and destination location are less than 20km from a motorway or dual carriageway, and that at least 20km of motorway travel is involved. This strategy assumes that motorway and dual carriageway legs are contiguous.
5. LHV’s allowed on all motorways, dual carriageways and primary routes only. This was a route definition that gave the closest possible approximation of one set of route restrictions that stakeholders at the infrastructure focus group suggested might present the least difficulties in terms of implementation within the regulatory framework, although it was acknowledged that many individual roads on such a network may not be suitable for LHVs.
6. This strategy examined a subset of the trips in the CSRGT sample by considering the possible use of LHV’s on any road, for any trip that had a port origin or destination, and had a mode of appearance classification of “large freight containers including ISO”. This strategy was included in order to isolate the effects of port traffic because other analysis had shown that this was an area particularly sensitive to modal shift. Defining this strategy enabled an estimate to be made of the effect of permitting LHVs generally but prohibiting them from carrying shipping containers, in order to prevent mode shift from rail, if a mechanism for achieving such a situation could be found.
7. This last option considered permitting LHVs for a different subset of the trips available in the CSRGT sample. The results were assessed for each of the different route restrictions described in strategies 1 to 5, and the subset selected on the basis of those goods groups and mode of appearance that the stakeholders attending road freight focus groups had suggested were most likely to use LHVs if they were made available. The extracted subset was:
    - Goods group as follows:
        - 3 Other foodstuffs
        - 4 Wood, timber & cork
        - 15 Iron and steel products

- 18 Miscellaneous manufactures

- and within this goods group, mode of appearance as follows:
  - 2 Large freight containers inc ISO
  - 4 Palletised goods

G.3 Results

It had been suggested by a wide variety of stakeholders that not every trip undertaken by current articulated vehicles could be replaced by an LHV trip so it was considered important to study the total number of trips captured by the CSRGT and the number and proportion of those trips that were considered likely to be able to be replaced by LHVs. The numbers thus represent the maximum adoption rate of LHVs if every trip that could possibly be undertaken by LHVs was undertaken by LHVs. The results are shown in Table 21, below.

Table 100. Proportion of 2004/5 CSRGT recorded trips being candidates for LHVs

	Trip Records	% diff
All HGV's over 32 tonnes	245,000	
32 - 43 tonnes weight / volume constrained & all 44 tonnes	140,829	57.5%
Candidate trips for LHVs	77,073	31.5%
Strategy 1 - LHV's allowed on all roads	77,073	31.5%
Strategy 2 - LHV's allowed on routes within 20km of a m'way (No coupling / decoupling points)	20,362	8.3%
Strategy 3 - LHV's allowed on motorways only (Coupling / decoupling at any motorway junction)	47,241	19.3%
Strategy 4 - LHV's within 20km of a m'way or dual carr.	47,240	19.3%
Strategy 5 - LHV's allowed on m'ways, dual carr. & primary only	24,650	10.1%
Strategy 6 - Port ISO vehicles	3,170	1.3%
Strategy 7 - 4 goods group & 2 mode of appearance	12,156	5.0%

The trips that could theoretically be carried out by an LHV were defined by the exclusions described in section G.2. Strategies 2 and 4 were based on the assumption that LHVs would only be used for point to point journeys and there would be no coupling or de-coupling at interchange points, whereas strategies 3 and 5 assumed that LHVs would undertake all parts of journeys that took place on roads on which they were permitted and interchange points would be used such that standard vehicles took the loads on to their destinations.

Subsequently, a base case strategy was modelled against which the use of different types of LHV could be compared. Each of the four vehicle groupings were analysed by weight constrained, volume constrained, and unconstrained trips. The gross tonnes lifted was measured, as was the number of trips, total kilometres, hours and cost, the total litres of diesel fuel and the estimated CO_2 emitted. The results are shown in Table 101 below.

Table 101: Base case results

		Total tonnes lifted	No. of Trips	Tonnes /trip	Tot Dist (km)	Tot Time (hrs)	Total Cost	Tot fuel (lt)	Tot tonnes CO2
32-37 tonne vehs	Wt constrained	48,428,316	2,475,282	19.56	218,601,238	3,443,996	£137,820,710	73,192,379	196,156
	Cube constrained	38,428,320	3,858,818	9.96	418,135,207	6,329,771	£258,323,467	140,000,627	375,202
	Cube&Wt cons	249,765,871	12,758,647	19.58	925,387,286	15,036,277	£592,815,768	309,839,493	830,370
	Total	336,622,507	19,092,747	17.63	1,562,123,730	24,810,043	£988,959,944	523,032,499	1,401,727
38-40 tonne vehs	Wt constrained	16,562,845	729,240	22.71	106,959,676	1,578,082	£68,208,782	37,603,011	100,776
	Cube constrained	148,988,382	12,187,478	12.22	1,841,469,139	27,121,121	£1,173,297,380	647,391,494	1,735,009
	Cube&Wt cons	83,016,211	3,655,860	22.71	545,329,753	8,089,348	£348,685,239	191,717,491	513,803
	Total	248,567,438	16,572,578	15.00	2,493,758,568	36,788,552	£1,590,191,401	876,711,997	2,349,588
41-43 tonne vehs	Wt constrained	3,613,949	147,731	24.46	18,358,888	282,432	£12,630,230	6,884,583	18,451
	Cube constrained	20,080,841	1,466,386	13.69	241,718,414	3,554,825	£162,694,656	90,644,405	242,927
	Cube&Wt cons	18,065,305	729,318	24.77	105,135,001	1,584,107	£71,597,559	39,425,626	105,661
	Total	41,760,096	2,343,435	17.82	365,212,303	5,421,363	£246,922,445	136,954,614	367,038
44 tonne vehs	Wt constrained	55,293,608	2,076,734	26.63	325,314,681	4,855,327	£229,434,413	127,076,047	340,564
	Cube constrained	300,277,803	18,338,434	16.37	3,162,468,759	46,523,885	£2,214,958,260	1,235,339,359	3,310,709
	Cube&Wt cons	310,080,280	11,499,776	26.96	1,682,348,746	25,384,049	£1,192,786,204	657,167,479	1,761,209
	Not cube or wt cons	127,948,636	13,124,620	9.75	1,851,427,544	27,775,797	£1,309,024,275	723,213,884	1,938,213
	Total	793,600,328	45,039,564	17.62	7,021,559,730	104,539,058	£4,946,203,151	2,742,796,770	7,350,695
All vehicles	Wt constrained	123,898,719	5,428,987	22.82	669,234,483	10,159,837	£448,094,136	244,756,020	655,946
	Cube constrained	507,775,347	35,851,116	14.16	5,663,791,519	83,529,601	£3,809,273,762	2,113,375,886	5,663,847
	Cube&Wt cons	660,927,666	28,643,601	23.07	3,258,200,786	50,093,781	£2,205,884,769	1,198,150,089	3,211,042
	Not cube or wt cons	127,948,636	13,124,620	9.75	1,851,427,544	27,775,797	£1,309,024,275	723,213,884	1,938,213
	Total	1,420,550,368	83,048,324	17.11	11,442,654,332	171,559,016	£7,772,276,941	4,279,495,879	11,469,049

The tonnes per trip column shows the overall average load carried and the average load for trips with different constraints (weight, volume, both). For instance, in the 32 to 37 tonne vehicle range, weight constrained trips averaged close to the carrying capacity of this category of vehicles at 19.56 tonnes per trip, whereas the volume constrained trips in this vehicle category only averaged 9.96 tonnes per trip.

The results of the first six strategies are summarised in Table 102, below.

Table 102: Summary results of strategies 1 to 6

	Strategy 1 - LHV's allowed on all roads 77073 trip records				Strategy 2 - LHV's allowed on routes within 20km of a m'way - 20362 trip records				Strategy 3 - LHV's allowed on motorways only - 47241 trip records			
All values in millions	Trips	Kms	Cost	Tns CO2	Trips	Kms	Cost	Tns CO2	Trips	Kms	Cost	Tns CO2
Base case - current vehs	83	11,443	£7,772	11.5	83	11,443	£7,772	11.5	83	11,443	£7,772	11.5
Tractor, 16m semi	76	10,400	£7,138	10.6	81	11,137	£7,595	11.2	81	10,879	£7,454	10.2
Tractor/Interlinksemi/semi/44	73	9,798	£7,150	10.9	80	10,946	£7,582	11.3	79	10,536	£7,447	10.3
Rigid/A dolly/semi/44	73	9,770	£7,078	10.9	80	10,939	£7,565	11.3	79	10,523	£7,420	10.3
Tractor/Interlinksemi/semi/60	54	7,548	£5,926	9.5	76	10,444	£7,323	11.0	74	9,522	£6,949	9.4
Rigid/A dolly/semi/60	53	7,521	£6,038	10.5	75	10,438	£7,355	11.2	74	9,509	£7,017	9.8
Tractor, Semi+Csemi/82	39	5,545	£5,045	9.4	72	9,937	£7,119	11.0	70	8,531	£6,576	9.4
Percentage change over base case												
Tractor, 16m semi	-7.9%	-9.1%	-8.2%	-7.4%	-2.4%	-2.7%	-2.3%	-2.2%	-2.8%	-4.9%	-4.1%	-11.0%
Tractor/Interlinksemi/semi/44	-12.2%	-14.4%	-8.0%	-4.6%	-3.7%	-4.3%	-2.5%	-1.6%	-4.4%	-7.9%	-4.2%	-10.1%
Rigid/A dolly/semi/44	-12.5%	-14.6%	-8.9%	-4.8%	-3.8%	-4.4%	-2.7%	-1.7%	-4.5%	-8.0%	-4.5%	-10.2%
Tractor/Interlinksemi/semi/60	-35.4%	-34.0%	-23.7%	-17.2%	-9.0%	-8.7%	-5.8%	-4.4%	-10.4%	-16.8%	-10.6%	-17.6%
Rigid/A dolly/semi/60	-35.6%	-34.3%	-22.3%	-8.4%	-9.1%	-8.8%	-5.4%	-2.1%	-10.4%	-16.9%	-9.7%	-14.2%
Tractor, Semi+Csemi/82	-52.9%	-51.5%	-35.1%	-17.8%	-13.5%	-13.2%	-8.4%	-4.4%	-15.7%	-25.4%	-15.4%	-17.7%

	Strategy 4 - LHV's within 20km of a m'way or dual carr. - 47240 trip records				Strategy 5 - LHV's allowed on m'ways, dual carr. & primary - 24650 trip records			
All values in millions	Trips	Kms	Cost	Tns CO2	Trips	Kms	Cost	Tns CO2
Base case - current vehs	83	11,443	£7,772	11.5	83	11,443	£7,772	11.5
Tractor, 16m semi	78	10,546	£7,231	10.7	81	11,146	£7,592	11.2
Tractor/Interlinksemi/semi/44	76	10,011	£7,222	11.0	80	10,979	£7,602	11.3
Rigid/A dolly/semi/44	76	9,988	£7,166	11.0	80	10,970	£7,580	11.3
Tractor/Interlinksemi/semi/60	66	8,326	£6,324	9.9	74	10,291	£7,227	10.9
Rigid/A dolly/semi/60	66	8,305	£6,420	10.7	74	10,283	£7,259	11.2
Tractor, Semi+Csemi/82	57	6,709	£5,642	9.9	69	9,704	£6,966	10.9
Percentage change over base case								
Tractor, 16m semi	-5.6%	-7.8%	-7.0%	-6.4%	-2.4%	-2.6%	-2.3%	-2.1%
Tractor/Interlinksemi/semi/44	-8.8%	-12.5%	-7.1%	-4.4%	-3.7%	-4.1%	-2.2%	-1.2%
Rigid/A dolly/semi/44	-8.9%	-12.7%	-7.8%	-4.5%	-3.8%	-4.1%	-2.5%	-1.2%
Tractor/Interlinksemi/semi/60	-20.7%	-27.2%	-18.6%	-13.8%	-11.4%	-10.1%	-7.0%	-5.1%
Rigid/A dolly/semi/60	-20.9%	-27.4%	-17.4%	-6.7%	-11.4%	-10.1%	-6.6%	-2.5%
Tractor, Semi+Csemi/82	-31.4%	-41.4%	-27.4%	-14.0%	-17.0%	-15.2%	-10.4%	-5.3%

These results show the effect of possibly transferring up to 100% of trips from current vehicles to the different types of LHV. Not all trips will be able to be transferred because, for instance, if the LHV type being considered is limited to 44 tonnes, then any weight constrained trips will not be considered for transfer to the LHV.

For each of the strategies the number of trips, kilometres travelled, cost and tonnes of CO_2, all expressed in millions, has been calculated. The base case result is shown and then the results for each of the 6 LHV types, together with a table showing the percentage change over the base case. The results for the LHV options shown in Table 102 include all trips by LHVs and any trips that could not be transferred to the LHV and continued to be undertaken by the current vehicle. An analysis of strategy 1 showed that there is a strong linear relationship between the cost, distance and CO_2 emissions against the number of trips for the different percentage take up values used. Analysis of the different random selections of trips at uptake rates of less than 100% resulted in a standard deviation of less than 1% showing that random selection was a robust method. An example of the linear relationship between uptake rate and effect is shown in the graph below.

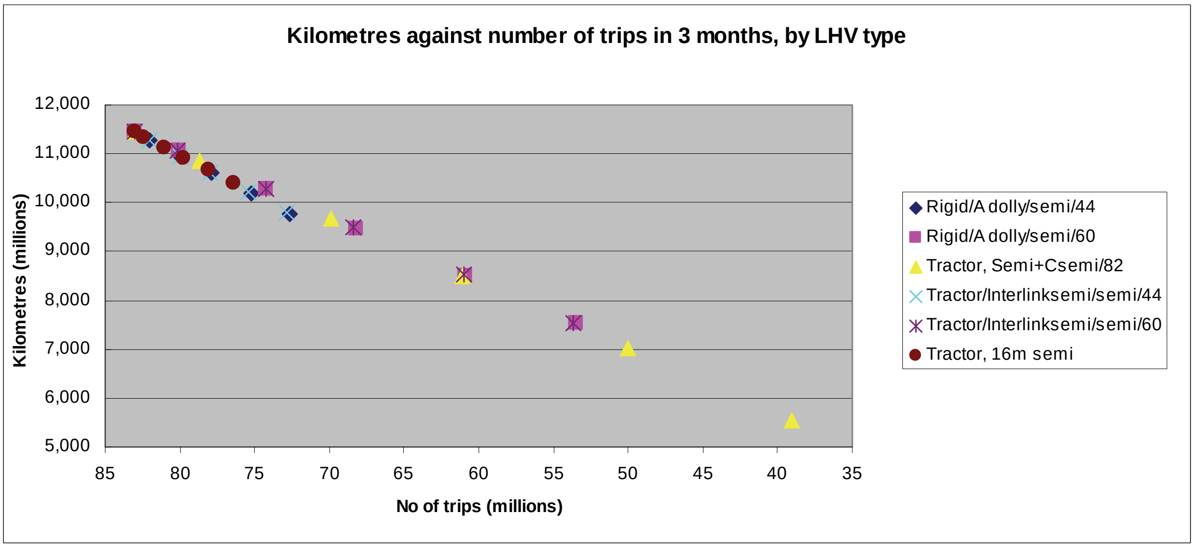

Figure 90: Plot of distance travelled against number of trips for a range of LHV types for 5 different percentage uptake values

Using strategy 1 as an example in which LHV's might be allowed on all roads, percentage values representing possible LHV uptake values of 10%, 30%, 50%, 75% and 100% were modelled for each of the six LHV types. The graph clearly shows the linear relationship between distance travelled and the number of trips. This relationship was also noted on other combinations of cost and CO2 emissions against the number of trips.

Consequently the results shown in Table 102, Table 103, and Table 22 relate to the maximum possible transfer of trips from the current vehicles to LHV's. If alternative percentages are to be considered then the values can be linearly interpolated between the maximum values and the values based on the original CSRGT sample.

Each of the strategies clearly show a reduction in trips, distance, cost and emissions if an LHV is used compared to the current vehicle. The greatest change would be expected if 34m, 82 tonne C-train LHV's were to be allowed on all roads (strategy 1), with a 53% reduction in trips, 52% reduction in distance, 35% reduction in cost and 18% reduction in CO_2 emissions. The smallest change in this strategy is with the 16m semi trailer, but this still shows some significant reductions of between 8% and 9%.

In strategy 2 only 20,362 of the 77,073 trip records satisfy the route limitations defined. There are still reductions in the four metrics, but less so. The CO_2 emissions for strategy 3 show a greater reduction, for the number of trips considered, in comparison to other strategies. The reason for this is that in this strategy LHV's are only allowed on motorways, in which case an improved level of fuel consumption is likely from these vehicles compared to the other strategies. The current vehicles serving the motorway coupling / decoupling points retain the average fuel consumption used in the other strategies.

The general outcome from the first five strategies clearly show that the more roads available to LHV's, the greater the possible reductions in trips, distance, cost and CO_2, over the base case. It is also clear that the two LHV combinations which retain the 44 tonne weight limit and the 16m semi trailer show less percentage reductions than the other LHV types because there are less trips for which these LHV's can be used.

For strategy 6, only 3,170 recorded trips in the CSRGT database fit the requirement of serving a port with ISO containers, equivalent to 1.3% of all of the recorded trips in the selected years and 4.1% of those trips satisfying the criteria for strategy 1. However, the different loading characteristics of vehicles used in this sector means that the reduction in trips that LHVs could offer differs from that when all sectors are considered meaning that it is not valid to say that because the port vehicles represent 4.1% of trips, excluding them would reduce the changes that LHVs produce by 4.1%. As an example, strategy 1 showed that replacing current vehicles with 25.25m B-doubles at 60 tonnes GVW and allowing them access to all roads would reduce the total kms travelled in the sample by 3.895 million. Applying the same criteria only to the port trips shows that the same vehicle would reduce the port kms by 167 million. Thus, prohibiting LHVs on such port traffic would reduce the changes exhibited in strategy 1 by 4.3%. Although such a move would reduce the benefits of consolidating goods transported by road it would prevent modal shift in the port sector, which may mean that the overall net effect is better. This concept has been evaluated further in the parametric cost model where mode shift has been accounted for.

Of the 77,073 trip records, 12,156 trips fit the limited goods group and mode of appearance requirements of strategy 7. In the base case, 12.7 million trips were made, travelling 2.07 billion kilometres at a cost of £1.4 billion and emitting 2.1 million tonnes of CO_2.The results of strategies 1 to 5 for this subset are shown in the table below:

Table 103: Summary of results for strategy 7

	Strategy 1 - LHV's allowed on all roads				Strategy 2 - LHV's allowed on routes within 20km of a m'way				Strategy 3 - LHV's allowed on motorways only			
All values in millions	**Trips**	**Kms**	**Cost**	**Tns CO2**	**Trips**	**Kms**	**Cost**	**Tns CO2**	**Trips**	**Kms**	**Cost**	**Tns CO2**
Base case - current vehs	12.6	2,069	£1,406	2.1	12.6	2,069	£1,406	2.1	12.6	2,069	£1,406	2.1
Tractor, 16m semi	11.1	1,808	£1,244	1.9	12.1	1,989	£1,357	2.0	12.0	1,924	£1,322	1.8
Tractor/Interlinksemi/semi/44	10.1	1,641	£1,221	1.9	11.8	1,935	£1,348	2.0	11.7	1,827	£1,308	1.8
Rigid/A dolly/semi/44	10.1	1,637	£1,207	1.9	11.8	1,933	£1,344	2.0	11.7	1,825	£1,303	1.8
Tractor/Interlinksemi/semi/60	8.3	1,356	£1,062	1.7	11.3	1,857	£1,307	2.0	11.1	1,680	£1,235	1.7
Rigid/A dolly/semi/60	8.2	1,353	£1,084	1.9	11.3	1,856	£1,315	2.0	11.1	1,678	£1,249	1.8
Tractor, Semi+Csemi/82	6.1	999	£916	1.7	10.7	1,752	£1,268	2.0	10.3	1,486	£1,166	1.7
Percentage change over base case												
Tractor, 16m semi	-12.4%	-12.6%	-11.6%	-10.6%	-3.8%	-3.9%	-3.5%	-3.3%	-4.5%	-7.0%	-6.0%	-14.7%
Tractor/Interlinksemi/semi/44	-19.7%	-20.7%	-13.2%	-9.1%	-6.2%	-6.5%	-4.1%	-3.1%	-7.4%	-11.7%	-7.0%	-14.3%
Rigid/A dolly/semi/44	-20.0%	-20.9%	-14.2%	-9.3%	-6.3%	-6.6%	-4.4%	-3.1%	-7.5%	-11.8%	-7.4%	-14.3%
Tractor/Interlinksemi/semi/60	-34.5%	-34.5%	-24.5%	-18.0%	-10.3%	-10.3%	-7.0%	-5.4%	-12.3%	-18.8%	-12.2%	-19.8%
Rigid/A dolly/semi/60	-34.6%	-34.6%	-22.9%	-8.8%	-10.4%	-10.3%	-6.5%	-2.7%	-12.4%	-18.9%	-11.2%	-16.0%
Tractor, Semi+Csemi/82	-51.8%	-51.7%	-34.9%	-16.9%	-15.4%	-15.3%	-9.9%	-5.0%	-18.5%	-28.2%	-17.1%	-19.3%

	Strategy 4 - LHV's within 20km of a m'way or dual carr.				Strategy 5 - LHV's allowed on m'ways, dual carr. & primary			
All values in millions	**Trips**	**Kms**	**Cost**	**Tns CO2**	**Trips**	**Kms**	**Cost**	**Tns CO2**
Base case - current vehs	12.6	2,069	£1,406	2.1	12.6	2,069	£1,406	2.1
Tractor, 16m semi	11.5	1,841	£1,266	1.9	12.1	1,991	£1,357	2.0
Tractor/Interlinksemi/semi/44	10.7	1,691	£1,242	1.9	11.8	1,943	£1,352	2.0
Rigid/A dolly/semi/44	10.7	1,687	£1,231	1.9	11.8	1,942	£1,348	2.0
Tractor/Interlinksemi/semi/60	9.5	1,455	£1,115	1.8	11.2	1,855	£1,302	2.0
Rigid/A dolly/semi/60	9.5	1,452	£1,135	1.9	11.2	1,854	£1,308	2.0
Tractor, Semi+Csemi/82	8.0	1,149	£994	1.8	10.5	1,747	£1,257	2.0
Percentage change over base case								
Tractor, 16m semi	-9.0%	-11.0%	-9.9%	-9.3%	-3.9%	-3.8%	-3.5%	-3.2%
Tractor/Interlinksemi/semi/44	-14.8%	-18.3%	-11.7%	-8.4%	-6.2%	-6.1%	-3.8%	-2.6%
Rigid/A dolly/semi/44	-15.0%	-18.5%	-12.5%	-8.5%	-6.3%	-6.2%	-4.2%	-2.6%
Tractor/Interlinksemi/semi/60	-24.6%	-29.7%	-20.7%	-15.5%	-11.0%	-10.4%	-7.4%	-5.5%
Rigid/A dolly/semi/60	-24.8%	-29.8%	-19.3%	-7.6%	-11.1%	-10.4%	-7.0%	-2.7%
Tractor, Semi+Csemi/82	-36.9%	-44.5%	-29.3%	-14.5%	-16.6%	-15.6%	-10.6%	-5.2%

This subset represents 15.8% of all trip records, 15% of trips but 18% of kilometres travelled, cost and CO_2 emissions. These LHV percentage reductions over the base case are very similar to those estimated for the first five strategies which cover all commodity groups and modes of appearance.

This analysis has used a subset of CSRGT data from 2004/5. Some data in the trips were incomplete and it is possible that in the last two years the profile of this data may have changed. For instance only 0.2% (157) of the trips were shown as using a draw bar trailer, and 1.8% (1,445) of the trips were shown as using double deck vehicles, which differs notably from the aggregate CSRGT data used elsewhere in this report. The reason for this was that for the majority of the trips the fields used to indicate these types were empty. Over the last two years there has been increasing use of double deck vehicles and, with increasing use of offshore sourcing, the trip profile could also have changed to more frequent use of container movements from ports. The cost and operating characteristics represent typical values for the different vehicle types, and the capital costs of the LHV options have been realistically estimated. The percentage differences between the base case and LHV options should therefore be considered comparable. The routes for each of the trips were generated using a road network from 2004 and were based on quickest time. There is a possibility that new roads will have been added or existing roads upgraded in the intervening 3 year period, which may cause changes to the timings and routes travelled. Inevitably there are many different routes that can be taken to get from an origin to a destination. From a sample of the routes generated, these appeared realistic and, because the routes are constant for each of the strategies, could be considered comparable with the base case. It could be argued that if LHV's were limited to selected roads, as in many of the strategies, alternative, 'LHV - specific' routes would be found. It is not possible to model these route options, though it is unlikely that their inclusion would affect the overall findings.

G.4 Discussion

The analysis indicates that the proportion of trips that actually could be replaced by an LHV is relatively low, thus supporting the views of the industry in the fact finding exercise that LHVs, if permitted, would be utilised in a few specific applications. In fact, the analysis has suggested that even if no route restrictions were imposed, only in the region of a third of all trips carried out by current vehicles >32 tonnes could be suitable for LHVs. If LHVs were to be only permitted on motorways, dual carriageways and primary routes, 10% of all trips would be suitable for LHVs, and if LHVs were to be prevented from carrying freight containers from and to ports, this would fall to less than 9% - approximately 21,500 trips in total.

The analysis of safety affects suggests that, if LHVs were to be permitted, restricting their use only to certain routes would help to mitigate the risks. Stakeholders involved in the information gathering exercise widely acknowledged the validity of this analysis and also identified that practical operational constraints would also restrict the routes, origins and destinations that could be used by such vehicles. Table 22, below, shows the effects of different LHV types on reductions in vehicle travel, and how the magnitude of those reductions decrease when different road restrictions are imposed. For the purpose of this analysis it was assumed that all trips would be point to point and there would be no coupling or de-coupling of the combinations.

Table 104: Relative impacts of different route restrictions

Vehicle Case	Gross Vehicle Weight (tonnes) and number of axles	% reduction in vehicle travel compared with the original CSRGT trip data (assuming maximum number of candidate trips taken-up)		
		All roads	Motorway and dual carriageway	Motorway
3 (longer semi-trailer)	44 tonnes / 6 axles	9%	8%	3%
4 (B-double)	44 tonnes / 8 axles	14%	13%	4%
5 (rigid + semi-trailer)	44 tonnes / 8 axles	15%	13%	4%
6 (B-double)	60 tonnes / 8 axles	34%	27%	9%
7 (rigid + semi-trailer)	60 tonnes / 8 axles	34%	27%	9%
8 (C-train)	82 tonnes / 11 axles	52%	41%	13%

Unsurprisingly, the modelling indicated that the more roads available to LHVs, the greater the possible reductions in trips, travel, cost and CO_2. The greatest possible reductions for travel would be for 82-tonne LHVs allowed on all roads, with a 52% reduction in distance travelled assuming that all trips that could possibly be transferred to LHVs were actually transferred at the same percentage vehicle fill. The lowest impacts for this strategy were for the longer semi-trailer – the reductions were between 8% and 9%. Restricting LHVs to Motorways (and routes within 20km of Motorways) would reduce these figures by 65%-75%. Restricting them to motorways and dual carriageways only would be a much smaller limitation of 11%-21%.

If the possibility of allowing coupling and decoupling at motorway exits is considered then, theoretically at least, all trips that use the motorway for at least 20km can transfer to LHV. However, because only part of each trip would be carried out by LHVs, the benefits are eroded such that there is a large increase in the benefits associated with motorway only restrictions but the benefit remains considerably lower than the option of permitting travel on motorways and dual carriageways.

However, the fact finding exercise with infrastructure owners has suggested that it may be very difficult to provide the facilities required for such coupling and decoupling. Assessing the feasibility of building such facilities and identifying the best locations for them would require considerable further research. In order to provide initial information that could be of use in such further research the modelling of the CSRGT trip data has been used to show the motorway nodes that had most HGV journeys passing through them. The results are shown in Table 105, below.

Table 105: Location of the most frequently used motorway nodes and the annual number of trips passing through them

Node	Location	No of trips
6930	Thurrock M25	965,364
4139	Tamworth M42	786,552
3833	Birmingham A38(M)	778,319
1915	Bristol M32	771,836
7533	Leeds A58(M)	763,736
4739	Daventry M1	625,294
3189	Rochdale A627(M)	612,615
555	Glasgow M8	576,370
919	Motherwell M74	567,062
4734	Milton Keynes M1	554,348
1907	Weston Super Mare M5	543,905
2743	Warrington M62	531,996
2746	Newton le Willows M6	498,781
4156	Dudley M5	475,220
3400	Wakefield M1	473,232
2697	Liverpool M62	469,404
7773	Lancaster M6	462,183
4596	Rugby M45	452,976
7795	Washington A1(M)	427,442
6257	Eastleigh M3	427,365

Appendix H. Costs and benefits of LHVs

It can be seen from the evidence presented in this report that there are a large number of variables that could affect the costs and benefits if the use of LHVs were to be permitted in the UK. Wherever possible these effects have been enumerated and incorporated as inputs to a parametric model of the total on-going costs (i.e. both the internal operating costs and those of externalities such as road casualties and vehicle emissions) of domestic freight transported by rail and by articulated heavy goods vehicles. This enabled the costs to be evaluated for each of the vehicle types and scenarios described above given a range of different input variables. In addition to this, there are a range of risk or opportunity factors to which it has not been possible to assign monetary values. These are also highlighted in this appendix. Almost all of the factors that could not be quantified financially represented capital investments that might be required to resolve potential problems with the widespread implementation of LHVs. Thus the net effects on the on-going transport costs can be considered the "benefits" of permitting LHVs, subject to the risk of a small number of unquantified effects, while the capital investments that may be required can be considered as the costs of such a move. The fact that most of the capital investments required could not be quantified accurately within the scope of this work has meant that it was not possible to calculate reliable benefit to cost ratios and the final conclusions are based on subjective judgements as to whether or not the calculated benefits are likely to exceed the unquantified costs.

H.1 Effects which could not be fully costed within the scope of this project

During the analysis a number of potential effects were identified, which could not be evaluated financially within the constraints of this project. The main such effects are listed below:

- **Bridge loading:** Based upon a conservative analysis, a 34 metre vehicle at 82 tonnes GVW was found to exceed the HA bridge design loads, both vertical and longitudinal (braking) loads, for standard vehicles for certain mid-range spans of bridge that were not designed to accommodate Abnormal Indivisible Load vehicles. This presents a higher risk of causing wear and damage to a relatively small proportion of bridges on the trunk road network. A number of trunk road bridges may, therefore, require strengthening or increased maintenance if such vehicles were permitted. Assigning a cost to this activity would be a major exercise that was beyond the scope of this project. For the other vehicle types assessed loads were below the HA design loads and were, therefore, not expected to cause any additional problems for bridges conforming to the latest standards. However, there may be a large number of bridges in local authority control that do not meet those standards and a comprehensive review of bridge standards may be required if any LHVs were permitted where an increased GVW would lead to a greater load per metre of bridge. It may also be possible that many of these bridges would already be inadequate for existing 44 tonne vehicles and may, therefore, already be appropriately restricted to heavy traffic and appropriately signed. These issues have not been assigned a cost in the parametric model.
- **Collisions with bridge supports:** Vehicle types with an increased GVW would apply additional forces to bridge structures if they collided with them. However, the minimum standards to which bridge supports and their protective standards are designed contain lower force requirements than would be applied by current articulated vehicles travelling at 56 mile/h. If structures are built to just pass these minimum requirements then it is possible that permitting LHVs at higher maximum weights would not represent an additional risk. This issue would require further investigation, likely to include physical testing, if higher maximum weight vehicles were to be considered. The cost of such an investigation and, if applicable, any remedial work required has not been included in the cost model.
- **The feasibility of providing additional parking and/or interchange points for LHVs:** There is a risk that providing such improvements may be difficult, even if the financial investment were made available, because existing MSAs are often not owned by Government, there may be little incentive for private MSAs to invest in facilities for trucks, there is a

scarcity of available land in areas likely to require facilities, and planning permission would be required. These problems are not considered likely to be insurmountable if Government policy was to develop such facilities for the benefit of the economy but will require further investigation if the possibility of permitting LHVs in excess of 18.75m is to be investigated further. It is considered that 18.75m articulated vehicles would not be substantially affected by this risk.

- **The interaction of UK regulations with EU Directives and the effects on the HGV fleet:** The options assessed in the parametric cost model were based on the assumption that the UK regulations could be amended independently. However, if UK regulations were amended without suitable amendments of European regulations then some changes could potentially result in even larger vehicles becoming permissible under Council Directive 96/53. This has not been quantified financially.
- **Undermining the rail resource base:** If the introduction of LHVs resulted in a substantial reduction in rail traffic then this could undermine the financial viability of some rail services such that they would have to be withdrawn completely. This could result in further mode shift, further undermining the resource base and so on. It has not been possible to fully assess the potential implications and the cost of such a process within the scope of this project.
- **Government investment in rail infrastructure:** The Government announced in October 2007 that it will provide capital investment of approximately £150million from the Transport Innovation Fund to improve rail capacity through rail infrastructure improvements. However, this announcement was made after the cost benefit analysis had been completed and the cost of the investment could not be included in the model.
- **Port congestion:** Predictions of the use of the UKs sea ports has suggested that, in the absence of capacity restrictions, road freight traffic from UK ports will increase by 106% by 2020. Stakeholders report that the roads in and around the UKs main ports are already very congested. It is possible, therefore, that extensive investment in the road infrastructure around ports may be required to ease these congestion problems if other solutions could not be developed. If capacity limited growth that may have adverse economic effects. These capacity constraints may act to limit the predicted mode shift because of the need for all available capacity. It has not been possible to fully assess and cost these factors within the scope of this project.

H.2 Parametric cost model

H.2.1 Overview

The parametric model has been developed as a complex spreadsheet model. It is based on predictions of annual freight traffic by road and rail and the following input information for each of the different vehicle types and transport modes (i.e. road and rail):

- Operational costs (see Table 18)
- Environmental costs (see Appendix C)
- Casualty costs (see Appendix B)
- Infrastructure costs (see Appendix D.3.2)
- Miscellaneous costs (e.g. admin/enforcement costs)
- Take-up rate (see Appendix F.16)
- Mode shift (see Appendix F.16)
- Induced demand (see Appendix F.16)

Information on each of these inputs was generated by the analyses described elsewhere in this report and the predictions of freight growth used were defined in section 3.4 of the main body of the report.

Each of these impacts can be assessed for different assumptions (e.g. euro emissions level, fuel cost, requirements for additional safety measures etc.). The impacts of these were then combined with estimates of key parameters such as take-up rate, mode shift, and route restrictions etc. to calculate total costs for each vehicle type, which, in turn were used to assess the options for different scenarios. The process is illustrated in Figure 91, Figure 92 and Figure 93, below.

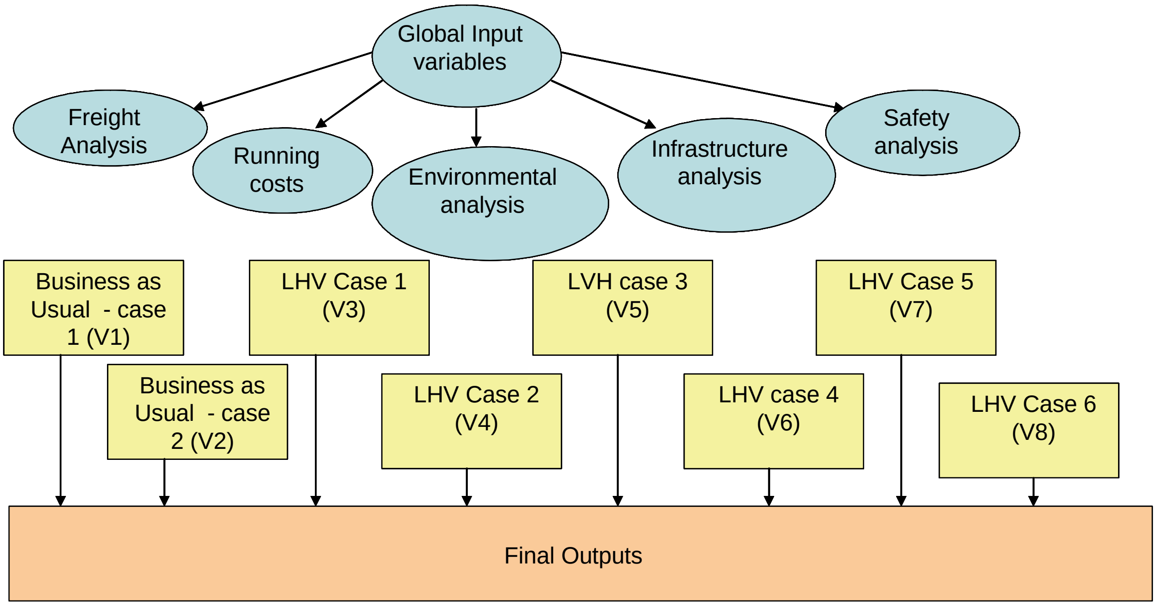

Figure 91. Overview of UK parametric cost model

Each of the modules that contain the analysis of specific impacts such as safety and infrastructure (blue backgrounds), feed into the each of the analyses of the baseline case(s) and the overall impact that each specific vehicle type would have on UK transport costs. A simplified example of the analyses for each vehicle type is illustrated in Figure 92, below.

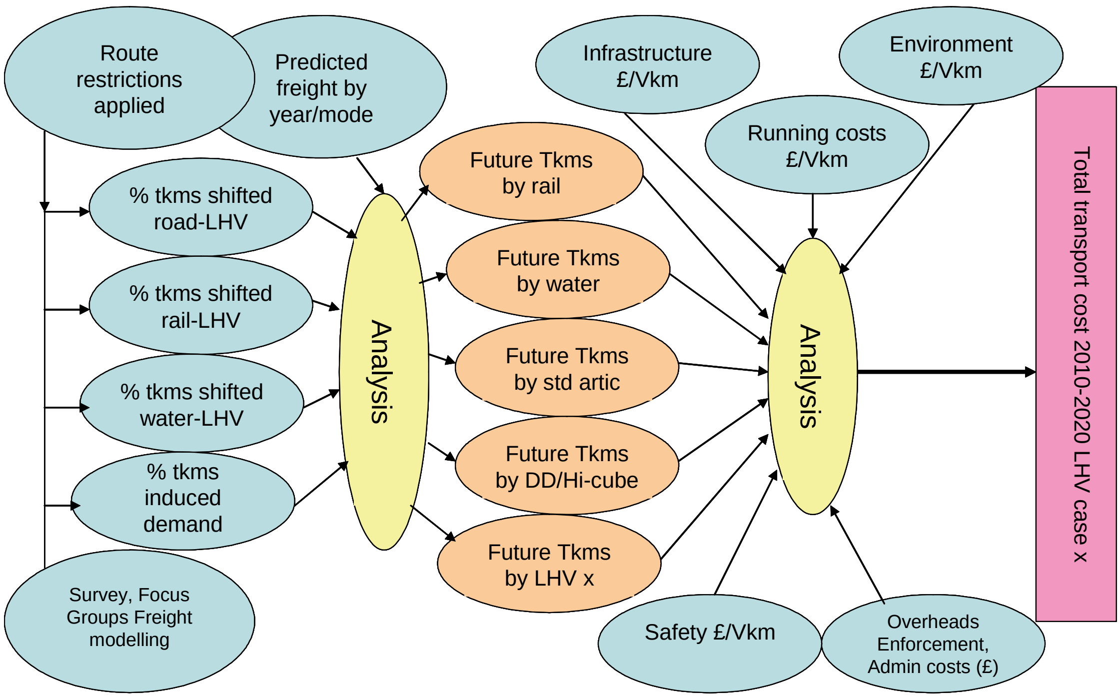

Figure 92. Simplified example of analysis of each vehicle type

The principle output of the analysis of each case is a total cost of UK freight transport for the years 2006-2020 but any of the main variables, such as number of fatalities or tonnes of CO_2, can be extracted. The scenarios were then evaluated by combining the results of the specific vehicle types correlating with each option, in the proportions that it would be expected that they would be used. A simple example is shown in Figure 93, below

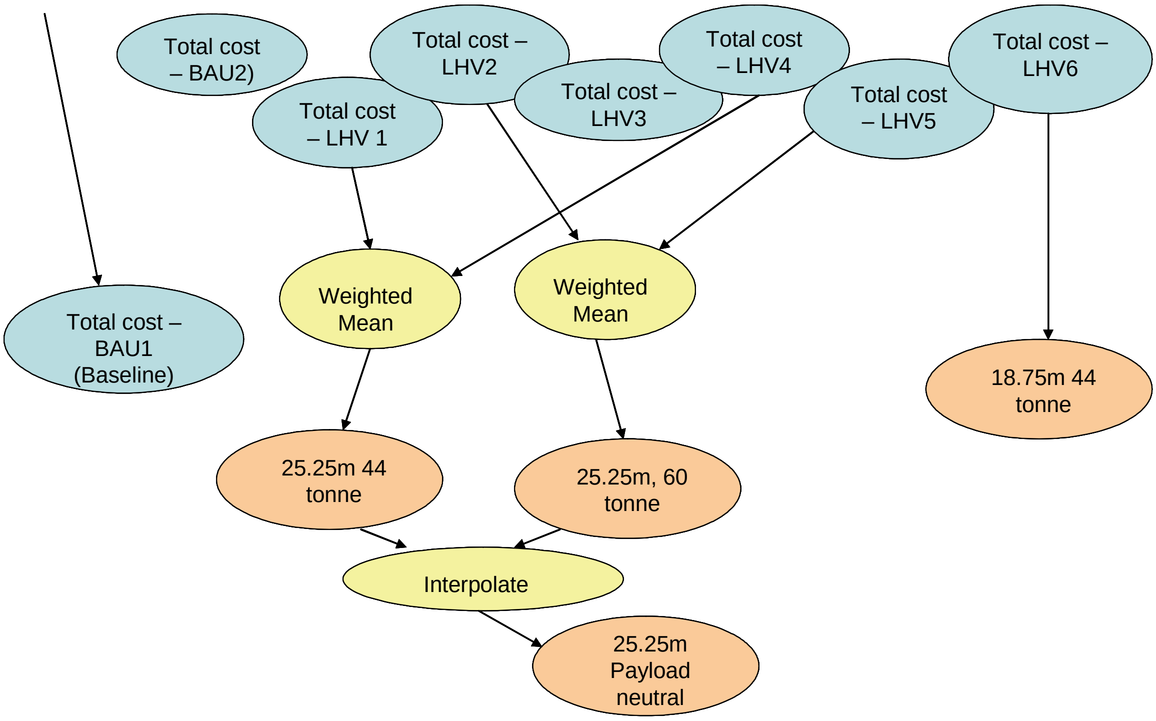

Figure 93. Example of conversion of vehicle based impacts to scenarios

Once the scenarios were evaluated, the results were analysed by subtracting key parameters in the baseline case from the same key parameters in the policy option under consideration. These included the total transport costs, the volume of traffic by heavy goods vehicles (vehicle kms), the tonnes of CO_2 emitted, and the number of fatalities from accidents involving heavy goods vehicles. Negative values represent a benefit and positive values represent a dis-benefit.

H.2.2 Results

An analysis of the sensitivity of the model has, perhaps unsurprisingly, supported the views of stakeholders that the costs and benefits are most sensitive to the input estimates of take up rate and mode shift. The impact analysis could not predict these inputs with certainty so the results have been expressed in terms of the effects if the take up rate and mode shift were at certain levels. This enables the potential effects of a decision to permit LHVs to be identified as well as the critical levels where benefits become disbenefits. The net effects are then identified for a range of combined inputs reflecting the judgements made on mode shift and take up on the basis of the analysis and the information gathered from stakeholders.

Factors such as the emissions level that engines are approved to (Euro 4 or 5 etc) and the price of diesel were found to have only a relatively small affect on the results, largely because the results were comparisons of scenarios that were all affected by such changes.

H.2.2.1 The effect of take up rate

In this section, the take up rate input has been considered in isolation in a manner intended to identify the maximum likely level of benefit that would be expected if LHVs were permitted and any negative factors could be controlled. It has been assumed that for each level, LHVs will be restricted to motorways and all rural “A” roads, with the exception of the longer semi-trailer. The reason for this exclusion was that, if permitted, there was little evidence identified to suggest that a longer semi-trailer should be restricted any more tightly than current vehicles, provided that it could meet the manoeuvrability criteria already in existence.

It has also been assumed in this section that LHVs are restricted to Euro 5 engines and the range of additional safety devices discussed in the report would become a requirement.

The take up rate was based on values categorised from very low to very high. However, there are fundamental factors affecting the likelihood of take-up rates for LHVs so, in order to provide a fair comparison of vehicles, the take up rates have not been applied uniformly to each vehicle type. For volume only increases, it has been assumed that such vehicles would only be adopted in sectors where volume constraints are common and, as such, it has been assumed that the take up of volume only increases would be only 55% of that of volume and weight increases. In addition to this, the longer semi-trailer was viewed less favourably than longer vehicles by industry stakeholders so it has been assumed that the take up of that vehicle will be only half of that of the 25.25m 44 tonne vehicle. The rates assumed are shown in Table 106, below. It should be noted that the “low” and “high” categories correspond to the best estimates of the actual likely take up proposed in F.16.1.

The model was based on a prediction that in the business as usual scenario the total quantity of goods moved by current articulated vehicles would be approximately 116 billion tonne kms in 2006 and approximately 121 billion tonne kms in 2020, giving an average per year of approximately 118 billion tonne kms per year. Thus if the take up rate of an LHV type was 10% then on average 11.8 billion tonne kms would be carried by the LHV.

Table 106. Take up rates assumed for sensitivity analysis

Scenario	Take up rate				
	Very low	Low	Medium	High	Very high
18.75m 44 tonnes	0.69%	1.38%	2.06%	2.75%	3.44%
18.75m Payload neutral	1.04%	2.07%	3.11%	4.14%	5.18%
25.25m 44 tonnes	1.38%	2.75%	4.13%	5.50%	6.88%
25.25m Payload neutral	1.76%	3.53%	5.29%	7.06%	8.82%
25.25 60 tonnes	2.50%	5.00%	7.50%	10.00%	12.50%
34m 63 tonnes	2.50%	5.00%	7.50%	10.00%	12.50%
34m 82 tonnes	2.50%	5.00%	7.50%	10.00%	12.50%

The total cost calculated by the parametric model includes the operation costs of vehicles and emissions for road and rail as well as the costs of road wear and accidents for the heavy vehicle fleet. Estimated additional costs representing greater administrative and enforcement efforts required for LHVs (>18.75m in length) over and above that normally required for standard HGVs have been added. Not all parameters were calculated for rigid HGVs and none were calculated for light vans. The absolute total value may, therefore, not be consistent with other attempts to calculate the total cost of freight transport. However, as a comparative tool, the findings are expected to be accurate. The effects of each LHV scenario, in comparison with the 1st baseline condition (mix of current road vehicle remaining static), is shown in Figure 94, below.

It can be seen that the effect for all LHVs is to reduce the total cost of transport and that the reduction increases linearly with increasing take-up. As would be expected the larger increases in capacity have the greatest potential cost reductions. The total magnitude of reduction is relatively small in percentage terms. However, it is important to note that the 4.67% cost reduction for the 34 m vehicle at 82 tonnes represents an annual cost reduction in the steady state period (i.e. once the haulage industry has fully adapted and vehicle mix has become constant) of almost £742million per year. Even the 0.03% reduction offered by the very low estimate of take-up for the longer semi-trailer represents approximately £5.25million per year reductions.

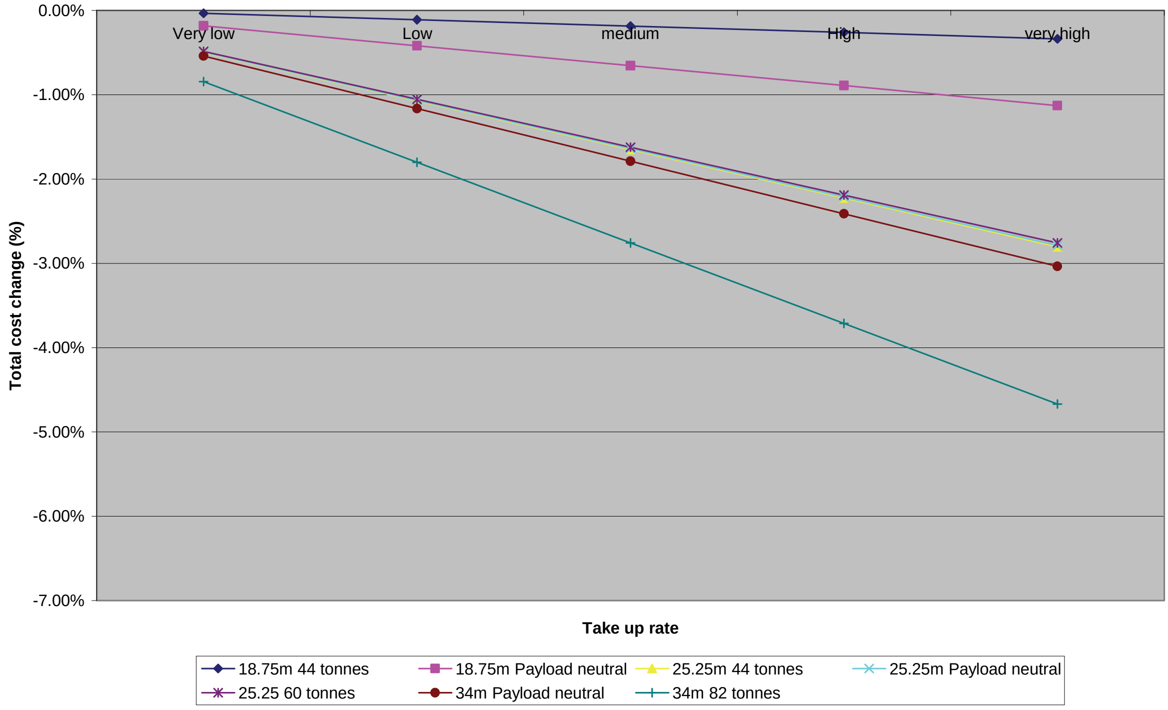

Figure 94. Effect of take-up rate of LHVs on total transport costs, assuming no mode shift or induced demand.

Although the total cost represents all of the main issues of economics, environment, safety and infrastructure using standard financial valuations, and is therefore a measure of the net effect of each of these, it is possible to consider each individually. For example, Figure 95, below, shows the effect on the number of fatalities in comparison with the business as usual scenario (fixed vehicle mix).

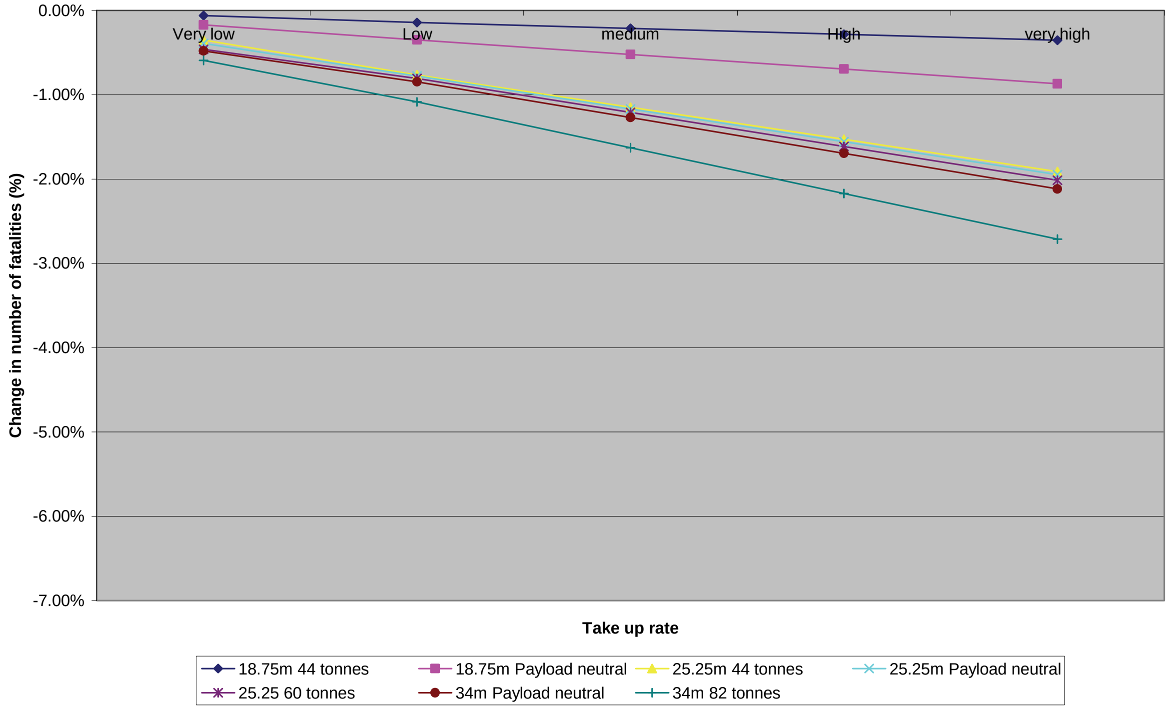

Figure 95. Effect of take up rate on accidents, assuming no mode shift or induced demand.

There is also a reduction in the number of accidents and fatalities, although the magnitude in percentage terms is less than for the total costs. Again, the percentages are small but represent fatality reductions of between one every 2.5 years and 16 per year, depending on the take-up rate and LHV scenario considered. The effect on the other key parameters such as vehicle kms driven and CO_2 emitted is very similar.

It is clear that, in the absence of adverse economic effects on modal split and freight demand, LHVs offer the potential to achieve substantial benefits for safety, the environment and, in particular, the economy.

H.2.2.2 The effect of modal shift from rail

In this section, the results from the analysis of take-up rate described above and the input quantifying mode shift from rail was varied within boundaries intended to represent the outer limits of what the preceding analyses suggested was feasible. The mode shift factors were expressed as a percentage of all rail tonne-kms that would be transferred to road and the entries tested are shown in Table 107, below. The total level of rail freight was predicted to be approximately 22 billion tonne kms in 2006 and 31 billion tonne kms in 2020 such that the average for the period assessed was approximately 26.5 billion tonne kms per year. Thus a mode shift of 10% equates on average to a transfer of 2.65 billion tonne kms per year. It should be noted that the low and high values correspond to the range of predicted effects proposed in F.16.3.5.

Table 107. Mode shift factors evaluated

Scenario	Mode shift from rail				
	Very low	Low	Medium	High	Very high
18.75m 44 tonnes	0.00%	0.25%	0.50%	0.75%	1.00%
18.75m Payload neutral	0.55%	1.59%	2.64%	3.68%	4.73%
25.25m 44 tonnes	1.00%	2.50%	4.00%	5.50%	7.00%
25.25m Payload neutral	1.69%	4.40%	7.11%	9.82%	12.53%
25.25 60 tonnes	3.00%	8.00%	13.00%	18.00%	23.00%
34m 63 tonnes	3.00%	8.00%	13.00%	18.00%	23.00%
34m 82 tonnes	3.00%	8.00%	13.00%	18.00%	23.00%

The logic behind the selection of these values was as follows:

- The low and high estimates of mode shift for the 18.75m 44 tonne, the 25.25m 44 tonne and all 60+ tonne scenarios are based directly on the analysis of mode shift factors described in section F.16.3.
- The very low, medium and very high estimates are based on linear extrapolation and interpolation of the low and high values.
- The 18.75m payload neutral option is an interpolation between the 18.75m 44 tonne and the 24.25m and the 25.25m payload neutral is an interpolation between the 44 tonne and 60 tonne versions of the same vehicle.
- The analysis in section F.16.3 suggested that LHV options without an increased payload capacity would not induce any mode shift from bulk rail.

The effect of these levels of mode shift on the tonnes of CO_2 emitted by freight transport (which was shown to be the parameter most sensitive to modal shift) are shown in Figure 96, below, based on the very high estimates of take-up rate as specified in Table 106.

It can be seen that the effect is always to increase the total amount of CO2 emitted but that the magnitude of the effect is quite different for different LHV scenarios. For the scenarios involving the longer semi-trailer the effect is small and the CO_2 emissions in this scenario remain less than in the baseline case. This is mainly because the mode shift estimates entered were low because there was no evidence found during the course of the project to suggest that this type of vehicle would cause mode shift. In actual fact with a high take-up rate of 3.44% a mode shift of approximately 4.5% would be required to produce a zero effect on CO_2 emissions. It is extremely unlikely that this level of mode shift would occur.

For the 25.25m and 34m scenarios at 60 tonnes, the CO_2 emissions are substantially affected by mode shift and show an adverse effect when the estimate of mode shift is"medium". The boundary condition for a high take-up rate of 12.5% for a 25.25m 60-tonne vehicle is that there is zero CO_2 effect when the mode shift reaches approximately 11%.

The 25.25m scenarios with lower maximum weights remain strongly affected by mode shift but do not reach adverse effects unless very high estimates are entered. This is because of the lower risk of mode shift with these types (no migration from bulk rail and only part of the deep sea container market vulnerable).

For the 34m scenarios at 82 tonnes, the CO_2 emissions are substantially affected by mode shift but the boundary condition is not reached within the range of inputs tested. In fact, with the very high take up rate estimate of 12.5% the mode shift would need to reach approximately 31% to produce a zero effect.

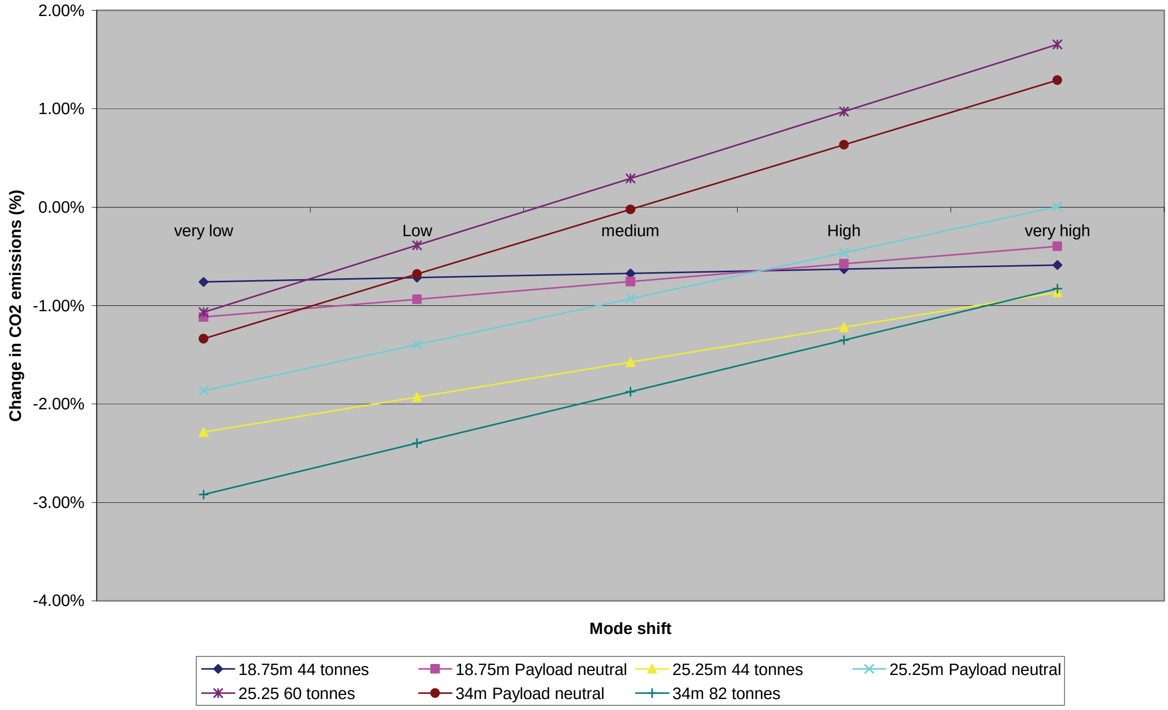

Figure 96. Effect of mode shift on CO_2 emitted assuming very high take-up and no induced demand

It should be noted that the main body of the analysis in this appendix uses mode shift estimates based on price elasticity values of 2 and 5. Freightliner had suggested an upper value of 6 should be used. If 6 was used the mode shift for a 60 tonne vehicle would have been approximately 21%. This falls within the range tested in the sensitivity analysis (between high and very high).

The emissions of CO_2 are particularly sensitive to mode shift because the emissions per tonne-km estimated for rail remains lower than even the most efficient LHV option assessed. However, the differentials vary for all of the various parameters so it is important to consider the net effects. This is shown in terms of the total transport costs in Figure 97, below.

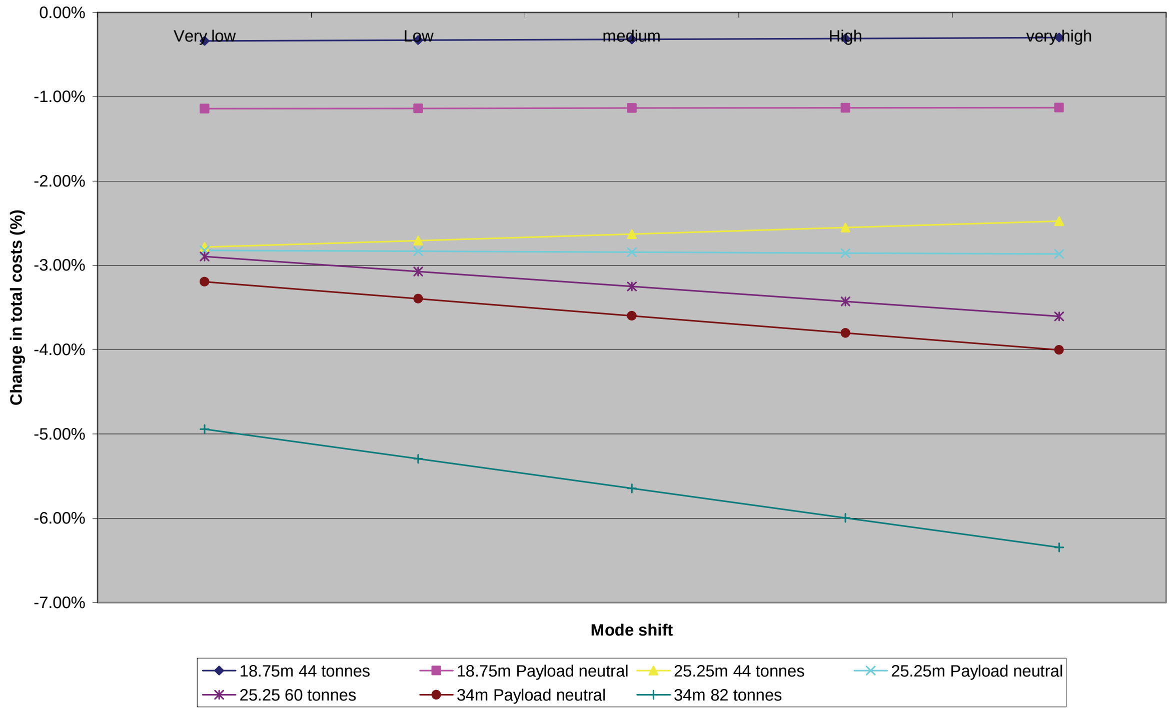

Figure 97. Effect of mode shift on total transport costs, assuming very high take-up and no induced demand

It can be seen that in all permutations assessed the total cost of the LHV scenarios is less than the baseline scenario.

The 18.75m options and the payload neutral version of the 25.25m vehicle remain almost unaffected by the estimates of mode shift assessed. For the 44 tonne version of the 25.25m scenario, modal shift reduces the magnitude of the cost reduction. However, within the assumption of very high take up, the modal shift would have to reach approximately 55% before the effect on total cost was zero.

For the 60 tonne 25.25m scenario and both 34m scenarios increasing mode shift actually increases the magnitude of the cost reduction. This is because of the greater differential in terms of operating cost. This means that when the various parameters are monetised using standard valuations then the objective analysis shows that the economic benefits outweigh the environmental and safety disbenefits, providing there is no induced demand, even if all rail freight was transferred to these vehicles. However, it should be noted that the heavier vehicles also involve a greater number of risks that could not be quantified financially (see section H.1).

The trends and directions shown in the analysis above will remain valid for different estimates of take up rate but the boundary values where effects become zero will change. The boundary values of mode shift assuming a very low take-up rate are shown in Table 108, below.

Table 108. Boundary values of mode shift assuming a very low take-up rate and no induced demand.

Vehicle length	**Mode shift (%)**	
	CO_2	**Total cost**
18.75m	0.9%	0.8%
25.25m 44 tonnes	2.15%	10.2%
25.25m 60 tonnes	2.2%	N/A*
34m 82 tonnes	6.2%	N/A*

* indicates boundary condition never reached i.e. there will always be an overall cost reduction irrespective of how much mode shift occurs

It can be assumed that mode shift factors below those for the CO_2 column in Table 108 will definitely mean that there are benefits in all key factors if LHVs were permitted. This would be the case even if the take-up of the vehicles were lower than has been suggested on the basis of other elements of work. For the 18.75m and 25.25m vehicles at 44 tonnes or payload neutral then values below those shown in the total cost column of the table will mean that the benefits outweigh the disbenefits. For the 60 tonne and bigger vehicles then the benefits are likely to outweigh the disbenefits at all levels of mode shift, at least for those factors that could be quantified in monetary terms.

H.2.2.3 Traffic generation (induced demand)

The analysis of traffic generation has been based on factors of price elasticity of demand. If the price elasticity of demand was 1 then a 10% reduction in the price of transport would lead to a 10% increase in the volume transported. However, it is important to note that the price elasticity of demand factor has only been applied to the quantity of goods moved by the LHV scenario under consideration because it is only the LHV under consideration that will offer a reduction in price and, as discussed elsewhere, a variety of other factors will limit the flows on which it can be used.

The effect in terms of trends and directions will be the same for each LHV scenario. This analysis has, therefore, simply assessed the price elasticity factor required to produce a zero effect on each of the key parameters, assuming zero mode shift. The factors required are shown in Table 109, below.

Table 109. Boundary values of price elasticity value assuming zero mode shift.

Scenario	Vehicle kms	CO_2	Fatalities	Total Cost
18.75m 44 tonnes	1.30	1.30	1.30	0.63
25.25m 44 tonnes	2.0	1.09	2.16	1.65
25.25m 60 tonnes	2.39	0.57	2.35	1.61
34m 82 tonnes	3.19	0.91	2.39	2.29

All of these values are substantially higher than would be expected based on the evidence from previous weight increases and the views of the freight industry. The overall conclusions are, therefore, unlikely to be particularly sensitive to any realistic estimate of price elasticity of demand.

H.2.2.4 Estimating the likely effects

It has not been possible to produce definitive estimates of the key input parameters (take-up rate and mode shift) with scientific confidence because there is very little empirical data to use and the wide range of possibilities under consideration has meant that the freight industry could not provide a comprehensive and uniform view of the likely usage of LHVs.

A range of plausible values has been defined based on the evidence available, which includes literature from other countries, the views of stakeholders, documentary evidence of analyses submitted directly to the project team from stakeholders and analysis of existing freight and econometric data. These values have been combined into two cases intended to indicate a plausible range of the effects that could occur if LHVs were to be permitted. The key input variables used in these cases are shown below:

• Case 1	• Case 2
• **Average load:** equal load factors (%) as current articulated vehicles	• **Average load:** equal load factors (%) as current articulated vehicles
• **Take-up rate**: Low end of range defined in F.16.1	• **Take-up rate**: High end of range defined in F.16.1
• **Mode shift:** Low end of range defined in F.16.3	• **Mode shift:** High end of range defined in F.16.3
• **Traffic generation:** Low end of range defined in F.16.4	• **Traffic generation:** High end of range defined in F.16.4
• **Accidents:** Assumed additional countermeasures are mandatory (B.9, Table 67)	• **Accidents:** Assumed no additional countermeasures fitted (B.9, Table 65)

The main results from the analysis of case 1 are shown in Table 110, below.

Table 110. Main results of case 1

Scenario	Total cost change		Total fatality change		Total CO2 change		Total vkms change	
	£	%	Number	%	Tonnes	%	BVKMs	%
18.75m 44t	-£23,218,367	-0.15%	-1	-0.17%	-44,557	-0.37%	-0.06	-0.20%
18.75m Payload neutral (c.46t)	-£55,509,936	-0.35%	-1	-0.19%	-22,493	-0.19%	-0.06	-0.21%
25.25m 44t	-£74,396,045	-0.47%	-1	-0.17%	3,586	0.03%	-0.05	-0.16%
25.25m Payload neutral (c.50t)	-£123,128,880	-0.77%	-1	-0.22%	23,710	0.20%	-0.07	-0.24%
25.25 60t	-£215,420,708	-1.36%	-2	-0.33%	61,820	0.52%	-0.11	-0.39%
34m Payload neutral (c.63t)	-£239,737,293	-1.51%	-2	-0.38%	45,401	0.38%	-0.14	-0.48%
34m 82t	-£382,597,225	-2.41%	-4	-0.70%	-51,059	-0.43%	-0.30	-1.04%

It can be seen that in terms of the net ongoing effect (i.e total change in internal and external costs excluding any initial capital investments in infrastructure that may be required), the benefits of permitting LHVs outweigh the disbenefits in all scenarios with a reduction in the internal and external costs of transport each year of between approximately £23million and £383million. In general, the effects are greater with vehicles of greater capacity and there are small beneficial effects on the number of fatalities and modest decreases in the total distance driven by heavy goods vehicles (note that these are in comparison to the baseline condition – growth in freight will mean that even with the 34m 82 tonne scenario freight traffic will be greater in 2020 than the actual traffic in 2006). However, for the 25.25m scenarios and the lower payload version of the 34 m scenario there is an adverse effect on the emissions, as represented by increase in CO_2, although for the 25.25m combination at 44 tonnes this is marginal. This is a function of the particular take up rate, mode shift, average load, unladen weight and emissions for these particular vehicle combinations.

The main results from the analysis of case 2 are shown in Table 111, below.

Table 111. Main results of case 2

Scenario	Total cost change		Total fatality		Total CO2 change		Total vkms change	
	£	%	Number	%	Tonnes	%	BVKMs	%
18.75m 44t	-£37,165,147	-0.23%	-1	-0.25%	-65,778	-0.55%	-0.08	-0.29%
18.75m Payload neutral (c.46t)	-£106,576,332	-0.67%	-2	-0.29%	-21,381	-0.18%	-0.09	-0.32%
25.25m 44t	-£149,692,794	-0.94%	-2	-0.27%	24,375	0.20%	-0.07	-0.24%
25.25m Payload neutral (c.50t)	-£251,924,209	-1.59%	-2	-0.36%	71,586	0.60%	-0.11	-0.37%
25.25 60t	-£445,533,386	-2.80%	-3	-0.52%	160,995	1.35%	-0.18	-0.62%
34m Payload neutral (c.63t)	-£495,647,339	-3.12%	-4	-0.63%	127,343	1.07%	-0.24	-0.82%
34m 82t	-£790,066,816	-4.97%	-8	-1.30%	-70,363	-0.59%	-0.58	-1.98%

It can be seen that for all scenarios the net ongoing effect is a greater reduction in total internal/external costs. For those scenarios that showed an environmental benefit in case 1, the environmental benefit is similar or greater with the input assumptions of case 2. For those with an adverse environmental effect in case 1, that adverse effect is greater in case 2.

However, it is important to note that there is a substantial inconsistency in the way that estimates of take up rate and mode shift have been defined and that this could potentially have a strong effect on the conclusions from the model. The analysis of CSRGT trip data identified an upper boundary for the level of take-up of LHVs and the estimates of the actual rate used in the Tables above were made based on a combination of the objective analysis of the maximum rates, literature from countries where they are already used and the views expressed in the information gathering exercise. This estimate took account of all the practical constraints that would affect the take up such as just-in-time deliveries, availability of suitable routes, available space at depots, the ability of small hauliers to access additional capital for the equipment, and the return on that capital investment. The analysis of the mode shift effect was predominantly econometric relying on estimates of price elasticity that were based on the use of existing vehicles that are much less constrained.

The take up rate for LHVs was estimated to be 5% to 10% of the traffic generated by the sectors identified that were likely to take it up. For the payload neutral and 44-tonne 25.25m LHVs this was assumed to be 5-10% of the 55% of tonne kms that were carried by sectors including pallet networks, fast moving consumer goods, other foodstuffs and miscellaneous manufacturing as well as deep-sea containers. The aggregated nature of the estimate and the parametric model means that this has effectively assumed that the take-up rate would be 5% to 10% in each relevant sector. Thus, the model assumes that 5% to 10% of the deep sea containers currently moved by road will transfer to LHVs. However, the mode shift estimate assumes that 22% to 54% of all deep sea containers currently moved by rail will switch to LHVs. Despite the fact that the rail share of the market is much smaller than road (25% compared with 75% respectively) this means that the model predicts that if LHVs were permitted, approximately 70% of the shipping containers carried by LHVs would originally have come from rail. This is not particularly plausible. If there are practical constraints that mean only 5% to 10% of the containers currently moved by road can switch to LHVs there is no obvious explanation of why 22% to 54% of those currently carried by rail could switch to LHVs. Equally if it is possible for 22% to 54% of containers currently transported by rail to move to LHVs there is no obvious reason why similar or even greater proportions of those moved by standard articulated vehicles could not move to LHVs.

There has been insufficient evidence presented during this project to enable this inconsistency to be accurately resolved. However, it is possible to test the extremes of the possible effects. It could be assumed that the econometric approach to the mode shift estimate is the correct approach and that, for some reason, the nature of the deep-sea container market means that the practical constraints limiting the take-up of LHVs in other sectors do not apply. In this case, the deep-sea container market would expect to see all current road traffic transferring to LHVs and 22% to 54% of rail traffic transferring based on the more competitive pricing LHVs would permit. In order to embody this, case 2 above (previously the largest adverse effects) has been modified such that 5%-10% of all markets likely to adopt LHVs will use LHVs but 100% of the 7.3billion container tonne-kms currently moved by articulated vehicles will move to LHVs. The results are shown in Table 112, below:

Table 112. Effects if 100% of deep-sea containers currently moved by road were to transfer to LHVs

Scenario	Total cost change		Total fatality		Total CO2 change		Total vkms change	
	£	%	Number	%	Tonnes	%	BVKMs	%
18.75m 44t	-£37,165,147	-0.23%	-1	-0.25%	-65,778	-0.55%	-0.08	-0.29%
18.75m Payload neutral (c.46t)	-£209,244,538	-1.32%	-4	-0.72%	-83,867	-0.70%	-0.23	-0.79%
25.25m 44t	-£569,673,081	-3.59%	-12	-2.03%	-246,709	-2.07%	-0.63	-2.15%
25.25m Payload neutral (c.50t)	-£569,580,900	-3.58%	-10	-1.70%	-121,746	-1.02%	-0.54	-1.85%
25.25 60t	-£569,406,325	-3.58%	-6	-1.08%	114,912	0.96%	-0.37	-1.27%
34m Payload neutral (c.63t)	-£632,081,610	-3.98%	-7	-1.22%	72,863	0.61%	-0.44	-1.52%
34m 82t	-£1,000,298,913	-6.30%	-12	-2.05%	-174,177	-1.46%	-0.86	-2.96%

It can be seen that at this extreme limit of take-up in the deep sea container market (combined with the 10% take-up level in other sectors) then the overall effects are changed substantially such that all vehicles with no payload increase compared with current vehicles are beneficial in all key parameters. However, the 60 tonne vehicles still retain an adverse environmental effect due to the higher mode shift induced in the deep sea container market and the estimated mode shift from bulk rail. For the 82 tonne vehicle, the greater productivity gain when replacing standard vehicles outweighs the negative environmental effect of switching goods from rail such that the net effect is still beneficial.

An alternative way to test the limits of the inconsistencies in the different approaches on take-up in the road sector and mode shift from rail is to limit the mode shift from rail by a factor relating to the constraints that would be applied to LHVs if they were permitted. The analysis of route restrictions using CSRGT trip data (see section G.3) suggested that limiting the routes that could be used to Motorways and dual carriageways would reduce the effectiveness of LHVs by 11% to 21%. The following results are based on applying an average reduction in effectiveness factor of 16% to the estimates of mode shift. Again, this is based on case 2, which previously showed the larger adverse effects.

Table 113. Effects if the mode-shift from rail is factored to allow for more restricted road access

Scenario	Total cost change		Total fatality		Total CO2 change		Total vkms change	
	£	%	Number	%	Tonnes	%	BVKMs	%
18.75m 44t	-£37,165,147	-0.23%	-1	-0.25%	-65,778	-0.55%	-0.08	-0.29%
18.75m Payload neutral (c.46t)	-£106,283,495	-0.67%	-2	-0.33%	-31,843	-0.27%	-0.11	-0.36%
25.25m 44t	-£156,878,662	-0.99%	-2	-0.36%	-425	0.00%	-0.10	-0.35%
25.25m Payload neutral (c.50t)	-£251,018,165	-1.58%	-3	-0.48%	39,216	0.33%	-0.15	-0.51%
25.25 60t	-£429,302,617	-2.70%	-4	-0.69%	114,289	0.96%	-0.24	-0.82%
34m Payload neutral (c.63t)	-£477,108,034	-3.00%	-5	-0.80%	82,204	0.69%	-0.29	-1.01%
34m 82t	-£757,964,861	-4.77%	-8	-1.43%	-106,293	-0.89%	-0.61	-2.11%

It can be seen that in this case the adverse effects seen in case 2 (see Table 111) have been reduced for all the 25.25m combinations, to the extent that the 44 tonne version is now marginally beneficial.

The likely effects of permitting LHVs, including consideration of the inconsistency described above has been summarised in percentage for in Table 114, and in numerical form in Table 115, below.

Table 114. Summary of potential effects if LHVs were permitted (%)

Scenario	Total cost change (%)		Total fatality change (%)		Total CO2 change (%)		Total vkms change (%)	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-0.23%	-0.15%	-0.25%	-0.17%	-0.55%	-0.37%	-0.29%	-0.20%
18.75m Payload neutral (c.46t)	-1.32%	-0.35%	-0.72%	-0.19%	-0.70%	-0.18%	-0.79%	-0.21%
25.25m 44t	-3.59%	-0.47%	-2.03%	-0.17%	-2.07%	0.20%	-2.15%	-0.16%
25.25m Payload neutral (c.50t)	-3.58%	-0.77%	-1.70%	-0.22%	-1.02%	0.60%	-1.85%	-0.24%
25.25 60t	-3.58%	-1.36%	-1.08%	-0.33%	0.52%	1.35%	-1.27%	-0.39%
34m Payload neutral (c.63t)	-3.98%	-1.51%	-1.22%	-0.38%	0.38%	1.07%	-1.52%	-0.48%
34m 82t	-6.30%	-2.41%	-2.05%	-0.70%	-1.46%	-0.43%	-2.96%	-1.04%

Table 115. Summary of potential effects if LHVs were permitted (Numerical)

Scenario	Total cost change (£)		Total fatality		Total CO2 change		Total vkms change	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-£37,165,147	-£23,218,367	-1.5	-1.0	-65,778	-44,557	-0.08	-0.06
18.75m Payload neutral (c.46t)	-£209,244,538	-£55,509,936	-4	-1	-83,867	-21,381	-0.23	-0.06
25.25m 44t	-£569,673,081	-£74,396,045	-12	-1	-246,709	24,375	-0.63	-0.05
25.25m Payload neutral (c.50t)	-£569,580,900	-£123,128,880	-10	-1	-121,746	71,586	-0.54	-0.07
25.25 60t	-£569,406,325	-£215,420,708	-6	-2	61,820	160,995	-0.37	-0.11
34m Payload neutral (c.63t)	-£632,081,610	-£239,737,293	-7	-2	45,401	127,343	-0.44	-0.14
34m 82t	-£1,000,298,913	-£382,597,225	-12	-4	-174,177	-51,059	-0.86	-0.30

Many measures that aim to reduce truck travel express the benefits in terms of the number of vehicle movements taken off the road. This can be derived from the data above by dividing the change in vehicle kms by the average length of haul for the vehicle. However, in the case of LHVs it is not known what the average length of haul would be. For standard articulated vehicles, which includes those making urban deliveries to shops, the average length of haul is 124 km. For rail freight it is 208km. It is reasonable to assume that LHVs would fall somewhere between the two because they are unlikely to be used on the shorter of the journeys currently undertaken by standard articulated vehicles and highly unlikely to travel longer distances on average than trains. Using these figures as boundary conditions produces a range of reductions in vehicle movements as shown in Table 116, below.

Table 116. Summary of estimated changes in vehicle movements

Scenario	Low	High
18.75m 44t	-276,409	-681,812
18.75m Payload neutral (c.46t)	-293,427	-1,861,918
25.25m 44t	-217,036	-5,048,539
25.25m Payload neutral (c.50t)	-329,062	-4,333,073
25.25 60t	-541,220	-2,978,102
34m Payload neutral (c.63t)	-674,964	-3,556,902
34m 82t	-1,460,713	-6,957,357

It can be seen that the net financial values of all effects combined is always a cost reduction. However, for 25.25m LHVs at 44 or ~50 tonnes (payload neutral) the effect on CO_2, and thus other noxious emissions could be either an increase or decrease. For 60 tonne vehicles, the model predicts an increase in emissions in all cases tested. Given current concerns regarding climate change, this represents a notable risk factor.

It has not been possible in this study of aggregate UK effects to estimate with certainty whether or not the mode shift effect would be sufficient to cause an overall adverse effect on the environment because of the lack of quantitative information and the methods that were available to estimate aggregate levels of UK take-up and mode shift. These issues would need to be studied in much more detail if it is considered necessary to quantify the overall effects more accurately. This would involve studying port activity in more detail and the constraints associated with the use of LHVs in a port/container transport context, and the effects that these constraints may have on existing price elasticity figures used in mode shift calculations, which are based predominantly on the lesser constraints of standard road vehicles. In addition to this, the critical levels at which rail services could no longer be supported if traffic was reduced may need to be identified.

The European Commission has defined the notion of *"co-modality"*, described as *"the efficient use of transport modes operating on their own or in multi-modal integration in the European transport systems to reach an optimal and sustainable utilisation of resources"*.

A blanket decision either to permit, or not to permit, LHVs greater than 18.75m in length could be considered counter to the notion of co-modality because, while the analysis suggests that permitting such LHVs in all sectors of the freight market would improve the efficiency of road freight on its own, there is a strong risk that it would have an adverse effect of the efficiency of freight transport on road and rail operating in a combined transport chain to the possible detriment of the environment. However, whilst a blanket decision not to permit LHVs in any sector of the freight market would not undermine current efficiencies achieved with road and rail working together, it would not improve the efficiency of road freight working on its own in sectors not competing with rail, such as overnight trunking on pallet load networks, because those sectors would be prevented from making improvements in efficiency that could otherwise be possible.

It may be possible to develop a mechanism that would prevent or limit mode shift in the deep-sea container market, particularly given the capacity constraints and predicted traffic growth at ports. If this resulted in as much port freight as efficiently possible being transported by rail and allowed what could not be carried by rail to be transported as efficiently as possible by road, such a mechanism would appear to be consistent with the notion of co-modality. If such a way could be found to implement LHVs then substantial benefits could potentially be achieved whilst avoiding the risk of adverse environmental effects.

Currently, it is not known how such a "co-modal" situation might be achieved. For the purposes of illustrating the potential, the concept has been assessed on the basis of excluding LHVs from the carriage of shipping containers. Based on this assumption the model predicts that the effects would be expected to be in the range suggested in Table 117 and Table 118, below.

Table 117. Potential effects if LHVs were permitted but were excluded from the carriage of shipping containers (%).

Scenario	Total cost change (%)		Total fatality change (%)		Total CO2 change (%)		Total vkms change (%)	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-0.23%	-0.15%	-0.25%	-0.17%	-0.55%	-0.37%	-0.29%	-0.20%
18.75m Payload neutral (c.46t)	-0.67%	-0.35%	-0.47%	-0.27%	-0.61%	-0.38%	-0.53%	-0.31%
25.25m 44t	-1.17%	-0.57%	-0.81%	-0.41%	-1.05%	-0.54%	-0.88%	-0.45%
25.25m Payload neutral (c.50t)	-1.57%	-0.77%	-0.92%	-0.47%	-0.72%	-0.40%	-1.02%	-0.53%
25.25 60t	-2.33%	-1.13%	-1.11%	-0.59%	-0.14%	-0.10%	-1.29%	-0.69%
34m Payload neutral (c.63t)	-2.58%	-1.26%	-1.20%	-0.63%	-0.33%	-0.25%	-1.45%	-0.76%
34m 82t	-4.05%	-1.98%	-1.72%	-0.89%	-1.64%	-0.90%	-2.37%	-1.22%

Table 118. Potential effects if LHVs were permitted but were excluded from the carriage of shipping containers (Numerical)

Scenario	Total cost change (£)		Total fatality change		Total CO2 change (tonnes)		Total vkms change (billion)	
	High	Low	High	Low	High	Low	High	Low
18.75m 44t	-£37,165,147	-£23,218,367	-1	-1	-65,778	-44,557	-0.08	-0.06
18.75m Payload neutral (c.46t)	-£105,840,650	-£55,035,928	-3	-2	-72,373	-45,596	-0.15	-0.09
25.25m 44t	-£186,195,551	-£90,796,965	-5	-2	-125,201	-64,255	-0.26	-0.13
25.25m Payload neutral (c.50t)	-£249,647,999	-£121,662,293	-5	-3	-86,183	-47,770	-0.30	-0.15
25.25 60t	-£369,816,307	-£180,116,053	-7	-3	-16,550	-12,290	-0.38	-0.20
34m Payload neutral (c.63t)	-£409,721,196	-£199,708,603	-7	-4	-39,025	-29,765	-0.42	-0.22
34m 82t	-£644,162,422	-£314,814,832	-10	-5	-196,094	-107,403	-0.69	-0.35

Using the same assumptions as previously, the vehicle kms change can be translated to the reductions in the number of vehicle movements shown in Table 119, below.

Table 119. Change in vehicle movements if LHVs were excluded from the carriage of deep sea containers from ports.

Scenario	Low	High
18.75m 44t	-276,409	-681,812
18.75m Payload neutral (c.46t)	-426,845	-1,238,760
25.25m 44t	-626,900	-2,074,666
25.25m Payload neutral (c.50t)	-741,860	-2,405,016
25.25 60t	-959,573	-3,030,644
34m Payload neutral (c.63t)	-1,067,358	-3,399,252
34m 82t	-1,700,592	-5,564,819

It can be seen that if LHVs were permitted in all sectors except the carriage of shipping containers then none of the scenarios would be expected to produce adverse environmental effects, although the environmental benefits from 60 tonne vehicles would be expected to be relatively small and smaller than for the other scenarios considered. The reason for this is that the increased weight options still retain estimates of mode shift from bulk rail and at 60 tonnes the predicted productivity improvements from consolidating existing road movements would only just be sufficient to outweigh the environmental disbenefits of this mode shift.

Modal shift was the only factor analysed in the parametric cost model that was found to have a sufficiently large effect to suggest that permitting LHVs could have net adverse consequences on any of the main key indicators and this depended heavily on the estimated take-up rate. This, and a wide range of other risks, are likely to require further investigation if the UK were to decide to further explore the possibility of permitting LHVs greater than 18.75m in length, particularly if vehicles of 60/63 tonnes were considered.

H.2.2.5 The potential for improvements within current limits

The business as usual scenario used as the reference baseline in the preceding analysis assumed that the proportion of tonne-kms carried by articulated vehicles, drawbar combinations and double decked articulated vehicles remained fixed at the actual values recorded in 2005. Each of the LHV scenarios was also based on the same assumption.

The proportion of goods moved by drawbar combinations and double decked articulated vehicles is relatively small but has increased substantially in recent years, particularly since the weight limits were increased to 41 tonnes and then 44 tonnes. Both these types of vehicles offer increased loading length compared with a standard articulated vehicle. A second business as usual scenario was, therefore, modelled based on the assumption that the use of double decked vehicles and drawbar combinations increased in line with current trends. This method produced the estimates of vehicle proportions shown in Table 120, below.

Table 120. Proportions of goods carried by different vehicles in the second “business as usual” scenario

Year	Proportion of tonne kms carried by….			
	Rigid	Single decked articulated	Double decked articulated	Drawbar combination
2006	21.7%	73.7%	2.3%	2.3%
2020	21.8%	67.2%	5.2%	5.7%

It should be emphasised that these predictions were based on simple extrapolation of trends over time and was not, therefore, a comparable step change approach as taken with the LHV scenarios. It was also not tested in terms of feasibility with the industry stakeholders and is assumed not to suffer from mode shift or induced demand effects, despite the fact that a double deck vehicle represents a very large step change in price per pallet km (almost halved) for very lightweight volume constrained goods compared with standard articulated vehicles. The parametric model predicts the following changes compared with the baseline condition (business as usual 1):

- Total cost reduced by 1.8%
- Total vehicle kms reduced by 1.2%
- Total CO_2 reduced by 2.35%
- Number of fatalities increased by 1%

It can be seen that in three of four key indicators, the increased use of drawbar and double decked vehicles was found to be substantially beneficial. These benefits were comparable to those of some of the LHV scenarios. However, an adverse effect on safety would be expected if this occurred. This is as a result of the accident rate derived for drawbar vehicles in the analysis of safety which was very high but was poorly based with a small sample sized and problems of differing coding definitions in different databases.

Business as usual 2 should not necessarily be considered as a direct alternative to any of the LHV scenarios because the use of drawbars and double decked vehicles may continue to rise even if LHVs are permitted, thus meaning that the effects of this scenario would be mixed with the effects of LHV scenarios. In fact, many stakeholders have suggested permitting double decked LHVs but this has not been evaluated at this time.

H.3 Investments

The research has highlighted a number of areas where capital investment in infrastructure may be required. The research has suggested that capital investment will be required on rail infrastructure in order to deliver the capacity required to be able to deliver the predicted growth in this area, which forms part of the business as usual scenario. For this scenario it was assumed that rail capacity would not limit the growth. It is expected that much of this investment will come from within the rail industry but some schemes are being considered for funding from the Transport Innovation Fund. In terms of roads, investment may be required for the development of suitable parking facilities, and reviews and modifications to bridge structures.

It has not been possible to reliably quantify the scale of investment required for these areas within the scope of this project. However, in order to inform decision makers about the order of magnitude of the investment that could be made for a benefit to cost ratio of one, a simplistic discounted cash flow calculation has been carried out. The results are shown in Table 121, below. This has assumed that the benefit each year is the average total cost reduction in the steady state period, as calculated by the parametric cost model for different scenarios where it is assumed that LHVs were introduced in all sectors without specific protection of deep sea container traffic carried by rail.

Inflation of 2% per annum and a discount factor of 3.5% have been applied. The calculation has been carried out for different pay-back periods. In a commercial environment, business cases for capital investment will usually be expected to show a return within 5 years. The effect over 15 years has also been calculated because this was the time period that the parametric model assessed. Major road schemes are usually evaluated over a 60 year period so this has also been assessed.

Table 121. Investment that can be made for a benefit to cost ratio of one

Scenario		Net present value of benefits in payback period (£million)		
		5	15	60
18.75m 44 tonnes	upper	£175.53	£359.27	£386.22
	lower	£109.66	£224.45	£241.28
18.75m Payload neutral	upper	£988.25	£2,022.76	£2,174.44
	lower	£262.17	£536.61	£576.85
25.25m 44 tonnes	upper	£2,690.54	£5,507.01	£5,919.97
	lower	£351.37	£719.18	£773.11
25.25m Payload neutral	upper	£2,690.11	£5,506.12	£5,919.01
	lower	£581.53	£1,190.28	£1,279.54
25.25 60 tonnes	upper	£2,689.28	£5,504.43	£5,917.20
	lower	£1,017.42	£2,082.47	£2,238.62
34m Payload neutral	upper	£2,985.29	£6,110.31	£6,568.51
	lower	£1,132.27	£2,317.53	£2,491.32
34m 82 tonnes	upper	£4,724.37	£9,669.86	£10,394.98
	lower	£1,806.99	£3,698.56	£3,975.90

It can be seen that the level of investment that would result in a benefit to cost ratio of 1 (i.e. where the investment in year 1 equals the net present value of benefits in a defined time period) varies considerably with vehicle type and spans the range of approximately £110million to £10.4billion. The investment required for each scenario could not be accurately quantified within the scope of this project but has been broadly categorised. If permitted, the 18.75m articulated vehicle is unlikely to require any substantial capital investment in the infrastructure and can be categorised as very low. It is, therefore, highly likely that a benefit to cost ratio in excess of one would be achieved. If LHVs of 25.25 m were to be permitted at 44 tonnes then substantial investment in parking facilities would be required and could be categorised as medium. If payload neutral versions were to be permitted then a limited amount of additional investment may be required to assess bridge structures that would be considered marginal for 44 tonne vehicles. However, this could still be categorised as medium. If 60 tonne versions were to be permitted then a larger investment would be required to assess and/or strengthen local authority bridges and the small percentage of trunk road bridges not up to HA standard. This could be categorised as a high investment. If 34m 82 tonne vehicles were to be permitted then a larger investment would be needed in parking facilities to accommodate the additional length and a much larger review of bridge structures and consequent improvements would be required for both local authority and up to a maximum 25% of trunk road bridges. This could be categorised as very high. For all investment levels categorised as medium or higher, the benefit to cost ratio is uncertain because it has been shown that the investment required in parking facilities could potentially be measured in £billions, although that would assume that new, dedicated, LHV facilities would have to be built from scratch.

H.4 Field definitions for model

Ref	Field	Description
	Base Data on UK Freight Movements	
		Inputs
1	Year	1996 – 2005
2	Total freight (all modes) btkm	Actual values 1996 – 2004 (Transport Statistics, DfT2006)
3	Rail freight btkm	Actual values 1996 – 2005 (Transport Statistics, DfT2006)
4	Water freight btkm	Actual values 1996 – 2005 (Transport Statistics, DfT2006)
5	Actual and predicted road freight btkm	Based on DfT 1997 freight prediction (Transport Statistics, DfT1998). 1997 prediction shown to be substantially inaccurate
6	Actual road freight btkm	Based on actual figures from 1996-2005 (Transport Statistics, DfT2006)
7	Road freight carried by vehicle type	Actual data (Transport Statistics, DfT, 2006) divided into rigid 3.5-17, 17-25, >25, articulated 3.5-33, >33, drawbar, double decked.
8	Total HGV>3.5t traffic BVK	Actual data from Transport Statistics, (DfT2006). Based on traffic census data
9	Traffic BVK by vehicle type and road class	Divided by rigid 2 axle, 3 axle, 4+ axles, articulated 3 or 4 axle, 5 axle, 6+ axle, motorways, rural trunk “A” roads, rural principal “A” roads, urban trunk “A” roads, urban principal “A” roads, minor roads.
10	Road freight btkm	From CSRGT divided by volume constrained, weight constrained, constrained by both, and unconstrained loads and vehicle type rigid, drawbar, double decked, articulated <38, artic =38, artic 38-41, artic =41, artic >41
11	Road traffic BVK	From CSRGT (Note: less than traffic census data – different sampling/estimating methods and excludes foreign registered vehicles) divided by volume constrained, weight constrained, constrained by both, and unconstrained loads and vehicle type rigid, drawbar, double decked, articulated <38, artic =38, artic 38-41, artic =41, artic >41

12	Traffic when laden BVK	From CSRGT divided by volume constrained, weight constrained, constrained by both, and unconstrained loads and vehicle type rigid, drawbar, double decked, articulated <38, artic =38, artic 38-41, artic =41, artic >41
13	Empty running BVK	From CSRGT divided by vehicle type rigid, drawbar, double decked, articulated <38, artic =38, artic 38-41, artic =41, artic >41
14	Average load when laden	From CSRGT divided by volume constrained, weight constrained, constrained by both, and unconstrained loads and vehicle type rigid, drawbar, double decked, articulated <38, artic =38, artic 38-41, artic =41, artic >41
15	Average load including empty running	From CSRGT divided by volume constrained, weight constrained, constrained by both, and unconstrained loads and vehicle type rigid, drawbar, double decked, articulated <38, artic =38, artic 38-41, artic =41, artic >41
	Outputs	
16	Predicted Total freight (all modes) btkm	Linear extrapolation to 2025 based on actual inputs (field 2). Consistent with EuroSTAT EU estimates
17	Predicted Rail freight btkm	Linear extrapolation to 2025 based on actual inputs (field 3). Slightly over-estimates growth compared with rail industry estimates and more substantially overestimates compared to EuroSTAT EU based estimates. Alternative estimates can be substituted
18	Predicted Water freight btkm	Linear extrapolation to 2025 based on actual inputs (field 4)
19	Predicted road freight	Linear extrapolation to 2025 based on actual inputs (field 6). Underestimates compared with EuroSTAT EU estimates
20	Road freight carried by vehicle type	Linear extrapolation to 2025 based on actual inputs and divided by vehicle type in the same way as the corresponding input (field 7)
21	Total HGV>3.5t traffic BVK	Linear extrapolation to 2025 based on actual inputs (field 8)
22	Predicted LHV average loads including empty running	Predictions made for volume only changes based on interpolation of standard articulated vehicles and double decks based on weight ratio with increase in average load of standard vehicles based on pallet ratio and all changes coming from volume constrained trips. Predictions for volume and weight increases based on an assumption that percentage load will be the same as for 44 tonne artic.
	Freight Transport Running costs	
	Inputs	
23	Fuel price per litre	£0.79
24	Fuel density (g/l)	0.84

25	Oil price	£0.0084/km
26	Unit cost of tyre	Tow vehicle=£211/trailer=£220
27	Annual distance travelled per vehicle	Assumed to be 144,000 km for all vehicle types
28	Fuel consumption (km/l)	Divided by vehicle type 6 axle artic, double decked, rigid/A/semi44, rigid/A/semi60, tractor/semi/C/semi, B-double44, Bdouble60, 18.75 semi44. All taken from emissions modelling output.
29	Capital cost tow vehicle	Based on FTA 2006 averages with assumptions and interpolations about power level and drive axles required for LHV tow vehicles.
30	Tow vehicle depreciation period	Assumed 6 years for all
31		
32	Trailer capital costs (incl multiples and dollies where applicable)	Based on FTA 2006 averages multiplied for combinations where applicable and including €16000 for "A" dollies based on Dutch literature with an additional $6000 for "C" dollies based on US research. Assumed B-double interlink semi 20% more expensive than standard partly based on Australian research suggesting a B-double combination was AUS$80,000 more expensive than a standard artic. Longer semi assumed to be 10% more expensive than standard to cover additional materials and steering axles.
33	Trailer vehicle depreciation period	Assumed 10 years for all
34	Number of tyres	Tow vehicle/trailer(s)
35	Tyre life	As Motor transport for Tow vehicle and trailer but modified with assumptions for dollies/interlinks etc.
36	Maintenance cost/km	Based on Motor Transport figures with assumptions regarding increase for steering axles, specialist trailers and dollies.
37	Wages +NI	Motor Transport – assumed constant for all types
38	Insurance	Motor transport plus assumed 10% increase for LHV types.
39	Excise duty	Assumed £1,200 for all
40	Days utilised/year	Assumed 225 for all
41	Hours utilised/day	Assumed to be 9 – i.e. max legal for single shift driving
42	Average load including empty running	Divided by vehicle type and taken directly from the relevant input to the freight section for current vehicles and the predicted output from the freight section for LHVs
43	Pallet capacity	Input based on defined vehicle specifications for assessed vehicles
44	Running costs/tkm rail	Based on £/tonne road/rail ratio from report describing the REPS scheme applied to baseline running cost per tonnekm (road) derived from fields above.

45	Running costs/tkm water	Not currently defined due to conclusion of zero mode shift from water
	Outputs	
46	Annual fuel cost	(Annual distance/kms per litre) * fuel cost for all vehicle types
47	Annual oil cost	Distance*oil cost
48	Tow vehicle depreciation cost	Capital cost / depreciation period
49	Trailer vehicle depreciation cost	Capital cost / depreciation period
50	Annual tyre cost	Number of tyres*tyre cost*annual distance/tyre life
51	Maintenance cost per year	Cost/km*annual distance
52	Fixed costs per year	Wages+duty+depreciation
53	Running costs/year	Fuel+oil+maintenance+tyres
54	Total internal costs/year	Fixed + running costs
55	Total internal Cost/km	Total/annual distance
56	Total internal Cost/tkm	(Total cost/km)/(average load including empty running)
57	Total internal cost/pallet km	(Total cost/km)/(pallet capacity)
58	Percentage change in internal cost/tonnekm	(Cost/tkm for each vehicle option minus cost/tkm for baseline vehicle)/(cost/tkm for baseline vehicle)
59	Percentage change in internal cost/palletkm	(Cost/palletkm for each vehicle option minus cost/palletkm for baseline vehicle)/(cost/palletkm for baseline vehicle)
	Emissions impact assessment	
	Inputs	
60	Euro level to assess	Select 4 or 5
61	CO (g/km)	For all 8 vehicle types, euro 4 and euro 5, modelled at full load (weight) and average load (weight assuming LHV % load factors the same as current 44 tonne artics). Taken from emissions modelling
62	HC (g/km)	For all 8 vehicle types, euro 4 and euro 5, modelled at full load (weight) and average load (weight assuming LHV % load factors the same as current 44 tonne artics) Taken from emissions modelling
63	NOx (g/km)	For all 8 vehicle types, euro 4 and euro 5, modelled at full load (weight) and average load (weight assuming LHV % load factors the same as current 44 tonne artics) Taken from emissions modelling
64	PM (g/km)	For all 8 vehicle types, euro 4 and euro 5, modelled at full load (weight) and average load (weight assuming LHV % load factors the same as current 44 tonne artics) Taken from emissions modelling
65	CO2 (g/km)	For all 8 vehicle types, euro 4 and euro 5, modelled at full load (weight) and average load (weight assuming LHV % load factors the same as current 44 tonne artics) Taken from emissions modelling
66	Fuel consumption (g/km)	For all 8 vehicle types, euro 4 and euro

		5, modelled at full load (weight) and average load (weight assuming LHV % load factors the same as current 44 tonne artics) Taken from emissions modelling
67	Rail emissions/tonnekm	Based on a study for EWS by Alan Mckinnon
68	Water emissions/tonnekm	Not currently defined due to conclusion of zero mode shift from water
69	Societal cost of SO2	Defra 2006
70	Societal cost of CO (£/tonne)	Not identified
71	Societal cost of HC (£/tonne)	Not identified
72	Societal cost of NOx (£/tonne)	DEFRA 2006
73	Societal cost of PM (£/tonne)	DEFRA 2006
74	Societal cost of CO2 (£/tonne)	DEFRA 2006
75	Average load including empty running	Divided by vehicle type and taken directly from the relevant input to the freight section for current vehicles and the predicted output from the freight section for LHVs
	Outputs	
76	CO (g/km)	Interpolated/extrapolated from inputs based on modelling to reflect values at varying average loads as defined by the outputs of the freight section.
77	HC (g/km)	Interpolated/extrapolated from inputs based on modelling to reflect values at varying average loads as defined by the outputs of the freight section.
78	NOx (g/km)	Interpolated/extrapolated from inputs based on modelling to reflect values at varying average loads as defined by the outputs of the freight section.
79	PM (g/km)	Interpolated/extrapolated from inputs based on modelling to reflect values at varying average loads as defined by the outputs of the freight section.
80	CO2 (g/km)	Interpolated/extrapolated from inputs based on modelling to reflect values at varying average loads as defined by the outputs of the freight section.
81	Fuel consumption (g/km)	Interpolated/extrapolated from inputs based on modelling to reflect values at varying average loads as defined by the outputs of the freight section.
82	Total societal cost of emissions (road £/vkm – rail £/tkm)	For road vehicles – each emission in g/km multiplied by the relevant scaling factor and the societal cost in £/tonne For rail – each emission in g/tkm multiplied by scaling factors and the societal cost in £/tonne
	Road wear impact assessment	
	Inputs	
83	Standard axles per vehicle km	For all vehicle types (drawbars assumed equal to 44 tonne artic) for average load based on current lading patterns and full load
84	Cost per standard axle km	For different classes of road
	Outputs	

85	Cost per BVK	Divided by vehicle and road type
	Safety impact assessment	
	Inputs	
86	Casualty rate per BVK	Divided by vehicle type and different road restrictions – motorways only, motorways and rural trunk “A” road, motorways and all rural “A” roads, motorways and all “A” roads, All roads. Actuals for standard artics and rigids, predictions based on three different approaches for other vehicle types involving a range of assumptions either extrapolating current high level data, modifying current data based on a bottom up risk approach and relying on values from literature. Minimum, maximum and central estimates provided from the safety analysis.
87	Fatal, serious and slight casualty prevention valuations	DfT standard values RCGB 2006
	Business as usual case 1	
	Inputs	
88	Year	All data divided by year 2006-2020
89	Tonne kms transported by rail	Taken from output of Freight section.
90	Tonne kms transported by water	Taken from output of Freight section.
91	Tonne kms transported by road	Taken from output of Freight section.
92	Investment costs	Assumed zero in this case
	Outputs	
93	Road tonne kms carried by each vehicle type	Divided by rigid, drawbar, standard articulated vehicle, double decked. Derived from actual data from freight section with the added assumption that the proportions carried by each type remain fixed at 2005 values.
94	Vehicle kms by vehicle type (CSRGT)	Tonne kms for each vehicle type (above) divided by average load outputs from freight section. Excludes foreign vehicle travel
95	Vehicle km ratio	Ratio of actual 2005 vehicle km values from traffic census data and CSRGT data inputs in freight section
96	Vehicle kms by vehicle type (Traffic census)	Vehicle kms (CSRGT)* vehicle km ratio. Reconciles the difference between CSRGT and traffic census estimates and therefore can be considered to include foreign registered vehicles with the assumption that foreign operators use the vehicles in the same proportion as UK operators and to the same quality.
97	Total running costs (road)	Running cost per km for each vehicle type multiplied by vehicle kms (traffic census) for each vehicle type (excluding rigids)
98	Total running costs (other modes)	Running costs per tonne km for rail multiplied by tonne kms for rail
99	Total road wear costs	Road wear costs per km for each vehicle type multiplied by vehicle kms (traffic census) for each vehicle type (excluding rigids)
100	Total emissions cost (road)	Societal emissions costs per km for each

		vehicle type multiplied by vehicle kms (traffic census) for each vehicle type (excluding rigids)
101	Total emissions cost (other modes)	Societal cost of emissions per tonne km for rail multiplied by tonne kms for rail
103	Accident cost	Fatal, serious, slight casualty rates per km multiplied by vehicle kms (Traffic census) multiplied by casualty valuations for fatal serious and slight casualties for all vehicle types
104	Accident cost other modes	Assumed zero due to low numbers and fact that reporting for rail in particular is in relation to passenger trains.
105	Total costs	Sum of other costs
	Business as usual case 2	
	As business as usual case 1 except that the use of drawbar combinations and double decked vehicles is assumed to increase in line with current trends (linear for double decked limited to a maximum of the current number of volume constrained loads, exponential for drawbar combinations	
	Rigid/A/semi 44 case	
	Inputs	
106	Road access limitation	Selectable from motorway only, motorways and rural trunk “A” road, Motorways and all rural “A” roads, Motorways and all “A” roads, All roads
107	Take up rate	Proportion of tonne kms currently transported by articulated vehicles that will transfer to LHV – will vary according to road restriction selected. Subjective judgement based on data from focus groups, literature and outputs from logistics modelling. For volume only options the percentage is factored to apply to only the volume constrained loads. For volume and weight options it will apply to all articulated vehicle freight.
108	Mode shift from rail	Proportion of tonne kms currently transported by rail that will shift to LHVs - will vary according to road restriction selected.
109	Mode shift from water	Proportion of tonne kms currently transported by water that will shift to LHVs - will vary according to road restriction selected– assumed zero
110	Price elasticity of demand	Judgement based on factors used in other literature, response from focus group sessions and analysis of actual changes after the 44 tonne introduction in relation to values assumed before the introduction.
111	Baseline tonnekms by Road	Taken from freight section outputs
112	Baseline tonnekms by Rail	Taken from freight section outputs
113	Baseline tonnekms by Water	Taken from freight section outputs
114	Administration costs	Adds an estimated allowance for the administration of any special orders required or any additional enforcement activities required to control LHV use
	Outputs	
115	Induced demand	Percentage increase in tonne kms

		transported by LHVs as a result of reduced cost of such transport. Price elasticity of demand multiplied by the reduction in running costs from the running cost section.
116	Tonne kms carried by rail	Baseline tonne kms by Rail minus (baseline tonne kms by rail*mode shift rail)
117	Tonne kms carried by water	Baseline tonne kms by water minus (baseline tonne kms by water*mode shift water)
118	Tonne kms carried by road	Divided by vehicle type assuming the proportion of tonne kms carried by drawbars and double decks remains at 2005 values. Articulated vehicles is the output from the freight section (baseline) minus (baseline tonne kms by articulated vehicles*take up rate). The value for LHVs will be the (Baseline articulated vehicle tonne kms* LHV take up rate)+(baseline tonne kmsby rail*mode shift rail)+(baseline tonne kmsby water*mode shift water)+ (Baseline articulated vehicle tonne kms* LHV take up rate*induced demand)
119	Vehicle kms by vehicle type (CSRGT)	Divided by rigid, drawbar, standard articulated vehicle, double decked and LHV based on the assumption that the proportions carried by each current type remain fixed at 2005 values. For volume only increases the average load susceptible to transfer to LHVs has been estimated based on the average load on double decked vehicles, the payload ratio and the pallet capacity ratio. New-post shift average loads have then been calculated for standard artics as a result of removing these light loads. The effect is that the average load on volume only LHV options is less than for standard artics due to lower payload weight but the average load on standard artics increases. For volume and weight increases it is assumed all loads are equally susceptible to transfer such that average load as a percentage of payload remain the same on artics and LHVs before and after the shift.
122	Vehicle km ratio	Ratio of 2005 vehicle km values from traffic census data and CSRGT from freight section
123	Vehicle kms by vehicle type (Traffic Census)	Vehicle kms (CSRGT)*vehicle km ratio for all vehicle types. Assumes that the foreign freight follows the same pattern as the domestic freight i.e. foreign operators use LHVs in the same proportion as domestic operators
124	Total running costs (road)	Running cost per km for each vehicle

		type multiplied by vehicle kms (traffic census) for each vehicle type (excluding rigids)
125	Total running costs (other modes)	Running costs per tonne km for rail and water multiplied by tonne kms carried for rail and water
126	Total road wear costs	Road wear costs per km (Traffic census) multiplied by vehicle kms for each vehicle type (excluding rigids)
127	Total emissions cost (road)	Societal emissions costs per km (Traffic census) multiplied by vehicle kms for each vehicle type (excluding rigids)
128	Total emissions cost (other modes)	Societal cost of emissions per tonne km for rail and water multiplied by tonne kms for rail and water
129	Accident cost	Fatal, serious, slight casualty rates per km multiplied by vehicle kms (Traffic census) multiplied by casualty valuations for fatal serious and slight casualties
130	Accident cost other modes	Assumed zero due to low numbers and fact that reporting for rail in particular is in relation to passenger trains.
131	Total costs	Sum of other costs
	Rigid/A/Semi60 case	
	As rigid/A/semi 44 case with differing values to account for the different vehicle type	
	Tractor/semi/C/semi	
	As rigid/A/semi 44 case with differing values to account for the different vehicle type	
	B-double44	
	As rigid/A/semi 44 case with differing values to account for the different vehicle type	
	B-double60	
	As rigid/A/semi 44 case with differing values to account for the different vehicle type	
	Longer semi-trailer44	
	As rigid/A/semi 44 case with differing values to account for the different vehicle type	
	Final Summary	
	Outputs	
132	Cost variance (improvement within current regulations)	Total cost for BAU2 minus total costs for BAU1 (£ and %)
133	Vehicle kms variance (improvement within current regulations)	Total vehicle kms (Standard artic, drawbar, double deck) for BAU2 minus total vehicle kms (Standard artic, drawbar, double deck) for BAU1 (kms and %)
134	CO2 variance (improvement within current regulations)	Total CO2 (Standard artic, drawbar, double deck) for BAU2 minus total CO2 (Standard artic, drawbar, double deck) for BAU1 (Tonnes and %)
135	Fatality variance (improvement within current regulations)	Total Fatalities (Rigid, standard artic, drawbar, double deck) for BAU2 minus total fatalities (Rigid, standard artic, drawbar, double deck) for BAU1 (Number and %)
136	Cost variance – longer semi trailer 18.75m 44 tonne	Total cost for 18.75/44 minus total costs for BAU1 (£ and %)
137	Vehicle kms variance – longer semi trailer 18.75m 44 tonne	Total vehicle kms (Standard artic, drawbar, double deck) for 18.75/44 minus total vehicle kms (Standard artic, drawbar, double deck) for BAU1 (kms and %)

138	CO2 variance – longer semi trailer 18.75m 44 tonne	Total CO2 (Standard artic, drawbar, double deck) for 18.75/44 minus total CO2 (Standard artic, drawbar, double deck) for BAU1 (Tonnes and %)
139	Fatality variance – longer semi trailer 18.75m 44 tonne	Total Fatalities (Rigid, standard artic, drawbar, double deck) for 18.75/44 minus total CO2 (Rigid, standard artic, drawbar, double deck) for BAU1 (Number and %)
140	longer semi trailer 18.75m payload neutral	Interpolation between 18.75/44t and 25.25m 44t
141	Cost variance – 25.25m 44 tonne	Simple mean of total cost for Rigid/A/Semi44 and B-double44 minus total cost for BAU1 (£ and %)
142	Vehicle kms variance– 25.25m 44 tonne	Simple mean of total vehicle kms for Rigid/A/Semi44 and B-double44 minus total vehicle kms BAU1 (Number and %)
143	CO2 variance -25.25m 44 tonne	Simple mean of total CO2 for Rigid/A/Semi44 and B-double44 minus total CO2 BAU1 (Tonnes and %)
144	Fatality variance - 25.25m 44 tonne	Simple mean of total fatalities for Rigid/A/Semi44 and B-double44 minus total fatalities BAU1 (Number and %)
145	Cost variance – 25.25m Payload neutral	Simple mean of (Interpolation between total cost Rigid/A/Semi44 and total cost Rigid/A/Semi60) and (interpolation between total cost B-double44 and total cost B-double 60) minus total cost for business as usual case 1
146	CO2 variance – 25.25m 44 payload neutral	Simple mean of (Interpolation between total CO2 Rigid/A/Semi44 and total CO2 Rigid/A/Semi60) and (interpolation between total CO2 B-double44 and total CO2 B-double 60) minus total CO2 for business as usual case 1
147	Vehicle kms variance – 25.25m 44 payload neutral	Simple mean of (Interpolation between total VKMs Rigid/A/Semi44 and total VKMs Rigid/A/Semi60) and (interpolation between total VKMs B-double44 and total VKMs B-double 60) minus total VKMs for business as usual case 1
148	Fatality variance – 25.25m 44 payload neutral	Simple mean of (Interpolation between total fatalities Rigid/A/Semi44 and total fatalities Rigid/A/Semi60) and (interpolation between total fatalities B-double44 and total CO2 B-double 60) minus total fatalities for business as usual case 1
149	Cost variance – 25.25m 60 tonne	Simple mean of total cost for Rigid/A/Semi60 and B-double60 minus total cost for BAU1 (£ and %)
150	Vehicle kms variance– 25.25m 60 tonne	Simple mean of total vehicle kms for Rigid/A/Semi60 and B-double60 minus total vehicle kms BAU1 (Number and %)
151	CO2 variance -25.25m 60 tonne	Simple mean of total CO2 for Rigid/A/Semi60 and B-double60 minus

		total CO2 BAU1 (Tonnes and %)
152	Fatality variance - 25.25m 60 tonne	Simple mean of total fatalities for Rigid/A/Semi60 and B-double60 minus total fatalities BAU1 (Number and %)
153	Cost variance – 34m 82 tonne	Total cost for 34/82 minus total costs for BAU1 (£ and %)
154	Vehicle kms variance– 34m 82tonne	Total vehicle kms 34/82 minus total vehicle kms for BAU1 (kms and %)
155	CO2 variance -34m 82 tonne	Total CO2 34/82 minus total CO2 for BAU1 (Tonnes and %)
156	Fatality variance – 34m 82 tonne	Total Fatalities 34/82 minus total fatalities for BAU1 (Number and %)

Abstract

Goods vehicles that are longer and/or longer and heavier (abbreviated as LHVs in this report) than those currently permitted in the UK are in use, under trial, or being considered, in a number of countries both within the European Union (EU) and elsewhere. The European legislation that controls the maximum dimensions of vehicles, and the maximum weight that guarantees free circulation within the EU, permits trials and the use of these vehicles under certain strict conditions. The legislation is also the subject of a review by the European Commission to consider whether such vehicles should be part of the Freight Transport Logistics Action Plan to improve the efficiency of transport and logistics in the EU by 2010.

In the UK, applications from two hauliers, each wishing to trial an LHV, were refused in 2005. However, interest has grown within the road freight industry both in the UK and elsewhere in Europe. In light of this, and the work of the European Commission, the UK Department for Transport (DfT) decided to undertake research better to inform policy making. TRL, in partnership with the Logistics Research Centre at Heriot-Watt University, were appointed to undertake this research - a formal assessment of the likely combined effects on road safety, the atmospheric and built environment, and the efficiency of freight transport, including the effects on modes other than road transport, if different types of LHV in excess of the current weights and/or dimensions limits were to be permitted in the UK. This involved assessing a wide variety of factors, including but not limited to:

- potential demand for LHV operations
- economic efficiency of such operations
- effect on other freight modes and the potential impact of freight traffic generation
- effect on the frequency and distance of vehicle movements
- effect on safety and accidents
- changes to vehicle emissions and the environment
- effects on infrastructure
- effects on drivers

This enabled the effects to be estimated and compared for eight scenarios, which were used to illustrate different potential regulatory approaches. This report fully describes the findings of the research.

Longer and/or Longer and Heavier Goods Vehicles (LHVs) – a Study of the Likely Effects if Permitted in the UK: Final Report

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