

# **The Centre for Sustainable Road Freight**



## **An assessment of the potential for demand-side fuel savings in the Heavy Goods Vehicle (HGV) sector**

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**December 2015**

## 1 Executive summary

### 1.1 Background

Meeting the UK's 2050 greenhouse gas (GHG) emissions reduction target (an 80% reduction from 1990 levels by 2050) at a manageable cost will require significant decarbonisation of the transport sector. Road freight is the second largest source of transport emissions in the UK, accounting for 22% (24MtCO<sub>2</sub>e) of surface transport emissions in 2013. This sector has traditionally been viewed as being difficult to decarbonise due to limited scope for electrification, significant barriers to adoption of hydrogen fuel cell vehicles, and limited availability of other power train options.

The Committee on Climate Change (CCC) has developed a trajectory for reducing emissions from road freight transport, with previous work focussing on supply-side measures, which improve the carbon intensity of new HGVs. Technology such as stop-start systems and vehicle light-weighting could improve new HGV efficiency by around 30% compared to today's levels by 2030. The CCC scenario for the 4th Carbon Budget period (2023-27) also included carbon savings from demand-side measures, such as improved logistics and modal shift. In the central case this scenario includes a reduction of km travelled by road freight of 6.5% relative to business as usual by 2030.

This project was commissioned by the CCC to improve the evidence base on demand-side measures (i.e. measures implemented by freight operators that affect how HGVs are used rather than the technical specification of trucks), to inform their advice on the fifth carbon budget (2028-2032). During the course of the project it was recognised that freight operators can fit technological improvements to existing vehicles (e.g. aerodynamic fairings or low rolling resistance tyres). Such measures were not included in previous CCC scenarios, which focussed technological improvements to new vehicles only. Whilst such measures could be considered to be on the supply-side, we group them with demand-side measures for the purposes this project, as the choice of whether to implement the measure lies with the freight operator rather than the vehicle manufacturer.

Three types of intervention were considered:

- Technological improvements to existing vehicles, for example technologies to improve aerodynamics.
- Measures to promote more efficient driving styles, which can reduce the carbon intensity of a given HGV km, for example eco-driving.
- Improvements to logistics operations from measures such as improved routing, use of consolidation and distribution centres, higher lading factors, a reduction in empty running and use of computerised technologies. These measures reduce emissions by reducing overall distance driven by HGVs.

In the results below, the first two measures, retrofitting technologies and measures to promote efficient driving are termed 'Operator efficiency', as they aim to reduce the carbon intensity of a given HGV-km. The third set, which aim to reduce distance travelled through improved logistics, are referred to as 'Logistics measures'. In addition, the project assessed the potential for shift of freight from road to rail.

### 1.2 Methodology

In order to assess the potential for carbon savings from demand-side measures, a model of the current HGV fleet was developed. This used data predominantly from the Department for Transport's Continuing Survey of Road Goods Transport (CSRGT) to describe the current HGV

sector in terms of vehicle types, performance characteristics, operational constraints, km driven, carbon emissions and sector characteristics. Future projections of vehicle-km were taken from the Department for Transport's National Transport Model and projections of improving new vehicle efficiency were based on previous work commissioned by the CCC (AEA 2012). This enabled us to develop a baseline of current and future HGV fleet characteristics, running from 2010 to 2035, on which we could model the take-up of the three types of demand-side interventions.

Uptake rates for the measures considered were developed through a review of existing literature and by conducting surveys and focus groups with freight sector experts. Given the considerable uncertainty in take-up of the measures, three scenarios were developed reflecting high, medium and low uptake rates. These addressed the extent to which non-financial barriers to take-up of these measures might be overcome.

For improvements to operator efficiency, measures were only adopted if found to be cost-effective using a cost-benefit analysis. The level of adoption for cost-effective measures was then given by the uptake rates. Sensitivity analysis was also carried out by varying the cost-effectiveness criteria (discount rates and payback periods) and fuel prices.

It was not possible to estimate the costs of the logistics measures due to the heterogeneous nature of the sector and the sensitivity of costs to the type of freight activity. For example, the business case for an urban consolidation centre would need to consider land costs, which would be dependent on the scale of the operation, which in turn would be dependent on the number of users. In order to restrict the analysis to feasible GHG savings, the logistics measures were only applied to sectors and freight activity suitable for the measure being considered. Within this subset of freight activity, we then applied the uptake rates, drawn from the survey of freight operators mentioned above. Whilst we were not able to assess the cost-effectiveness of these measures, the implicit assumption underlying this is that the level of uptake anticipated by freight operators reflects the financial viability of the measure from a commercial perspective.

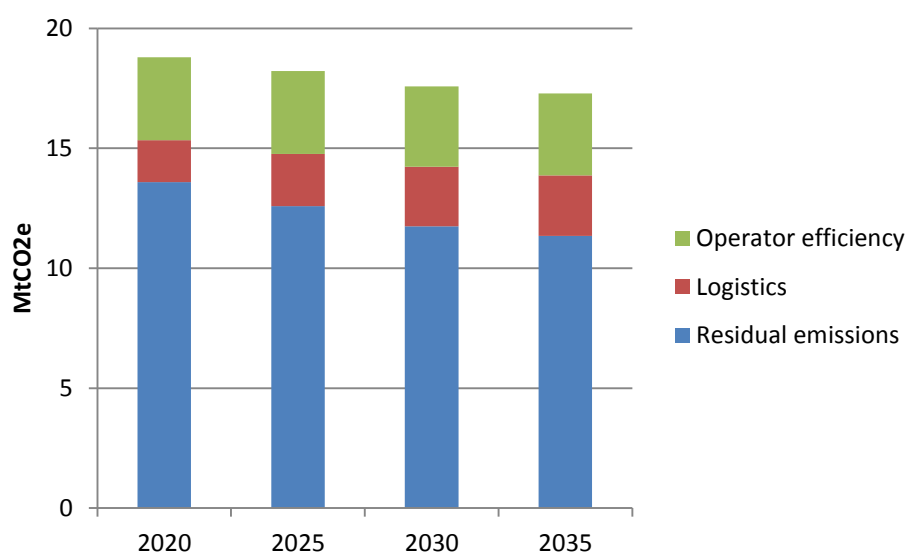
### **1.3 Summary of results**

Our analysis suggests that potential carbon savings from operator efficiency and logistics measures range from 5.1- 6.5 (central case 5.9) MtCO<sub>2</sub> by 2035 versus a baseline scenario in which HGV kms increase and new HGV efficiency improves in line with CCC projections. Table 1 shows the range of potential emissions savings from improved operator efficiency and logistics measures in 2020 and 2035. This represents a saving of 25% (central case) relative to baseline HGV emissions, with around 60% of savings coming from measures to improve operator efficiency and 40% associated with logistics measures. Figure 1 shows emissions savings over time under the central take-up scenario. Actual emission savings will depend on the extent to which non-financial barriers are overcome. The types of barriers considered include: restrictions on the use of high capacity vehicles, policies that restrict vehicle access, and land use allocations, discussed in Section 1.4.

**Table 1: Modelled CO<sub>2</sub> savings from demand side measures in the HGV sector (MtCO<sub>2</sub>)**

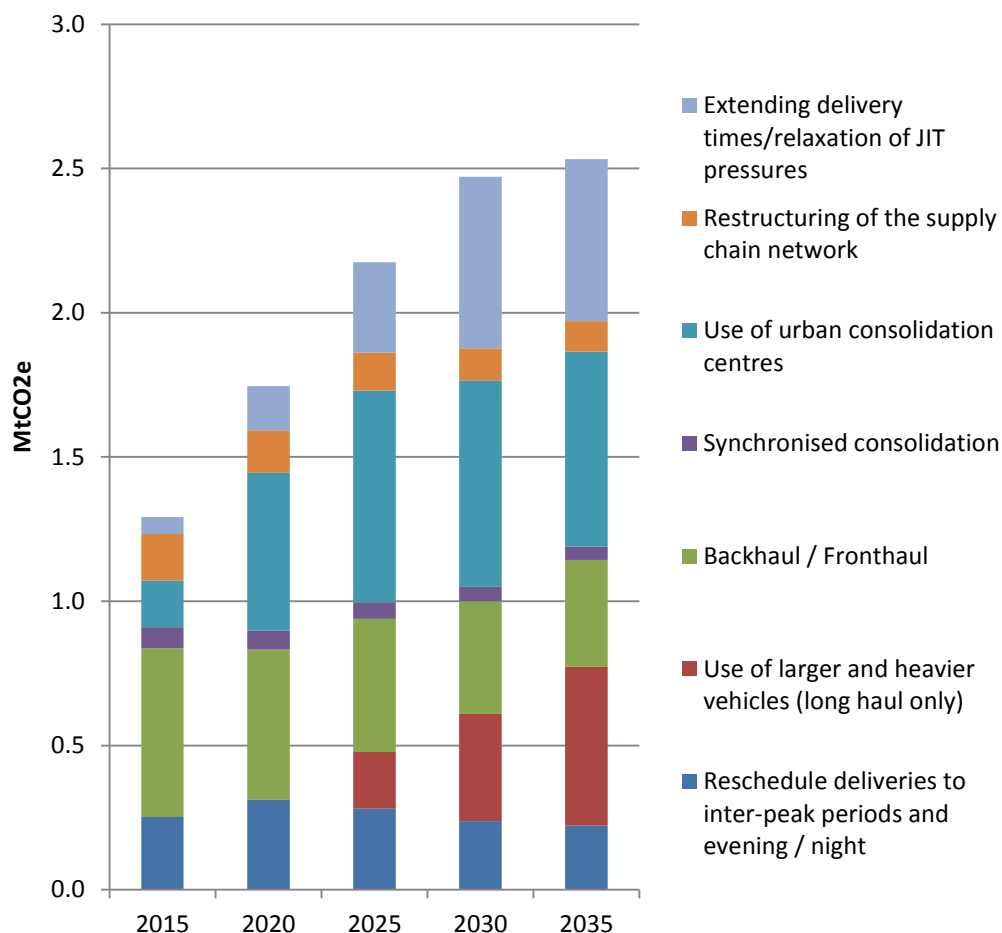
	<b>Operator efficiency</b>	<b>Logistics Measures</b>	<b>Total</b>
2020	2.9 – 3.7	1.7 – 1.8	4.6 – 5.5
2035	3.1 – 3.9	2.0 – 2.6	5.1 – 6.5

**Figure 1: Modelled CO<sub>2</sub> savings from demand side measures – central take-up**



Emissions savings from logistics operations disaggregated by measure are shown in Figure 2. The results show the biggest potential savings are from using urban consolidation centres (0.7MtCO<sub>2</sub>e by 2035), followed by extending delivery times and use of larger, heavier vehicles (0.6MtCO<sub>2</sub>e each by 2035).

**Figure 2: Modelled CO<sub>2</sub> savings from logistics measures – central take-up**



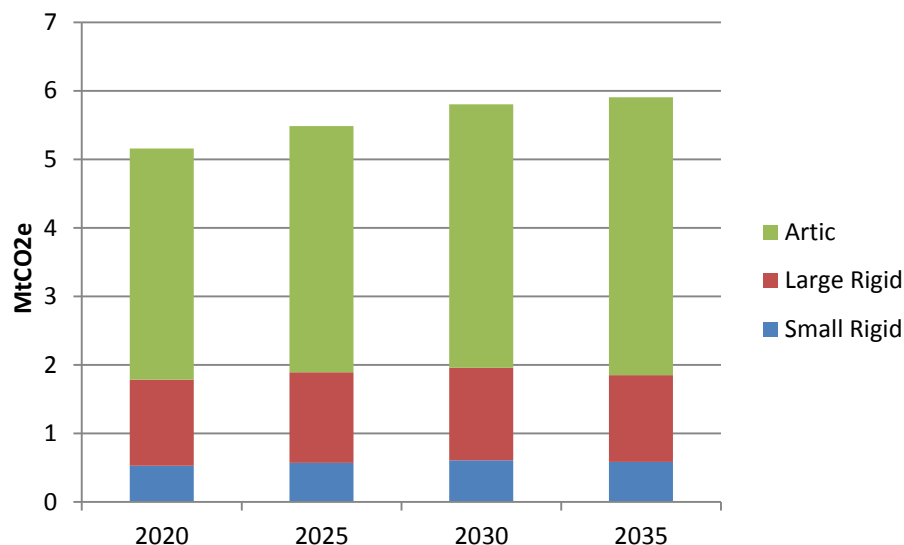
Among the measures to improve operator efficiency, retrofitting technologies to improve HGV aerodynamics, rolling resistance and interventions to improve driving styles had the greatest potential to reduce emissions. Aerodynamic improvements to vehicles and measures to reduce rolling resistance are widely understood by freight operators and are generally found to be cost-effective at DECC projected carbon values and respectively account for 0.5 and 0.4 MtCO<sub>2</sub>e reductions by 2035. Driver training and monitoring have the lowest implementation costs and have significant impact on reducing carbon emissions (2.3 MtCO<sub>2</sub>e by 2035).

Looking at different types of HGVs, articulated trucks on long haul logistics operations have most potential to reduce emissions, largely because they account for a high proportion of HGV kms. This is illustrated in Figure 3.

The sector with the biggest potential for improvement is the hire and reward sector<sup>1</sup>, mainly due to its operational profile. This sector accounts for approximately 50% of the kms driven by articulated trucks, and is not constrained by specific supply chains. Furthermore, success in the hire and reward sector depends on being able to deploy vehicles across multiple contracts.

<sup>1</sup> Hire and reward is generally accepted to mean transport providing firms such as 3<sup>rd</sup> party logistics.

**Figure 3: CO<sub>2</sub> savings from demand-side measures by vehicle type, 2035**



#### 1.4 Non-financial barriers

The logistics operations measures considered in this study will require a number of changes in industry practice. Within eligible sectors and journey types, there is significant potential to implement these measures, but there are a series of non-financial barriers that would need to be addressed in order to achieve the CO<sub>2</sub> savings included in our scenarios:

- Collaborative interventions such as backhaul and synchronised consolidation require common standards of load description, in particular the availability of weight and volume data would enable more collaborative ventures to form. National standards for road freight data could facilitate collaboration and provide a more robust foundation for the calculation of logistics efficiency and more meaningful insights into best practice.
- Demand-side interventions involve collaboration and coordination across HGV operators and between freight owning companies. Successful implementation of these interventions would need to address barriers in data availability, identification of potential collaborative partners, clarification of competition law and the associated allocation of economic benefits. Furthermore, companies have in the past found it difficult to agree on the fair distribution of costs and benefits.
- Longer, heavier vehicles (LHVs) are currently only permitted to operate on UK roads as part of Government trials. More widespread deployment would require regulatory changes, safety concerns to be addressed and logistics networks to be reconfigured. Given the controversial nature of these vehicles, this measure is assumed to have a lower level of deployment than other logistics measures in our scenarios.
- There is little data on freight flows at local authority level, which can mean that local transport plans and land use policies do not adequately address key issues enabling more efficient urban freight solutions. A key example of this is the use of Urban Consolidation Centres (UCCs), which can be very effective at reducing freight traffic and emissions in urban areas. Local authorities would benefit from more guidance and advice on UCCs, with a particular focus on demonstrating the benefits of existing successful schemes, to ensure that they are considered as part of local freight transport strategies and land use policies.

## 1.5 Key findings from the modal shift analysis

Shifting around a third of the longest road freight journeys to a lower carbon mode, such as rail, could result in GHG emission savings of 0.3 - 1.1MtCO<sub>2</sub> but there are a number of barriers that have to be overcome for such a modal shift to materialise:

- Infrastructure and service offering. The mixed-use rail infrastructure in the UK results in timetabling priority being given to passenger trains when capacity is inadequate or disruptions occur.
- Awareness, knowledge, and skills. Environmental considerations are still given too little weight in corporate mode choice decision making.
- Investment cycles. There is a mismatch between the length of the investment cycle for rail and short-term public policy decisions. The longer investment cycles associated with the use of rail and water also conflict with corporate requirements for short payback periods.
- Availability of rolling stock. Changes in commodity mix moved by rail will drive the need for investment in certain type of rolling stock from rail freight operators. For instance, an increase in biomass movements will result in greater demand for covered wagons.

Intermodal rail services to and from deep-sea ports and domestic non-port intermodal services, serving mainly the retail sector, offer the greatest potential for significant growth of the UK rail freight market.

## 1.6 Summary and conclusions

This project found that there is the potential for demand-side measures to reduce emissions by around 34% of baseline HGV emissions by 2035. The bulk of the savings, around 60%, are from measures to improve operator efficiency, with the remainder being from logistics measures.

The extent to which potential carbon and cost savings from improvements to logistics operations are realised in practice depends on a range of other factors including: the way the industry will evolve, future collaboration practices and overcoming the non-financial barriers to measure adoption.

The costs and benefits associated with improvements to logistics operations are highly contextual and therefore cannot be completely generalised. However, the study identified a number of key areas that policy makers might consider to facilitate the transition to more efficient logistics operations. Key areas that would need to be addressed are:

- Improving the availability of logistics data to facilitate collaboration and improved planning operations.
- Clarification of permissible forms of collaboration in the context of anti-competitive regulation.
- The development of strategies to permit the use of longer heavier vehicles.
- Facilitation of land use considerations for urban consolidation centres.

The emissions reductions from logistics interventions reported in this document assume that uptake is not inhibited by lack of appropriate data, anti-competitive regulation, restricted use of LHV's or restricted land use.





## List of Acronyms:

<b>CBA</b>	Cost Benefit Analysis
<b>CCC</b>	Committee on Climate Change
<b>CSRG</b>	Continuing Survey of Road Goods Transport
<b>DfT</b>	Department for Transport
<b>FMCG</b>	Fast Moving Consumer Goods
<b>FTA</b>	Freight Transport Association
<b>GHG</b>	Greenhouse Gas
<b>HGV</b>	Heavy Goods Vehicle
<b>LCRS</b>	Logistics Carbon Reduction Scheme
<b>NPV</b>	Net Present Value
<b>NRTS</b>	National Road Traffic Survey
<b>PP</b>	Payback Period
<b>RHA</b>	Road Haulage Association
<b>SRF</b>	Centre for Sustainable Road Freight
<b>UCC</b>	Urban Consolidation Centre
<b>UK</b>	United Kingdom

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## **2 Background and Context**

Meeting the UK's 2050 GHG emissions reduction target (at least an 80% reduction from 1990 levels by 2050) at a manageable cost will require significant decarbonisation of the transport sector. Road freight is the second largest source of transport emissions in the UK, accounting for 22% (24MtCO<sub>2</sub>e) of surface transport emissions in 2013. This sector has traditionally been viewed as being difficult to decarbonise due to limited scope for electrification, significant barriers to adoption of hydrogen fuel cell vehicles, and limited availability of other power train options.

The Committee on Climate Change (CCC) has developed a trajectory for reducing emissions from road freight, with previous work focusing on supply-side measures which improve the carbon intensity of new HGVs. CCC trajectories suggest technologies such as stop-start systems, improved aerodynamics and vehicle light-weighting could improve new HGV efficiency by around 30% compared to today's levels by 2030. The CCC scenario for the 4th Carbon Budget period (2023-27) also included carbon savings from demand-side measures, such as improved logistics and modal shift. In the central case this scenario includes a reduction of km travelled by road freight of 6.5% relative to business as usual by 2030.

The CCC has commissioned this report to develop a more robust evidence base on demand-side measures to update their scenarios to 2030 and extend them to 2035 as part of their work for the fifth carbon budget (2028-32).

### 3 Scope and approach

This project combines data from both the National Road Traffic Survey (NRTS) and the Continuing Survey of Road Goods Transport (CSRGT) to develop a comprehensive description of the HGV sector (vehicles in excess of 3.5 tonnes), kms driven and tonne-kms, which provided a baseline of key industry characteristics. In order to assess future supply-side changes in this sector we used data provided by the CCC based on previous work by AEA (2012), reflecting improvements in new HGV vehicle technology that are consistent with the CCC scenarios for the 4<sup>th</sup> carbon budget review (2013). This enabled us to develop a baseline of current and future HGV fleet characteristics, running from 2010 to 2035, on which we could model the take-up of three categories of demand-side interventions:

- Technological improvements to existing vehicles reducing the carbon emissions at a vehicle level, for example technologies to improve aerodynamics.
- Measures to promote more efficient driving styles, which can reduce the carbon intensity of a given HGV km, for example eco-driving.
- Improvements to logistics operations from measures such as improved routing, use of consolidation and distribution centres, higher lading factors, a reduction in empty running and use of computerised technologies. These measures reduce emissions by reducing overall distance driven by HGVs – ‘Reduced km’.

Throughout this report, the first two measures, retrofitting technologies and measures to promote efficient driving are termed ‘Operator efficiency’, as they aim to reduce the carbon intensity of a given HGV-km. The third set, which aim to reduce distance travelled through improved logistics, are referred to as ‘Logistics measures’. The impact of these measures was considered under various scenarios to 2035. In addition, illustrative scenarios to 2050 are included to demonstrate the freight sector’s potential contribution to meeting the 2050 GHG target.

#### 3.1 The HGV sector

Our analysis covers HGVs (i.e. rigid and articulated trucks in excess of 3.5 tonnes) and excludes vans. For the purpose of this project, we were given access to an extract of data from the CSRGT from 2004 to 2013, which provided aggregated data on the activities of individual vehicles in a given survey week. The profile of vehicles was then modified with data from the NRTS which include vehicles from Northern Ireland and overseas<sup>2</sup>. The synthesised data provides a comprehensive description of HGV activity in the UK disaggregated by industry sector.

This report adopts the classification of HGVs previously used by the CCC, specifically:

- Small rigid HGVs (<15t gross train weight)
- Large rigid HGVs (>15t gross train weight)
- Articulated HGVs

The drive cycle of each vehicle class plays a significant role in determining which demand side interventions are appropriate for that vehicle. For the purposes of this research small rigids are assumed to be primarily deployed on urban logistics tasks, large rigids on regional distribution, and articulated HGVs on long haul distribution.

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<sup>2</sup> Data provided by the Department of Transport (2014) suggest that foreign vehicles account for 6.1% of road freight transport. Although Northern Ireland also operates a CSRGT NI the data from this source has been excluded from considerations.

### **3.2 Demand-side measures**

Demand-side measures are actions taken by organisations to reduce fuel consumption through improved vehicle utilisation (fuel/km) or to reduce the number of kilometres driven. By contrast, supply-side measures typically refer to technology fitted by manufacturers to new vehicles to improve their efficiency. This distinction allows for consideration of the different decision making processes that might be used by vehicle manufacturers as compared to freight operators. This distinction will be particularly important if GHG emissions from new HGVs are regulated in the future when manufacturer decisions will be influenced by both operator demands and regulatory requirements.

During the course of the project it was recognised that many vehicle operators implement aftermarket technology interventions to reduce GHG emissions (e.g. aerodynamic fairings or low rolling resistance tyres). The classification of these interventions lies somewhere between demand- and supply-side, as they are technological in nature but implementation is the operator's decision, rather than the manufacturer's. It was decided to include these interventions in our assessment of potential emissions reduction.

This resulted in 2 types of demand-side measure we considered for this project:

- Technological improvements to existing vehicles and interventions aimed at improved driving which reduces the carbon intensity of a given HGV km – 'Improved operator efficiency'. This includes use of tear-drop trailers, retrofitting measures to improve HGV aerodynamics and measures aimed at driver behaviour.
- Improvements focused on reducing overall kms driven by HGVs – 'logistics measures'. This includes changes to logistics operations from measures such as improved routing, use of consolidation and distribution centres, higher lading factors, a reduction in empty running and use of information technology.

### **3.3 Evidence base**

In order to model the characteristics of the current and future HGV fleet, a review of existing evidence was undertaken. This provided an assessment of the composition and activity of the current HGV fleet, as well as likely future changes in the fleet due the implementation of new technologies and logistics practices. This section briefly summarises the main sources of evidence used. More detail is provided in Section 4.

The profile and activity of the existing HGV fleet was assessed using the CSRGT data. Within the dataset, vehicles are categorised by vehicle type, and according to 19 different business sectors. Categorising the vehicles in this way allows for the allocation of relevant interventions to the specific drive cycle and sector. This dataset also provides the baseline vehicle-kms for each sector and vehicle type, which are projected forward taking account of economic growth.

The CSRGT provides data on fuel consumption in the survey week. This subset of data may not be fully reliable due to inaccuracies in the data collection. For instance, it does not reflect the amount of fuel in the vehicle at the beginning of the survey period. Baseline fuel efficiency data was therefore derived from a blend of data from Motor Transport, Commercial Motor, the Freight Transport Association (FTA) and Road Haulage Association (RHA) cost tables.

The impacts of different demand-side measures were estimated using the outputs from a series of previous projects carried out by the authors, including:

- **The CO3 project** (Palmer, Saenz et al. 2012) which was designed to develop collaborative logistics models. The research identified barriers and enablers to collaboration but also applied findings of the research into a number of collaborative case studies across Europe.
- **The Starfish project** (Palmer and McKinnon 2011) also explored the potential improvements in logistics operations as a consequence of collaboration. The project drew on detailed logistics activities from 27 companies from the Fast Moving Consumer Goods (FMCG) sector using a model to identify opportunities for improvements as a consequence of various interventions including improved backhaul, synchronised consolidation, and the reconfiguration of logistics networks. The opportunities identified were constrained by realistic factors such as time constraints, and load/vehicle mismatches.
- **The Green Logistics project** (McKinnon 2010) was a collaboration between Leeds, Heriot Watt, Lancaster, Cardiff, Southampton and Westminster universities with the purpose of examining how freight transport could reduce its environmental impact. Specific consideration was given to improving vehicle utilisation and urban distribution.
- **The Longer Heavier Vehicle (LHV) study** was primarily focused on the economic case for longer heavier vehicles although specific consideration was given to safety and society impacts. Within the context of this research the study provides insights into the application of longer semitrailers to different sectors or journey types.

Two focus group workshops were used to complement the data sets described above. The first workshop drew 22 freight owners, freight movers and experts together to discuss the adoption rates of after-market vehicle level interventions, and improvements in logistics operations. The workshop participants were divided into 3 groups with each given a set of interventions to discuss. Facilitators guided the discussion to verify key modelling parameters and their justification. Specifically the delegates were asked to agree on current uptake of improvement measures, the saturation uptake and when the saturation uptake was likely to occur. This information was used to develop adoption curves for interventions included in the model.

The focus group was followed by a questionnaire survey asking the respondents to express their opinion on:

- The current penetration of each measure included in the model
- When will each measure reach maximum penetration
- What is the maximum penetration of each measure likely to be

22 useable responses were collected, and combined with data obtained from the focus group discussion, previous project and academic literature to provide inputs into the model.

The second workshop was focused on the potential impact of mode shift on road freight transport. This workshop comprised 19 freight owners, rail freight movers and rail and waterborne transport experts. Both workshops comprised 3 stakeholder groups: academics, operators, and solution providers.

### 3.4 Modelling framework

As mentioned above, the starting point of our analysis was the development of the current and future characteristics of the HGV fleet, broken down by sector, vehicle type, and geographical

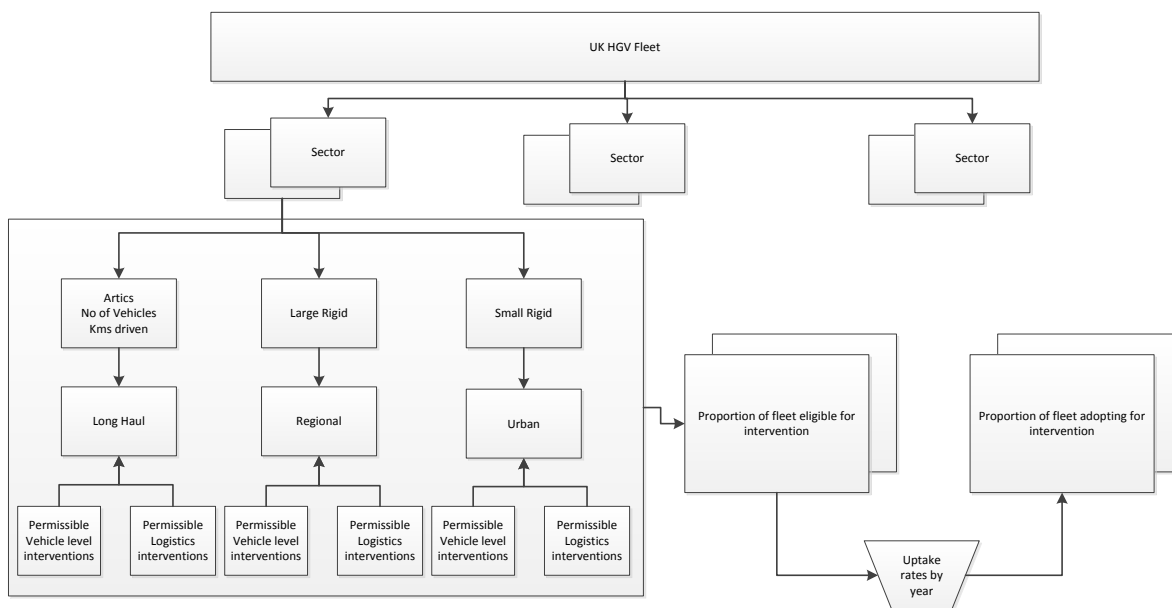
journey type. We used an existing model developed by the Centre for Sustainable Road Freight (SRF) to assess the commercial viability of vehicle level measures to improve operator efficiency. The model inputs fleet profiles (by vehicle type, fuel used and kilometres driven and logistics tasks undertaken), and calculates the carbon and financial implications of each intervention. The interventions can be prioritised according to payback period (PP) and cost-effectiveness (NPV). Finally the model allocates interventions in a stepwise manner to incorporate the compounding effect of multiple interventions.

The model was extended for this project in several ways:

- GB fleet operations were incorporated by including commodity sectors into the vehicle/ logistics operation matrix.
- The timeframe of the model was extended to 2035, with variables such as projections of kms driven taken from DfT's National Transport Model (NTM<sup>3</sup>).
- Fuel prices and uptake of supply side interventions for new vehicles were based on data provided by the CCC, and previous research by AEA (2012).

The resulting conceptual framework of the extended model is shown in Figure 4.

**Figure 4: Model conceptual framework**



### 3.4.1 Modelling uptake and costs of demand-side measures

In order to adequately characterise uptake rates of the different demand-side interventions, it is necessary to develop an understanding of current adoption, maximum penetration of the intervention, and the likely date of maximum penetration. There is little information with which current uptake rates can be profiled across the GB fleet. The uptake rates assumed in the analysis came from a survey supported by the focus group discussion. Where possible, the outputs were also validated against existing research. More detailed descriptions of the outcomes from the survey and focus group discussion can be found in sections 5 and 6.

<sup>3</sup> It should be noted that different generations of NTM forecasts, reported in DfT's publications, under different scenarios have led to estimates that are subject to relatively wide confidence intervals.



The model assumes that commercial decisions are made based on the NPV of an investment over a specific PP. Calculation of the PP and NPV requires inputs of costs, savings and residual values. Appendix 1 sets out how these are estimated. Where vehicle level interventions are cost-effective, the model adopts measures that are the most cost-effective first, which reduces the amount of money that can be saved from further investments making them less attractive. This iterative approach ensures that interactions between measures are taken into account.

Costs associated with operational interventions (such as use of consolidation centres, front/back hauling, extending delivery times) are very sensitive to the nature of the logistics activity, thus specific to company contexts. As a consequence the model does not estimate the costs associated with operational interventions as they cannot be generalised. Instead, these interventions were only applied to appropriate sectors/routes and at a level judged to be feasible by freight operators who provided evidence for this research. Therefore, while a full cost-benefit analysis was not possible for these measures, it is thought that they are within range of being commercially cost-effective.

### 3.5 Scenario development

Given uncertainty in key factors affecting the decision of HGV operators to take-up the demand-side interventions, we developed a number of scenarios to reflect the impact of these measures under different states of the world. The scenarios reflect uncertainty in key drivers of the analysis such as discount rates, pay-back periods, fuel prices and take-up rates.

Take-up of measures that improve operator efficiency (e.g. retrofitting technologies and eco-driving) were modelled from both a commercial and social cost benefit perspective. In the commercial case we assume discount rates of 10%, standard PP of maximum 3 years (with a sensitivity around this of 2 years to reflect more competitive, low margin sectors), and retail fuel prices. Measures are assumed to be taken up if they have a positive NPV. As well as the pure commercial decision to undertake a measure, we assess whether there are non-financial barriers such as lack of information or competition from alternative business investments that can prevent operators from undertaking investments. This resulted in three different take-up scenarios.

In the social cost-benefit analysis we use assumptions in line with HMT Green Book guidance – a 3.5% discount rate and long-run variable fuel costs and carbon prices in line with DECC assumptions (Treasury 2013). The resulting social NPV is the sum of all monetised costs and benefits, discounted to the base year chosen. Within this NPV will be a valuation of the changes in GHG emissions resulting from the proposal. If the NPV is positive the policy is estimated to provide a net monetised benefit, and conversely if the NPV is negative, then the policy is estimated to result in an overall monetised cost to society. If a measure is socially cost-effective (i.e. has a positive NPV) but is not being implemented for some reason, Government intervention may be warranted to promote its uptake.

Three basic scenarios were constructed:

- **Baseline scenario** - What happens to emissions in the absence of demand-side measures to improve logistics operations and reduce HGV kms. This scenario takes into account improvements in new vehicle efficiency, in line with CCC assumptions, from 2010 to 2035. This provides a baseline against which other scenarios are compared, and includes variables such as vehicle-kilometres, fuel used, and CO<sub>2</sub>e emissions.

- **Commercial scenario** – This assesses the cost effectiveness of aftermarket vehicle and logistics improvements from a commercial perspective. This includes sensitivities on fuel prices, pay-back periods and up-take rates.
- **Social cost scenario** – This assess which measures are socially cost effective under the assumptions detailed above. This includes three sensitivities around the fuel price, assuming the central take-up rate.

The modelled scenarios and sensitivities are set out in Table 2.

**Table 2: Parameterisation of key scenarios modelled**

Scenario	Fuel price (taxed) Low, Medium, High	Fuel cost (untaxed) Low, Medium, High	Carbon price Yes/No	Discount rate Social/Commercial	Maximum payback period (years)	Uptake rates Low/Central/High
<b>Commercial</b>	H		N	C	3	C
	M		N	C	2	C
	M		N	C	3	C
	L		N	C	3	C
	M		N	C	3	H
	M		N	C	4	L
<b>Social</b>		H	Y	S	7	C
		M	Y	S	7	C
		L	Y	S	7	C

### 3.6 Key parameters considered

The key parameters that are varied across the scenarios are:

- **Fuel prices.** These are based on DfT analysis of DECC oil price projections. In the central case oil prices rise to \$135pb by 2035 with a range of \$75pb in the low scenario and \$190pb in the high scenario. These are used as a basis for calculating the retail prices for the commercial scenarios and long-run variable fuel costs in the social cost benefit scenario.
- **Carbon prices.** The cost of carbon used in the social cost benefit analysis is in line with DECC's central carbon price assumptions, which rise to around £80/tCO<sub>2</sub>e by 2030.
- **Discount rates.** These are assumed to be 10% in the commercial scenarios, reflecting typical rates for commercial investments, and 3.5% in the social cost-benefit scenarios, based on the social time-time preference rates in HMT Green Book guidance.
- **Payback period.** As well as the NPV calculation, which estimates the monetary value of the discounted future stream of costs and benefits, we also use the PP as a measure to assess whether the intervention is worthwhile. The PP is the time allowed to recover the costs of the investment; if an investment takes longer than this to pay back then it will not be adopted. We assume PP of 3 years in the central case, which is commonly used to assess commercial investments, with a sensitivity around this of 2 years, reflecting more stringent investment criteria which could be used in more competitive, low-margin sectors.. The social CBA assumes that benefits and costs accrue over the life-time of the vehicle assumed to be 7 years.
- **Eligibility.** It is not appropriate to apply the demand-side interventions to all types of HGV operation, sectors, or pay-loads. Eligibility for an intervention is defined by the appropriateness of the intervention to the vehicle type, the logistics task being undertaken (urban, regional or long haul), and the industry sector. For instance the model assumes that only certain sectors using articulated trucks on long haul duties are eligible to benefit from improvements in the level of backhaulage. Only a proportion of this eligible fleet are likely to adopt this measure in any year, this is reflected in the uptake rates derived from surveys and workshops.

- **Take-up rates.** As well as the pure financial investment criteria used in the analysis, take-up of measures will be subject to a number of non-financial barriers that would need to be overcome in order for the investment to go ahead. This is particularly true of the measures designed to reduce HGV-kms. Many of the interventions identified by this report require intra-or inter-organisational collaboration which adds complexity to business processes and can reduce a collaborating organisation's ability to react to changes in its market. The risk associated with collaboration therefore presents an additional barrier to investments in logistics improvements. Some measures impact on other stakeholders. For instance, the relaxation of time constraints permitting night-time deliveries in urban areas presents potential problems with regard to nuisance noise. To reflect these issues, 3 different take-up rates are used in this study, which are assumed to increase over time up to maximum saturation levels of 95% in the central case, 90% in the low and 100% in the high scenario. The speed with which these levels are achieved also varies in the low and high scenarios. These take-up rates are discussed further in Section 4.

### 3.7 Summary

- We have developed a model of the HGV sector in GB, Northern Ireland and foreign operated vehicles in the UK based on DfT road traffic data and the CSRG.
- This model applies CCC assumptions on the efficiency improvements to HGV vehicles to 2035.
- This provides a baseline characterisation of the HGV fleet to 2035 which we use as a basis for assessing the impact of demand-side interventions.
- Two types of demand-side measures were modelled: measures to reduce fuel-intensity ('improved operator efficiency') and measures to reduce HGV-kms ('reduced kms'). The former includes aftermarket intervention to vehicles.
- We have constructed scenarios to assess the cost-effectiveness of the interventions in terms of NPV and PP.
- Commercial and social cost-benefit analyses scenarios are used to estimate the levels of adoption of vehicle-level measures to improve operator efficiency..
- Sensitivities around fuel prices, carbon prices, PPs and up-take rates are tested.
- The level of adoption of logistics measures is determined by the eligibility of different types of freight activity and by different uptake rates, reflecting the extent to which non-financial barriers prevent their adoption.

## **4 Evidence underpinning scenario development**

In this section we provide an overview of the structure of the HGV sector, recent trends in distance travelled and take-up of technologies aimed at improving HGV logistic operations. We then review existing evidence about the impact of logistics measures and set out the assumptions used in our modelling. We also assess the role of aftermarket technical vehicle-level interventions, set out how we have incorporated these into the model and the key assumptions around these. Finally we consider the evidence regarding measures to change driver behaviour, and the assumptions we have made in the model.

### **4.1 Composition of the HGV sector**

DfT's Continuing Survey of Road Goods Transport (CSRGT) provides a source of data of the HGV sector – in terms of trends in kms driven, fuel used, types of trucks driven and trends in vehicle utilisation. We have used data from the 2008-2013 surveys to provide an overview of the sector, which provided a benchmark on which we could develop our assumptions of eligibility and take-up of measures aimed at reducing kms driven. Note however, that the methodology DfT use to process CSRGT data changed in 2011 therefore comparisons over time should be treated with caution<sup>4</sup>.

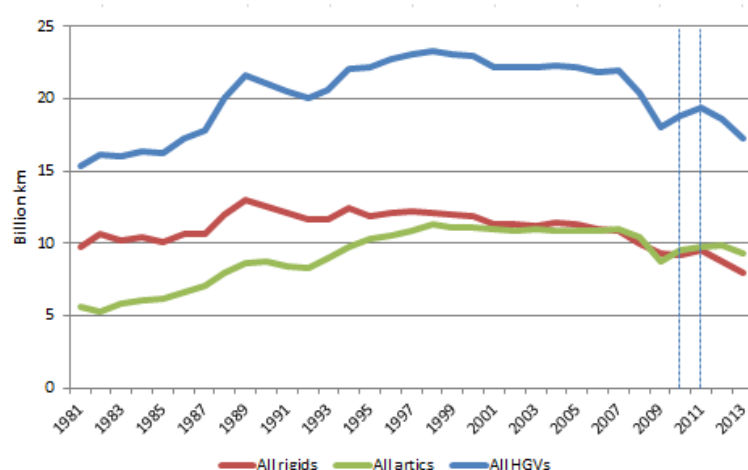
The total distance travelled by HGVs remained relatively stable between mid-1990s and mid-2000s, but declined sharply in 2009 following a fall in manufacturing output. Distance travelled re-bounded slightly in 2010 but fell again between 2012 and 2013. Over the same period both goods lifted and goods moved (tonne/kms) fell by 7%.

There has been a change in the composition of HGV traffic (Figure 5) over the last few decades. Whilst distance travelled by articulated HGVs has grown from the early 1980s to 2007, HGV kms travelled by rigid vehicles have declined.

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<sup>4</sup> Further details can be found at [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/405230/rfs-notes-and-definitions.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/405230/rfs-notes-and-definitions.pdf)

**Figure 5: Kilometres driven in the UK by GB-registered HGVs**

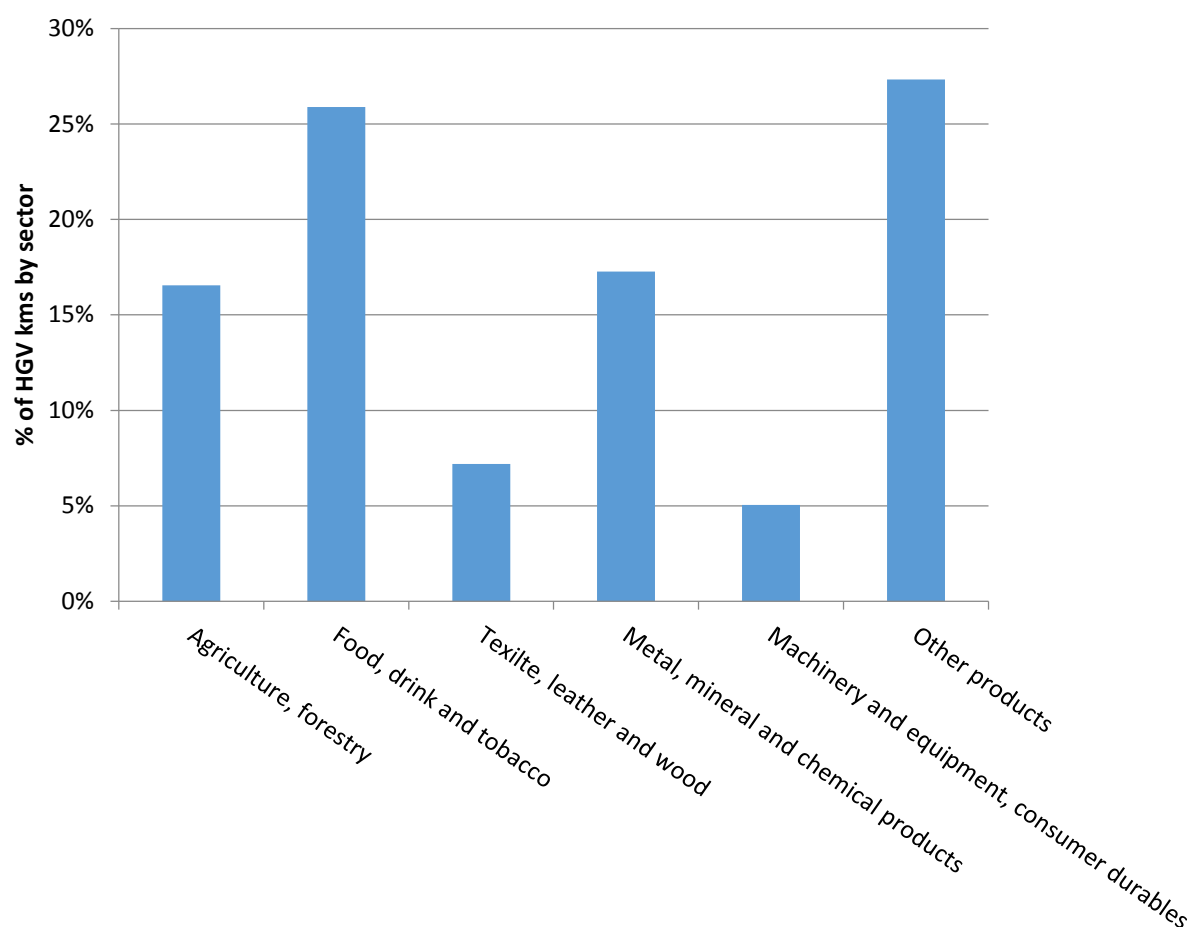


Source: CSRG

The trend in distance travelled is mirrored in the amount of goods moved. Since 1990 the amount of goods moved by rigid vehicles has decreased by 24% compared to a 20% increase in the amount of goods moved by articulated vehicles. While the amount of goods moved by rigid vehicles as a whole decreased, goods moved by large rigid HGVs (over 25 tonnes) increased by 66% between 1990 and 2013. Therefore there has been a clear shift towards using larger vehicles in this sector. Moving freight in bigger vehicles improves economic and environmental performance if operators are able to ensure high levels of vehicle utilisation. The shift towards bigger vehicles was accompanied by an increase in the average payload weight, resulting in long-term improvements in the carbon intensity of road freight movements in the UK (Piecyk and McKinnon, 2013).

Looking at goods moved by the commodity group (Figure 6), in 2013 the largest share of goods moved was 'Other products' (27%) which includes waste related products and grouped goods. The second most common group was 'Food products' (26%).

**Figure 6: % of freight distance travelled by sector, 2013**



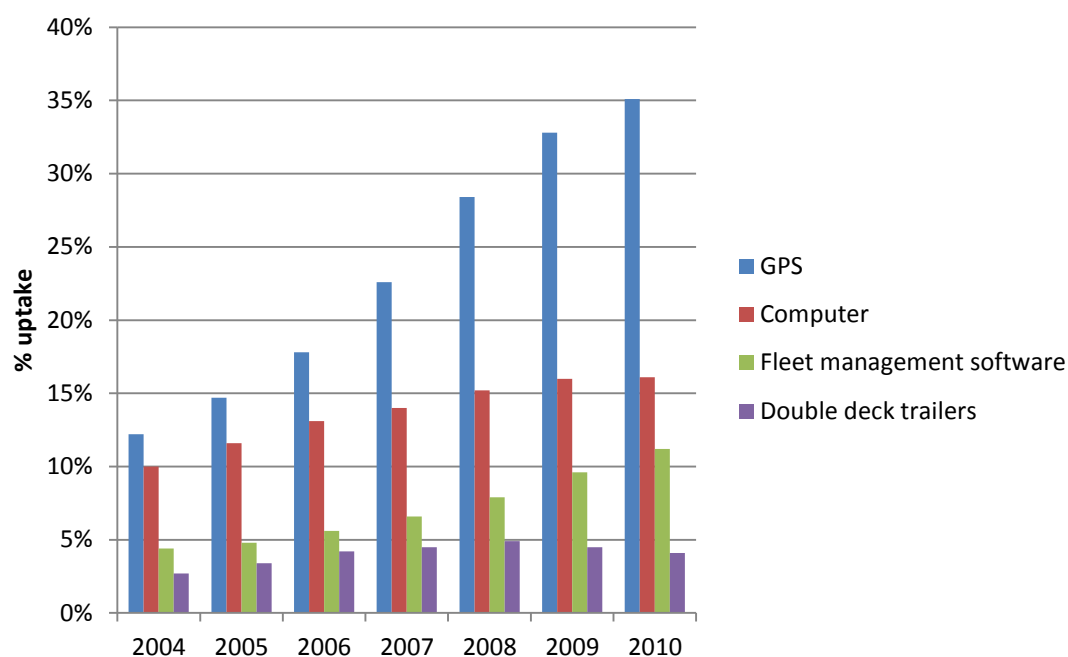
Source: CSRG

#### **4.2 Uptake of measures to reduce freight distance travelled**

Measures which have the potential to reduce distance travelled by road include technologies to improve routing; improve vehicle fill and changes in logistics operations such as synchronised consolidation, reconfiguration and logistics networks, use of higher capacity vehicles and use of urban consolidation centres. Recent trends in these are considered below.

There is some evidence of an increasing use of measures to improve routing amongst HGV operators. Between 2003 and 2010 the proportion of vehicles fitted with on-board computer systems, GPS systems and/or telematics in the freight sector grew sharply, increasing year on year for all measures (Figure 7).

**Figure 7: Use of technology measures in freight logistics 2004-2010**



Source: CSRG T (2010)

Vehicle lading can be increased through, for example, use of double deck trailers, back-loading of deliveries, use of consolidation centres, and horizontal collaboration between operators. Data show that uptake of double deck trailers amongst articulated vehicles increased between 2004 and 2010, from 2.7% of vehicles to 4.1% (Figure 7).

Over the same period there has been an upward trend in empty running of vehicles. The proportion of HGV kms running empty increased from 27% in 2004 to 29% in 2013 (DfT, 2015). This increase may be partly attributed to a tightening of delivery time constraints. Both empirical and simulation studies have shown that time constraints impede efforts to reduce empty running and load consolidation (McKinnon and Ge, 2006, Cherret et al, 2012). On the other hand, recent CSRG T data indicate that the average loading of laden vehicles appears to be improving, despite an increase in scheduling constraints. This increase in average load factors may be due in part to a greater use of higher capacity vehicles in some sectors.

The retail sector tends to be more time constrained than most and the low density of freight carried means it is suitable for the use of high capacity vehicles. CSRG T data show that whilst the use of double-deck trailers has increased in this sector, this has been accompanied by the rise in the level of empty running (2010-2013). Evidence shows that over 70% of operators within the voluntary Low Carbon Reduction Scheme (LCRS) have taken action to improve vehicle fill on laden trips, over 50% have made greater use of double deck/high cube vehicles, and just under 40% have consolidated loads on longer and/or heavier vehicles (FTA 2015). However, LCRS membership covers only a small fraction of the HGV fleet.



Most of the existing UK focused literature addresses the levels of benefits that can be achieved in specific sectors (i.e. FMCG) or types of operation and fall short of any global assessment of uptake. Surveys in the United States undertaken by NACFE (2014) have monitored the rate of adoption of a range of technical and operational fuel saving interventions in the trucking sector over the past decade. Table 3 summarises the uptake rates of interventions to reduce kms driven in the United States (NACFE, 2014). Although the US experience generally supports that of the UK, one must exercise caution in extrapolating from the US experience to the UK because of fundamental differences in the geography of the two countries, the level of fuel prices and the nature of their road freight markets.

**Table 3: NACFE 2014 uptake rates**

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Limit speed</b>	85%	85%	85%	85%	85%	85%	90%	90%	90%	90%	90%
<b>Reduce empty running</b>	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
<b>Driver training</b>	85%	85%	85%	85%	85%	85%	85%	90%	90%	90%	83%
<b>In Cab driver feedback</b>	50%	50%	50%	50%	50%	50%	50%	50%	50%	60%	42%

Source: NACFE (2014)

### 4.3 Evidence on the potential impact of logistics measures

The previous section looked at overall trends in uptake of measures aimed at reducing HGV kms demand. Whilst these provide an overall picture of recent trends, they do not provide evidence of the total potential that exists in different sectors to reduce kms driven through measures such as synchronised consolidation; reconfiguration of logistics networks; use of higher capacity vehicles; and the use of urban consolidation centres. The following sections aim to do this by setting out the evidence base for these interventions drawing on existing literature, surveys carried out in support of this research and focus group discussions.

#### 4.3.1 Reduce empty running

There are two primary sources of research into backhaul opportunities in the UK. The first considers grocery distribution (McKinnon and Ge, 2006) and the second (Palmer and McKinnon 2011) concentrated on the Fast Moving Consumer Goods (FMCG) sector (Starfish). It should be noted that there is a high degree of overlap between these sectors.

McKinnon and Ge (2006) conducted a retrospective analysis of over 20,000 HGV trips, 9,000 of which were empty. The analysis focused on 573 of these trips which were over

100km long. This filtering criterion was developed from a survey of operators amongst whom there was wide acceptance that backhauling opportunities on shorter journeys were harder to justify. The empty journeys were filtered again to remove capacity and vehicle specificity mismatches. Capacity mismatches reflected situations where the backhaul opportunity could not be accommodated by the vehicle due to weight or volume constraints. Specificity mismatches reflect situations where specialised vehicles had been used on the outbound journey but are not suitable for the potential backhaul. McKinnon and Ge (2006) concluded that approximately 2% of empty journeys could be backhauled resulting in a 2% reduction in kms driven.

In contrast, the Starfish research identified a perceived opportunity to reduce kms driven by 7.9% through backhauling (Palmer and McKinnon, 2011). This could be achieved if time constraints were relaxed, permitting a greater coordination of delivery and pickup windows and hence greater exploitation of backloading opportunities. Therefore, our scenarios assume a 7.9% reduction in kilometres and an 8.2% reduction in fuel used<sup>5</sup> as a consequence of implementing backhaul operations (Palmer and McKinnon 2011), though this is contingent on the relaxation of time constraints (discussed later in this section). Whilst this evidence is generally a reflection of the retail sector no alternative evidence was found from other sectors, and consequently these improvements have been applied to all sectors where the expert panel considered the measure to be applicable (i.e. backhauling was not considered appropriate for the construction sector in the model).

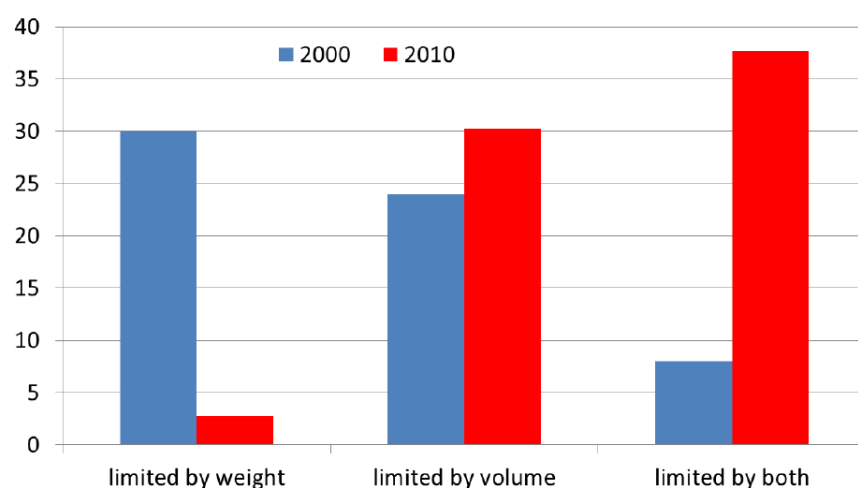
#### **4.3.2 Load consolidation**

The Transport Key Performance Indicator (KPI) surveys, commissioned by the UK government between 1997 and 2009, collected large amounts of data on the utilisation of vehicle capacity on laden trips across six sectors (McKinnon and Piecyk 2009). Unlike the CSRG, these surveys monitored not only the proportion of weight carrying capacity used, but also the utilisation of vehicle floorspace (or 'footprint'), as well as cubic capacity utilisation. It is important to supplement weight-based measures of loading with volumetric assessments as a large proportion of loads 'cube-out' or 'floor-out' before they reach the maximum weight limit. Figure 8 profiles HGV journeys in terms of weight and volume. The KPI surveys revealed significant underloading of lorries both in terms of weight and volume, suggesting the potential exists to increase vehicle load factors by between 30-50%. This is supported by CSRG data on the proportion of HGV tonne-kms subject to weight and/or volume constraints in 2010; around 70% of tonne-kms moved in trucks were constrained by weight and / or volume, increasing from 61% in 2001. Whilst this provides a limit to the additional potential to improve HGV utilisation, there are other constraints on a company's ability to increase vehicle lading. Figure 9 shows 10 of the main factors constraining vehicle loading, classified into five categories (McKinnon, 2014). Whilst most of these constraints can be overcome, relaxing them will, in some cases, require fundamental changes in business practice, regulation and equipment. Over the 20 year time-frame for the fifth Carbon Budget, such changes are feasible.

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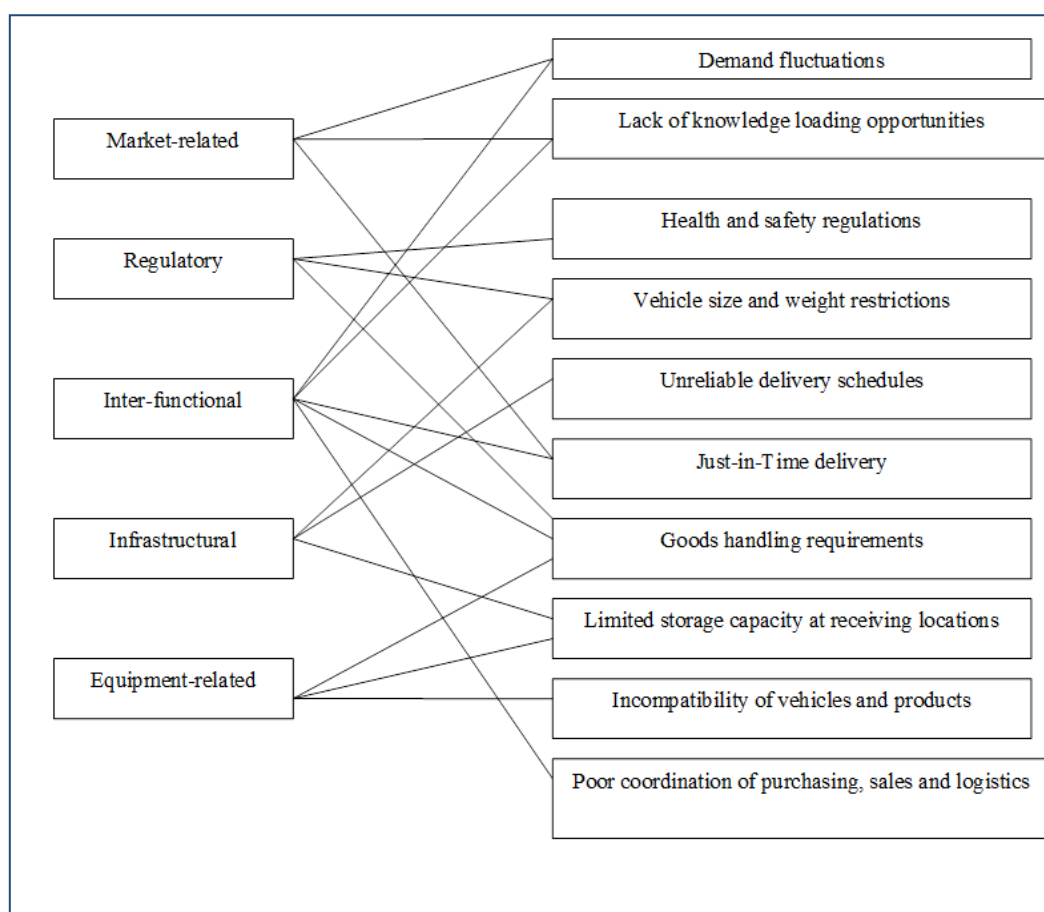
<sup>5</sup> Fuel savings do not correspond directly to km savings because different vehicles with varying fuel efficiency may be used for backhauls.

**Figure 8: Proportion of HGV tonne-kms limited by weight or volume.**



Source: CSRG

**Figure 9: Main factors constraining the loading of HGVs**



Source: McKinnon, 2014

The factors listed in McKinnon (2014) relate to individual businesses trying to raise their vehicle load factor in isolation. Where companies collaborate and are prepared to share vehicle capacity, the opportunities for improving utilisation are significantly enhanced. This was demonstrated by the modelling work undertaken by the Starfish project. In the most basic of the collaborative scenarios modelled by the Starfish project (Palmer and McKinnon

2011) combining part loads moving between origin and destination zones (i.e. synchronised consolidation) reduced HGV-kms by roughly 1% and fuel consumption by 0.8%. Other more radical scenarios, involving the channelling of freight through regional consolidation centres, yielded around 5% savings in both HGV-kms and fuel consumption. Our scenarios assume a 1.0% reduction in kilometres and an 0.8% reduction in fuel used, in keeping with the Starfish project findings

#### **4.3.3 Urban Consolidation Centres (UCCs)**

An UCC is a logistics facility that is situated close to an urban area that it serves, for instance a city centre or a specific site such as a shopping centre, airport or hospital. Goods to these locations are dropped off at UCC by logistics companies, where they are sorted and consolidated to be delivered to final destinations. By improving the loading factor of goods vehicles making final deliveries in congested locations, UCCs can reduce the total distance travelled in urban areas. However, as UCCs add an extra node and link to the supply chain, they can increase delivery costs (Browne, Sweet et al. 2005, Cherrett, Allen et al. 2012), which need to be balanced against other benefits.

Recent research has revealed a number of benefits derived from UCCs (Allen, Browne et al. 2012). These include increases in loading factors (by 15 to 100%), reductions in vehicle kilometres of between 60 and 80% and reductions in GHG emissions of between 20 and 80%. Co-benefits of urban freight consolidation include reduced congestion as a consequence of higher loading factors and in some cases a reduction in the time taken to make a delivery. These reductions apply to the urban logistics component of the supply chain (sometimes referred to as the last mile logistics) and do not reflect the impact of urban consolidation centres on the whole supply chain. The Starfish project modelled the impact of UCCs in the more holistic supply chain context identifying potential of approximately 3.7% reductions in GHG emissions and 4.3% in kms saved across the supply chain. Our scenarios assume a 4.3 % reduction in kilometres and an 3.7% reduction in fuel used

Whilst costs of UCCs have not been taken into account in this project, there is a general consensus in the literature that the increased handling associated with UCCs, coupled with the difficulty of coordinating logistical activities across organisational boundaries requires external financial support in the short term (Boerkamps and Van Binsbergen 1999, Patier 2006, TTR 2007). Participation in an urban consolidation scheme can also be incentivised in other ways by, for example, granting privileged access to bus lanes and partial exemption from delivery restrictions. Consequently the impact of this measure has been constrained within the model to those sectors where the benefit has been demonstrated and widely accepted (i.e. in the construction, hire or reward, public services, recycling and wholesale trade sectors).

#### **4.3.4 Higher Capacity Vehicles**

The use of higher capacity vehicles provides an opportunity to deliver more freight in a single journey, reducing fuel consumption and GHG emissions per tonne-km of freight movement. Estimates of the GHG reduction potential associated with higher capacity vehicles depend on the size of vehicles and type of goods being transported. A study conducted by TRL suggested that carbon intensity could be reduced by up to 13% for one longer and heavier vehicle configuration (Knight, Newton et al. 2008). An analysis in Sweden found that if the country did not operate longer and heavier vehicles (up to 25.5 metres and 60 tonne

capacity) kilometres travelled would increase by 25% and GHG emissions by 6% (Vierth, Berell et al. 2008). Some indication of the difficulty surrounding estimates of carbon reductions from the use of higher capacity vehicles can be found in the variety of estimates of changes in fuel consumption. Tunnel and Brewster (2005) found between 4 and 27% reductions in fuel consumptions. Other estimates (OECD 2010, McKinnon 2012) generally support this wide range of savings.

A possible negative impact of increasing the capacity of road vehicles is that it could reduce the competitiveness of rail and therefore incentivise the shift from rail to road (Knight et al, 2008), although this impact could be mitigated by increasing the maximum length of HGVs but not their weight limit. However, even once allowance is made for some modal shift from rail to road, there are still significant net GHG savings.

For the purposes of this project a 13.9 % reduction in kms driven was assumed in sectors where the use of higher capacity vehicles was appropriate, this is in keeping with the findings of the Starfish project and consistent with the findings reported from other research

#### **4.3.5 Relaxed time constraints**

Legal limits on driving time determine the maximum number of destinations that can be visited on a single trip. Distances and congestion also play a significant role in limiting the number of deliveries and collections than can be made on a trip, and hence the vehicle loading. However, little attention has been paid in the literature to the impact of dwell times at destinations, i.e. the amount of time it takes to load / unload a vehicle and sort out any related administration. (Cherrett, Allen et al. 2012) argue that 30 minutes should be allowed for the average articulated delivery, 20 minutes for rigids and only 10 minutes for vans. Accelerating delivery reception processes at factories, warehouses and shops can reduce these times, increasing the number of drops / collections per delivery and thereby cutting the number of trips. According to Anderson et al (2005), for example, removing access restrictions on the permissible delivery times would make it possible to reduce GHG emissions by up to 7%.

Akyol and Koster (2013) developed an intermediate strategy whereby local time constraints could be respected and the logistics efficiency improved through the coordination of time constraints over extended geographies. For example, time constraints inside Manchester city centre could be coordinated with time constraints in Salford to produce carbon savings whilst respecting the social benefits yielded by delivery constraints at particular times of day.

The impact of relaxing time constraints is difficult to predict as the benefit amplifies the effect of other logistics improvement measures which have already been implemented. However, it was assumed that relaxing time constraint would reduce the kms driven by 3%.

#### **4.3.6 Restructuring the supply chain network**

This report characterises logistics into three types of activity: long haul distribution, regional distribution and urban distribution. The different distribution types reflect different supply chain structures. For example long haul distribution is concerned with inter-regional movements between factories and warehouses. Urban distribution involves mainly local delivery within urban areas or short-range movements to/from nearby distribution centres.

Irrespective of the logistics activity focus, reconfiguration of supply chain networks is generally framed as an optimisation problem with the objective function of minimising overall costs to a focal company. Supply chain costs are generally considered to comprise inventory, storage (warehousing) and transport elements. Optimising the number of warehouses in a logistical system involves trading off these three cost elements to minimise total costs within customer service constraints.

Insights into the benefits of redesigning the supply chain network can be found in practitioner literature and in a database maintained by the Institute of Grocery Distribution. However, supply chain reorganisation occurs rarely and carbon reduction benefits are not often reported. Despite this, Tesco have recently reported an 8% improvement in CO<sub>2</sub> emissions as a consequence of reorganising their distribution network. In the absence of alternative generalizable evidence this study assumes that most supply chains are routinely optimised and reductions in kms driven as a consequence of restructuring are modest (1.5%).

#### 4.3.7 Rescheduling of deliveries to inter-peak periods

Palmer and McKinnon (2011) showed that making deliveries outside the peak periods avoids congestion thereby reducing travel time by up to 16%. This infers that less load plans will be time constrained resulting in higher load factors and fewer journeys resulting in a 3% reduction in kms travelled. Further reductions in kms travelled are possible if relaxed time constraints permit the extension of the journey plan to incorporate more destinations.

The impact of congestion avoidance on vehicle fuel efficiency is hard to quantify in terms of carbon abatement as the fuel efficiency of a vehicle is highly dependent on the number of acceleration and deceleration cycles experienced. Acceleration and deceleration cycles are more prevalent in congested conditions.

For the purpose of this study it is assumed that benefit of rescheduling deliveries to inter-peak periods will result in a 4.25% reduction in kms travelled. This level of reduction reflects both the reduction in kms driven as a consequence of better vehicle fill and the reduced number of journeys as a consequence of more efficient journey plans.

#### 4.3.8 Summary of Logistics measures take-up assumptions

A summary of the assumptions used for the logistics measures in this project are shown in Table 4.

**Table 4: Logistic measures central case uptake assumptions**

Logistics Measures	Percent of total HGV km eligible for measure	2010 uptake on eligible km	2020 uptake on eligible km	2030 uptake on eligible km
Reschedule deliveries to inter-peak periods and evening / night	30%	1%	100%	100%
Use of larger and heavier vehicles	55%	0%	0%	72%
Reducing Empty running	79%	66%	100%	100%

<b>Synchronised consolidation</b>	78%	66%	100%	100%
<b>Use of urban consolidation centres</b>	83%	1%	55%	100%
<b>Restructuring of the supply chain network</b>	86%	55%	100%	100%
<b>Relaxation of time constraints</b>	85%	1%	6%	100%

The percentage of total HGV km eligible for each measure is calculated from the CSRG T data using vehicle and journey type eligibility criteria and the number of km driven by different vehicle types on different journeys. An uptake rate of 100% means that 100% of eligible HGV kms are affected.

The take-up assumptions used above were derived from both the literature review and focus group responses carried out as part of this research. However, there is still a lot of uncertainty about take-up rates, for example because the sectors are quite aggregated and take-up may not be applicable to all parts of the sectors, the extent to which operators overcome non-financial barriers in taking up these measures, and whether these prove to be cost-effective for operators in the future. To reflect this uncertainty, we develop high and low take-up rates around this central case to reflect possibilities that a given measure won't always be applicable to every single vehicle and journey in that category. For example, there could be a percentage of journeys which are only just long enough to fall into long-haul category and therefore might not be long enough to justify the expense of measures being implemented.

#### 4.4 Technological improvements to existing vehicles

Technological improvements to new HGVs have been incorporated into the baseline for this project, and are in line with CCC assumptions based on take-up rates based on AEA (2012) research. In the short term, similar technologies can be deployed by operators for existing HGVs as an additional abatement measure. Evidence on the current uptake of such measures is limited, but formed a significant component of the survey and focus group activity undertaken as part of this research. A summary of the focus group and survey findings is provided in Table 5.

**Table 5: Take-up rates for logistics measures, central commercial scenario.**

Retro-fit measures	2010			2030		
	Small rigid	Large rigid	Artics	Small rigid	Large rigid	Artics
Use trailer with sloping front roof (double deck/high cube vehicles)	0%	0%	2%	0%	0%	15%
Use tear-drop trailers	0%	0%	1%	0%	0%	5%
Reduce engine idling	0%	0%	0%	53%	53%	53%
Switch from powered to fixed-deck trailers	0%	0%	1%	0%	0%	13%
Reduce vehicle tare weight	1%	1%	1%	37%	37%	37%
Install cab roof fairing	0%	13%	13%	0%	56%	56%
Install body / trailer side panels	0%	6%	6%	0%	29%	29%
Install side skirts	0%	4%	4%	0%	14%	14%

Install boat tails	0%	0%	0%	0%	7%	7%
Adopt automated manual vehicle transmission	0%	0%	0%	53%	53%	53%
Set vehicle with slower speed	0%	5%	5%	0%	46%	46%
Reduce height of vehicle	0%	0%	0%	0%	14%	21%
More regular tyre inflation checks	1%	1%	1%	33%	33%	33%
Use low 'rolling-resistance' tyres	1%	1%	1%	36%	36%	36%
Fit super singles	0%	0%	0%	7%	5%	8%
Automatic tyre pressure adjustment	0%	0%	0%	33%	33%	33%
Use of fuel additives	5%	5%	5%	29%	29%	29%
Use of lubricants with lower viscosity	8%	8%	8%	44%	44%	44%
Use telematics to optimise vehicle routing	8%	8%	8%	68%	68%	68%

Note: This scenario relates to central fuel prices, central take-up and 3 year PP.

#### 4.5 Behavioural efficiencies: driver training and driver performance monitoring

Driver training is widely acknowledged to be one of the most cost-effective means of reducing fuel consumption and GHG emissions in the road freight sector. Drivers undergoing training as part of the government-sponsored safe and fuel efficient driving for HGVs (SAFED) programme have, on average, managed to improve the fuel efficiency of their driving by around 7%. The % saving that an individual company can achieve will depend on the calibre of the drivers, nature of the delivery operation, age of the fleet etc and so generalisation is difficult. There is, nevertheless, general agreement that driver training must be accompanied by monitoring, debriefing, publicity and incentive schemes to ensure that the 'eco-driving' practices are embedded after the training period. SAFED sessions cost from £150-300 per session and most companies have experienced a payback period of less than 2 years. For our assessment, we assume that as the improvements described the freight best practice programme are averages, long haul journeys will provide greater opportunity for improvement (9%) and urban journeys less opportunity (5%). Regional journeys are assumed to represent the average journey and deliver 7% fuel efficiency improvements.

It is important to note that the impact of driver training and driver performance monitoring is conditioned by the adoption of technical vehicle improvements (e.g. cruise control) but is greater for long haul journeys as a consequence of small percentage improvements in fuel efficiency aggregated over large distances. This contrasts with urban journeys where bigger fuel efficiencies may be secured but these are aggregated over relatively small distances.

As mentioned above, monitoring employee's behaviour is key to maintaining improved performance. With the development of telematics, companies can now closely monitor the behaviour of their drivers against a series of criteria, such as speed, gear changes, braking profile and overall fuel efficiency. 'Traffic-light' systems are becoming widely used to rate drivers' performance against these criteria and identify the need for additional training and support. Some companies have reported fuel efficiency gains of 15% from these schemes, though it can be difficult to determine how much of the improvement is due to driver training and how much to subsequent monitoring, de-briefing and incentivisation. The % saving will also depend on the average driving standard prior to the introduction of the scheme. A 4-5% fuel and GHG saving is probably a more realistic estimate for a company with a good record of fuel management and driver training (this also ensures no double-counting with fuel



savings due to driver training). The monitoring system can be purchased or rented from suppliers. Renting this equipment costs between £360-840 and an additional session may be required to train drivers that costs around £150 per session.

Uptake rates for driver training and monitoring are provided in Table 6.

**Table 6: Take-up rates for behavioural efficiency measures, central commercial scenario.**

Measures aimed at improving driving style	2010			2030		
	Small rigid	Large rigid	Artics	Small rigid	Large rigid	Artics
Give drivers training in fuel efficiency	8%	8%	8%	67%	67%	67%
Monitor and manage driver fuel performance (including use of telematics)	8%	8%	8%	67%	67%	67%

Note: This scenario relates to central fuel prices, central take-up and 3 year PP.

## 5 Scenarios and modelling results

This section sets out the modelling results for the key scenarios and highlights key impacts of the measures aimed to improve operator efficiency through retro-fitting technology options, improved driving styles and logistics improvements.

### 5.1 Baseline scenario

The baseline scenario reflects the business as usual case in the HGV sector. It assumes no technical or operational improvements to the existing fleet, but accepts technological improvements to new HGVs in line with CCC assumptions. Figure 10 shows resulting emissions, fuel, and kilometres driven in this scenario. All other scenarios are compared with the baseline scenario in calculating the impacts of measures.

**Figure 10: Key metrics for the baseline scenario.**

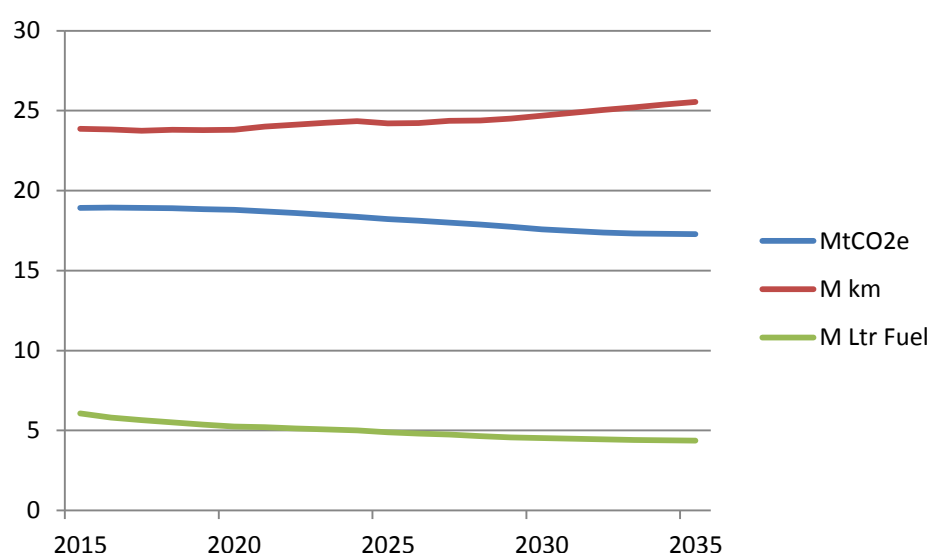


Figure 10 shows the increasing demand for HGV kms in the baseline case, rising by 2 million kms between 2015 and 2035. This assumes no demand-side interventions. It also highlights improvements in HGV fuel efficiency, driven by more efficient new trucks – as fuel consumed is relatively stable with increasing kms driven. Carbon emissions are expected to decrease by around 8% between 2015 and 2035 in this case.

### 5.2 Modelling results

In Section 3 we set out our modelling approach and scenarios considered. To recap, we considered two key scenarios:

- **Commercial Scenario**, where decisions to take-up measures reflect commercial considerations and market prices of fuel.
- **Social Cost Scenario** which assesses which measures are likely to be cost-effective from a social perspective, and including a carbon price. In this case the cost of fuel reflects producer costs and excludes taxes.

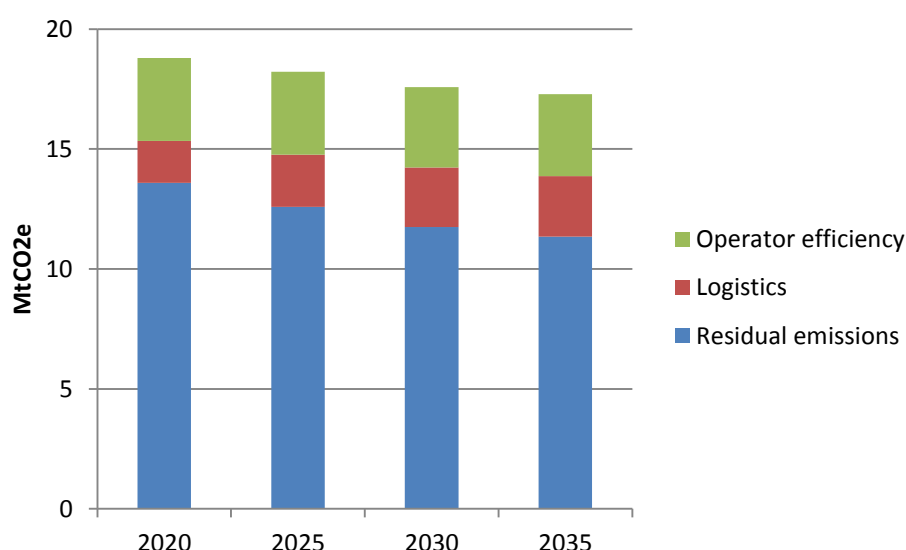
Various sensitivities are also modelled using take-up rates, fuel prices and payback periods. Table 7 sets out the modelling results, from the three types of intervention under central take-up rates.

**Table 7: Modelled CO<sub>2</sub>e savings (Mtonnes) from demand side measures under the central scenario by 2035 relative to the baseline scenario**

	Existing vehicle improvements	Driving styles	Reduced kms	Total
Modelled CO <sub>2</sub> e savings (Mtonnes)	0.9	2.5	2.5	5.9

The results show that potential carbon savings from the HGV sector are approximately 5.9 MtCO<sub>2</sub>e by 2035 from aftermarket improvements to vehicles, improvements to driving styles and measures to reduce kms driven under commercial discount rates. This represents a saving about 34% relative to baseline HGV emissions (which assumes improvements to new vehicles), with around 42% of this saving from improved driving style, 42% from improvements to logistics operations efficiency and the remainder from aftermarket improvements to vehicles. Figure 11 below shows emissions savings over time under the central take-up scenario.

**Figure 11: Modelled CO<sub>2</sub> savings from demand side measures – central take-up**

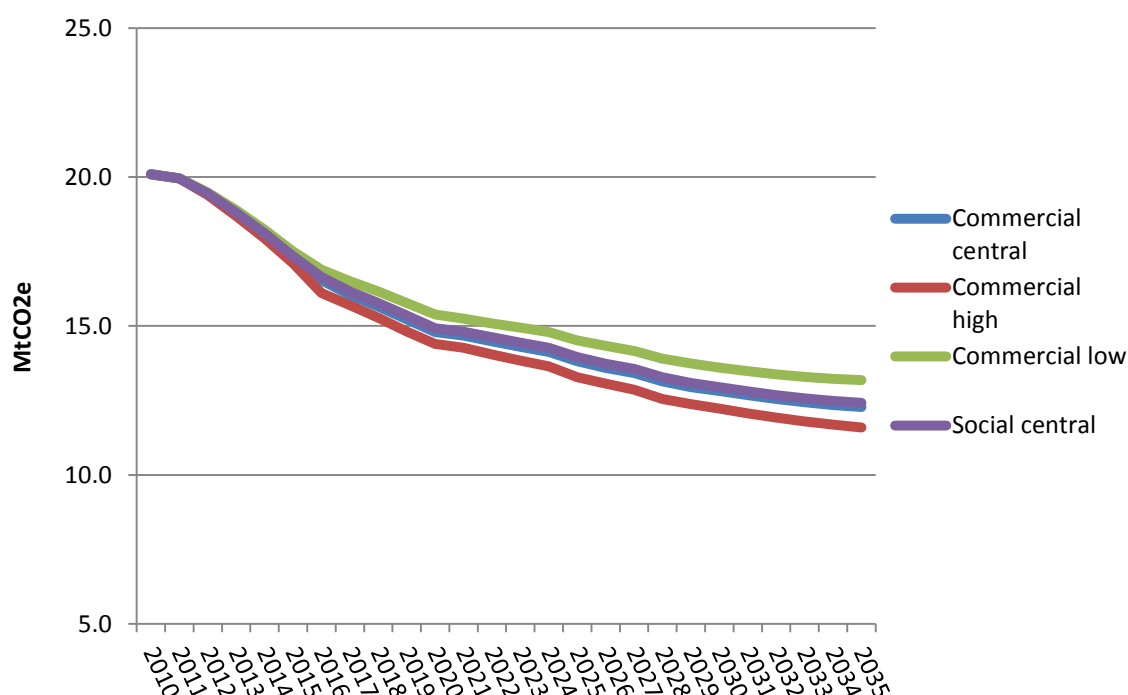


Note: Commercial discount rate used.

As shown below, the social cost scenario is close to the commercial scenario because the lower fuel prices and longer payback period in the social cost-benefit analysis are offset by the lower discount rate and introduction of carbon prices into the analysis. Using different take-up rates to reflect uncertainty over the extent to which non-financial barriers are overcome, leads to lower emissions savings in the social cost scenario (of around

0.1MtCO<sub>2</sub>e). This difference is so small because the investment case for improvements in operator efficiency are not sensitive to changes in fuel prices, and the changes in adoption rates for logistics impacts approximately a third of the overall abatement. The impact of these assumptions is shown in Figure 12 below.

**Figure 12: Modelled trajectory of CO<sub>2</sub> emissions from demand-side measures under different scenarios.**



We also considered the impact of varying fuel prices, based on DECC fossil fuel price projections. Under these assumptions, oil prices range from \$135pb in 2035 in the central case to \$75pb in the low scenario and \$190pb in the high scenario (these are used as a basis for calculating the retail prices for the commercial scenarios and long-run variable fuel costs in the social cost benefit scenario). However, our modelling showed that there was very little difference in the carbon and fuel savings from the demand side measures under different fuel prices. This is because the majority of savings are delivered through measures to improve driving style, which tend to pay back over a short period of time, and improvements to logistics, for which costs are not modelled. Therefore, neither of these measure-types is sensitive to variations in fuel price in our modelling.

### 5.2.1 Logistics measures

Whilst the take-up of aftermarket technology interventions is based on cost-benefit analysis, we do not explicitly model the costs of the logistics interventions, which are implicitly assumed to be cost-effective based on our focus-group research. The central take-up scenario reflects focus group views on the extent to which non-financial barriers such as planning, re-structuring supply chains, relaxing just in-time delivery constraints etc. can be overcome. The high take-up rate assumes higher saturation levels that are achieved earlier,

and the low take-up scenario reflects the opposite – both lower saturation levels and a longer time for these to be achieved.

Costs associated with the key logistics measures depend very much on the context in which HGVs operate, available ICT, the nature of products being transported and the physical location of distribution assets, suppliers and customers. In general, it should be easier for organisations to implement intra-organisational initiatives compared to inter-organisational or sector/regional/national interventions. Whilst explicitly costing these interventions was outside the scope of the study, it was possible to rank the demand-side interventions, which is summarised in Table 8 below.

**Table 8: Ranking of logistics measures by ease of implementation**

<b>Intervention</b>	<b>Ranking (lowest easiest to achieve)</b>	<b>Barriers</b>
<b>Backhaul</b>	1	Availability of data, time constraints, anti-competitive legislation
<b>Synchronised Consolidation</b>	2	Availability of data, time constraints, anti-competitive legislation
<b>Longer heavier vehicles</b>	3	Regulation, interaction with vulnerable road users, manoeuvrability, access restrictions
<b>Relaxation of time constraints</b>	4	Acceptance of night time deliveries, impact on inventory, increase labour cost to accommodate uncertainty
<b>Restructuring the supply chain</b>	5	Very long economic life of assets
<b>Urban consolidation centres</b>	6	Land use, inter-organisational coordination, use of higher capacity vehicles

The analysis identifies increased backhauling as the easiest to implement logistics measure. Backhauling can be framed as either inter or intra-company; the latter is relatively easy to organise and the former requires coordination across organisational boundaries. However, facilities such as freight exchanges have created platforms where opportunities for backhaul can be shared on an ad-hoc basis, complementing more formal and permanent arrangements between companies.

Synchronised consolidation represents a natural extension to backhaul operations. Synchronised consolidation (sometimes referred to as horizontal collaboration) and the relaxation of time constraints are both heavily dependent on data standards extending beyond organisational boundaries to facilitate the deployment of ICT systems capable of developing more complex transport arrangements. Whilst the benefits of data standardisation are widely accepted, its realisation remains elusive.

Relaxing time constraints generates more planning options. Whilst this in itself implies greater efficiency it also facilitates organisation across companies and geographies. This measure could therefore have amplifying effects on other measures such as: backhaul, synchronised consolidation, and the use of Urban Consolidation Centres.

The use of longer heavier vehicles (Higher capacity vehicles) is often framed by negative public opinion due to safety concerns and the need to modify regulations to permit their widespread deployment..

Restructuring supply chains, through for example the relocation of distribution centres may incur significant capital investment. Decisions of this nature are often prompted by a change in the profile of suppliers /customers, or significant changes in cost structures. However, these decisions have to weigh the barriers of high capital cost against the anticipated benefits.

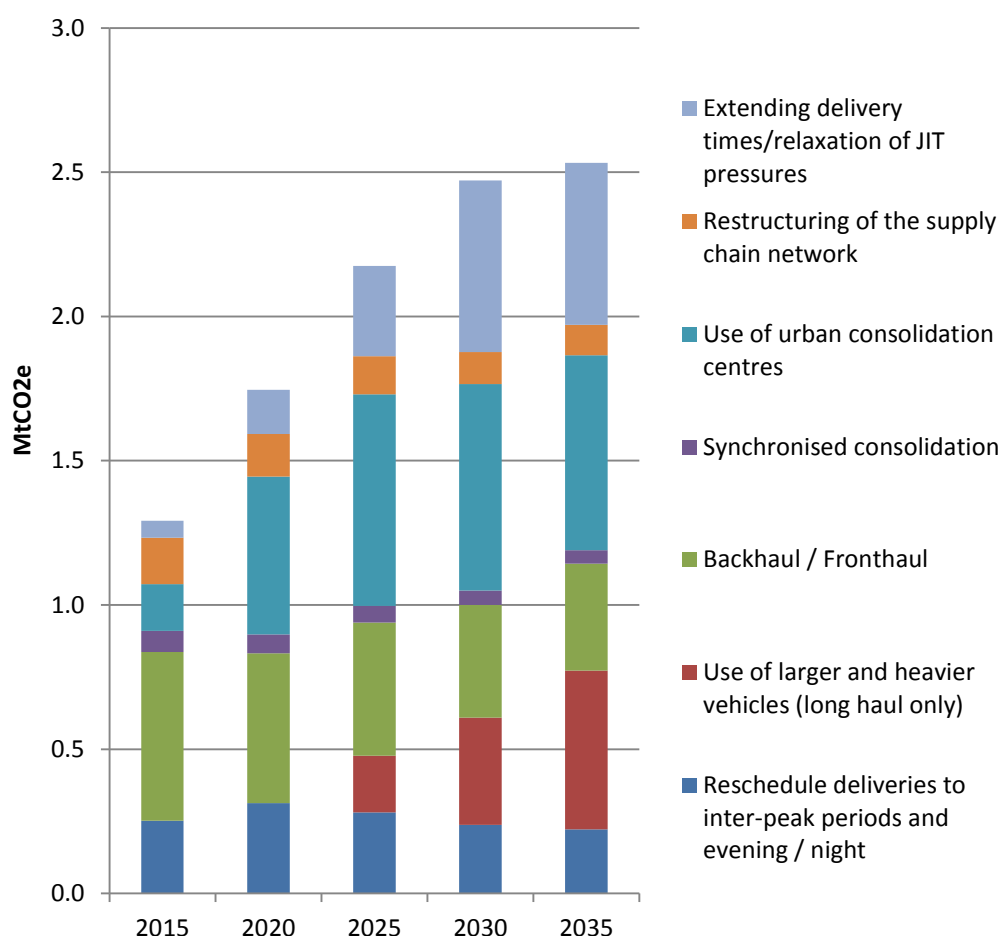
Urban Consolidation Centres (UCCs) are also based on forms of collaboration. The economic attractiveness of UCCs increases as the scale of their operations increases: the greater the scale of the operation the greater the potential for load consolidation.

The analysis of ease of implementation reveals three emergent themes:

- Data and associated ICT facilitates better organisation of logistics activity
- Collaboration underpinned by data and ICT extends the planning horizons
- Relaxing time constraints amplifies the potential to improve logistics efficiency

Figure 13 shows the contribution made from each of the logistics measures to carbon savings in 2035 under the central, commercial scenario assumptions.

**Figure 13: Modelled carbon savings from logistics measures in any year**



The analysis shows that the highest potential carbon savings can be achieved through the use of UCCs, use of Higher capacity vehicles and extending delivery times. Together, these account for nearly two-thirds of all savings from logistics measures by 2035.

The uptake rate for logistics interventions can be affected by regulation and policy. For instance, an alignment of planning policy with restricted urban access would change how the justification of UCCs is formulated. Similar arguments about the attractiveness of high capacity vehicle and time constraints can also be made. The uptake rates used in the model assume that there are no regulatory barriers to the implementation of logistics measures.

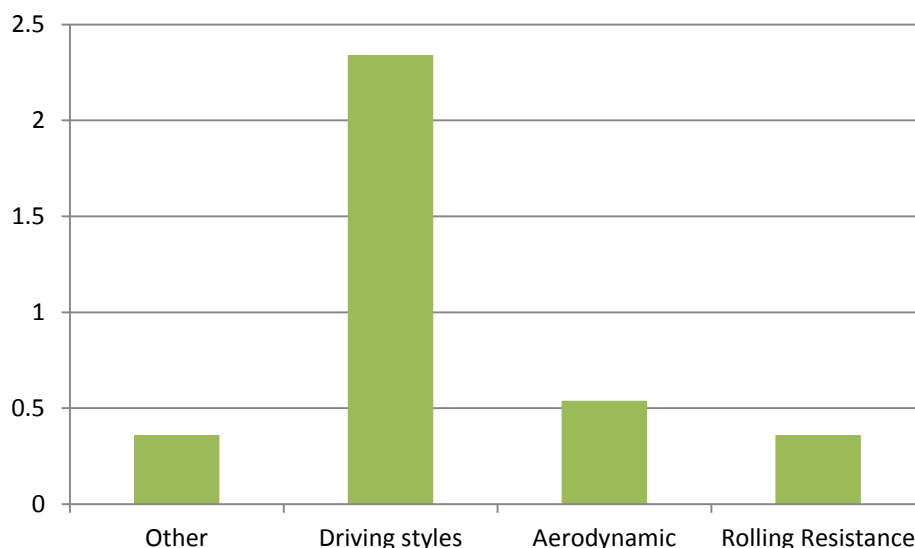
### 5.2.2 Improved operator efficiency (technology and driving styles)

For the purposes of analysis improved operator efficiency has been divided into:

- Aerodynamic improvements
- Rolling resistance improvements
- Other measures (e.g. lubricants)
- Driving styles

Figure 14 summarises the contribution made by each of these categories to the overall benefit attributed to improved operator efficiency until 2035.

**Figure 14: contribution of each category of intervention**



The analysis of measures to improve operator efficiency identifies “Driving styles” as the measure that has the greatest benefit. This is not surprising as this measure has application in all classes of vehicles in all sectors, and most significantly can be implemented at little or no cost. Improving driving style through both driver training and driver monitoring accounts for approximately 65% of the savings identified as operator efficiency.

“Other” measures include use of low viscosity lubricants, use of fuel additives, weight reduction and the adoption of automated manual vehicle transmission. Of these measures low viscosity lubricants and fuel additives are relatively low cost and are therefore widely adopted as interventions.

Whilst aerodynamic and rolling resistance interventions are more costly than the “other” measures they have proven efficiency and cost effectiveness.

To summarise the interventions which make for the best investments (using commercial investment criteria) generate the largest proportion of operator efficiency savings. Sensitivity analysis around investment criteria showed these measures were not sensitive to changes in investment parameters such as payback period. However some companies may be reluctant to invest in technologies/practices where the benefit evidence base is weak.

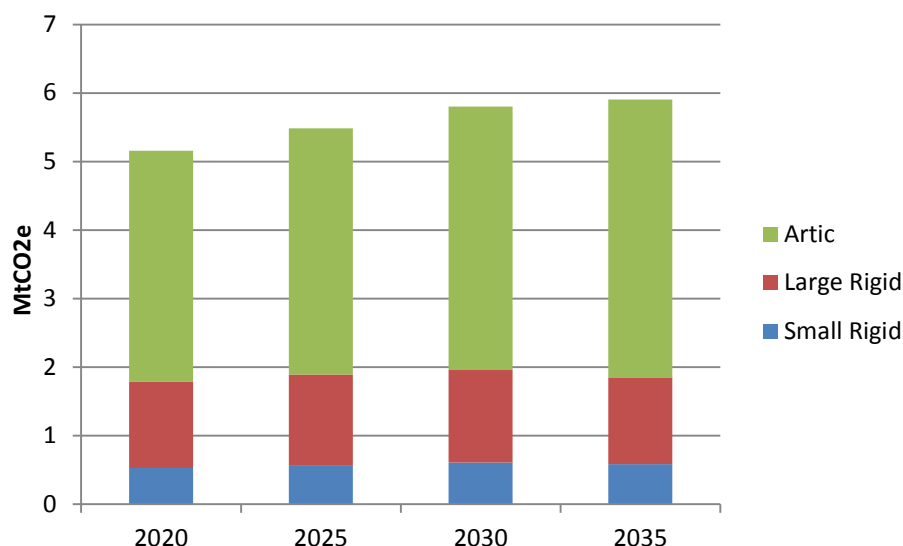
### **5.3 Role of different vehicles, journey types and sectors**

Looking at different types of HGVs in use, in all scenarios the largest carbon emissions are attributed to articulated trucks on long haul operations – around 70% of all savings are from these vehicles. These operations typically involve larger (by volume and weight) payloads resulting in higher fuel consumption. Therefore it is not surprising to find most of the logistics



interventions applied to this group of vehicles. Figure 15 shows demand-side savings for 2020-2035.

**Figure 15: Carbon savings from demand side measures by vehicle type, 2020-2035**



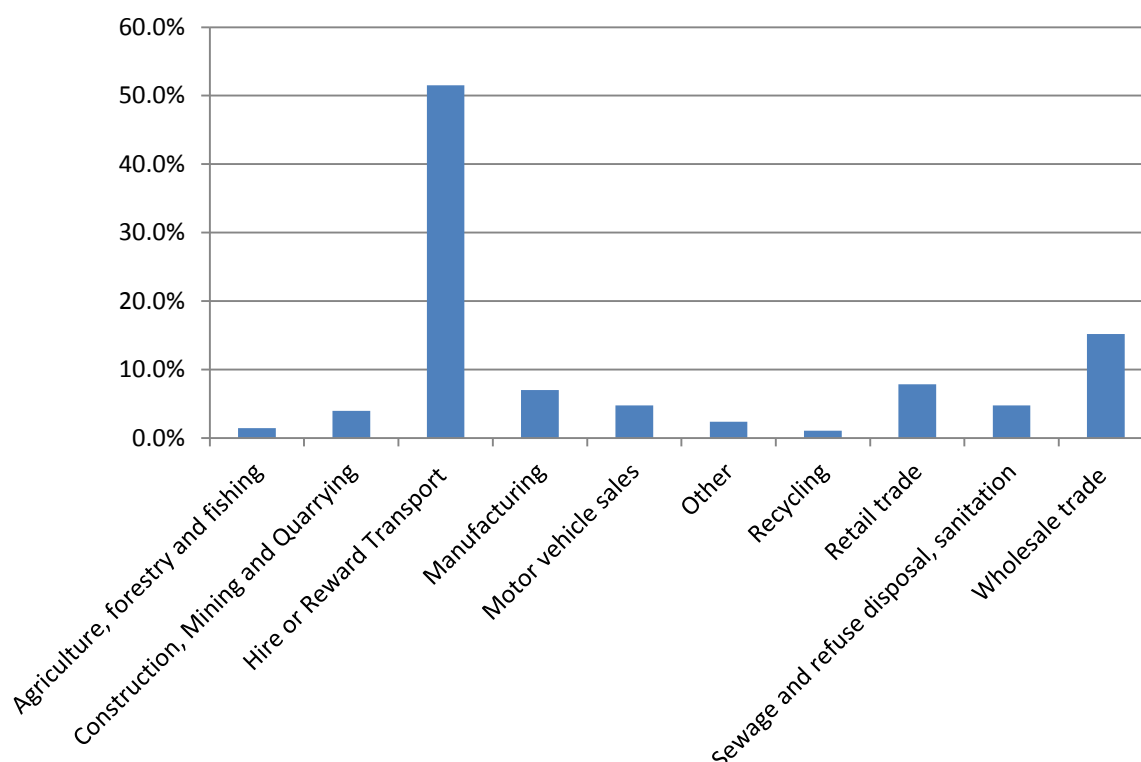
Some interventions such as backhaul and load consolidation are applicable to all HGV categories. However they have the biggest impact on long haul operations using larger vehicles (i.e. articulated trucks) due to their high share of km and suitability for backhaul operations. Furthermore, interventions such as the reconfiguration of the logistics network, use of alternative transport modes and the adoption of longer heavier vehicles are particularly relevant to the long haul operation.

This is not to say that other vehicle types do not offer improvement opportunities. Large rigid trucks are typically used on regional distribution tasks, with less than truckload fill rates. This presents an opportunity for horizontal collaboration (often between competitors) and synchronised load consolidation. Small rigid vehicles are assumed to be deployed on urban logistics tasks and, like large rigids, offer the opportunity for collaborative synchronised load consolidation within a multi-drop strategy. However, the drive cycle associated with the urban logistics, with frequent acceleration/deceleration makes it more difficult to realise savings from these interventions.

A breakdown by business sector shows that the highest potential carbon savings are in the hire and reward sector. This is the biggest sector serviced by HGVs, representing 49% of all kms forecasted in 2035.

Figure 16 summarises the carbon reducing potential by 2035 for each of the sectors as defined in the CSRGT.

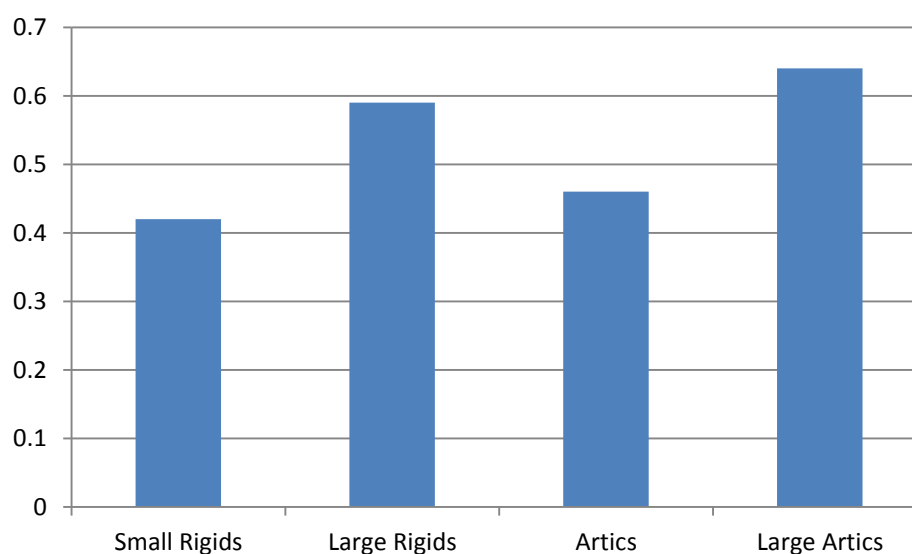
**Figure 16: Modelled carbon savings from demand-side measures by sector, 2035**



Note: manufacturing sectors have been combined

Further evidence of the importance of certain vehicle types can be found in the examination of the CSRGT data and in particular the profiles of load capacity utilisation and empty running. In general, larger vehicles tend to be better utilised. The load capacity utilisation for vehicle types and proportion of HGV kms running empty by sector in 2013 are shown in Figures 17 and 18.

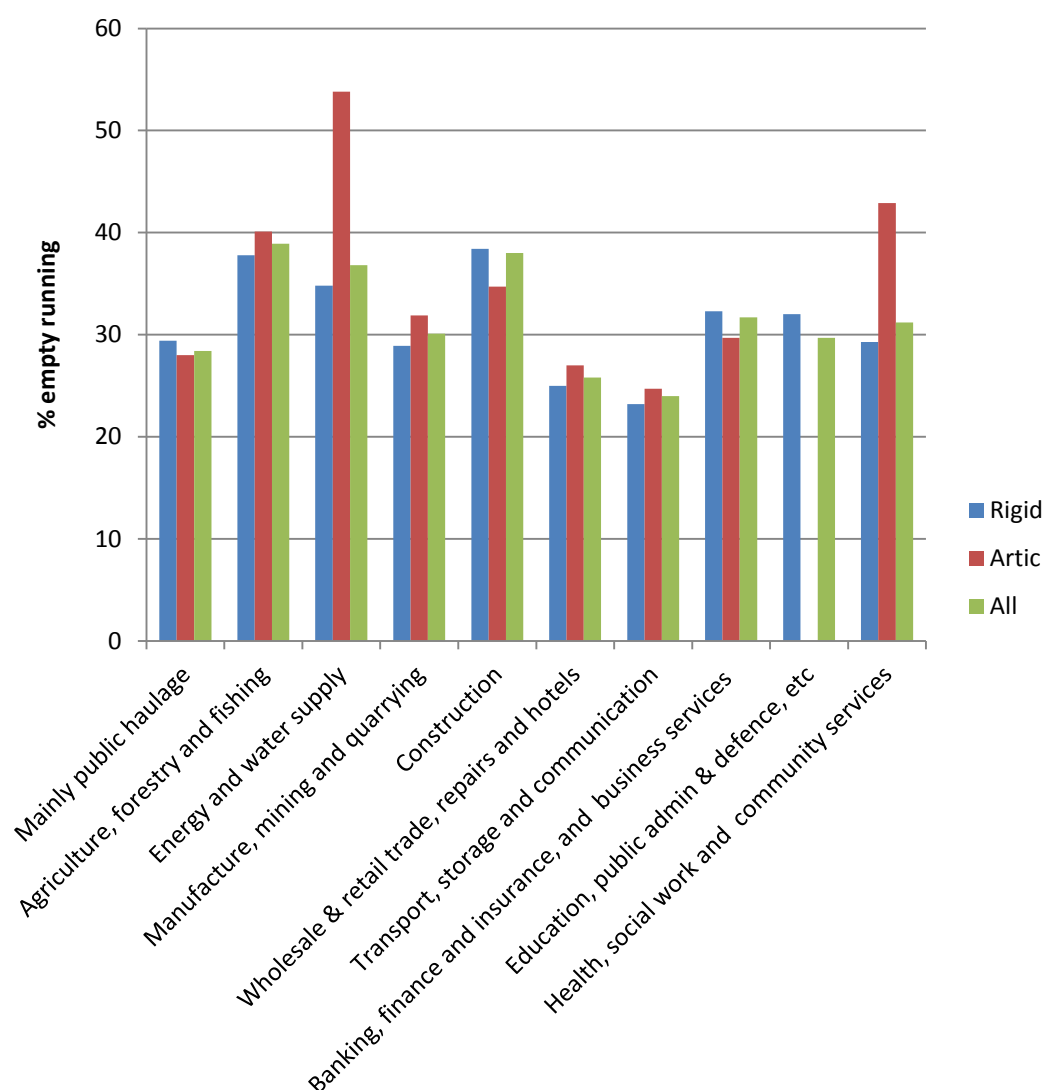
**Figure 17: Average HGV capacity utilisation by vehicle type**



Source: CSRGT

Figure 18 summarises the proportion of journeys that are run empty for each category of HGV transporting particular commodity groups. The hire and reward sector has above average load capacity utilisation but runs 30% of its kms empty. The significance of this sector in reducing carbon emissions is further underlined by two metrics: the sector accounts for 54% of the artics used for long haul, and 72% of the total long haul tonne-kms. Securing back hauls in regional and urban operations is more difficult as extra journeys to collect the backhaul incur larger percentage increases in total journey than those experienced in long haul operations.

**Figure 18: Percentage of HGV kms running empty by sector in 2013**



Source: CSRG

#### 5.4 Summary of modelling results

- The baseline scenario shows that emissions would decrease by 8% between 2015 and 2035 due to the introduction of new more efficient vehicles (supply-side improvements)

- A 34% reduction in emissions relative to baseline HGV emissions (which assumes improvements to new vehicles) could be achieved, with around 42% from improved driving style, 42% from improvements to logistics operations efficiency and the remainder from aftermarket improvements to vehicles.
- The use of UCCs, relaxation of delivery times and the use of higher capacity vehicles generate the biggest improvements in logistics efficiency in the period 2020-2035. These measures also have significant implementation barriers.
- Improvements to driving styles offer the biggest opportunity for improvements in operator efficiency. These measures also have the lowest cost of implementation.
- The hire and reward sector is the most efficient sector in terms of vehicle utilisation. However, as a consequence of its overall size, small improvements in this sector would also have the biggest impact on emissions.
- Larger vehicles are generally better utilised.

### **5.5 Non-financial barriers to decarbonisation initiatives**

The analysis of factors driving the take-up of measures aimed at reducing HGV kms considered in this study suggests that a number of changes in industry practice and overcoming other non-financial barriers may be necessary before they can be implemented at a larger scale. The key non-financial barriers that would need to be overcome, at least in parts of the HGV sector, to deliver these savings are considered below.

- Demand-side interventions very often involve collaboration and coordination across HGV operators and between freight owning companies. Successful implementation of these interventions will need to address barriers in data availability, identification of potential collaborative partners, clarification of competition law and the associated allocation of economic benefits.
- The deployment of Higher capacity vehicles may require changes to policy and regulation. This measure is assumed to have a lower saturation level of 50% in the central case by 2035 in applicable sectors, due to the controversial nature of these HGVs.
- The opportunity to deploy Higher capacity vehicles could be contingent on separating vulnerable road users from HGV traffic flows. This segregation could be developed using temporal or spatial separation. In this context, UCCs could provide an acceptable terminus for Higher capacity vehicles, whilst relaxed time constraints could enable fewer vehicles to service urban demand from UCCs. UCCs could also act as concentrators of reverse flows developing backhaul opportunities.
- The relaxation of time constraints extends potential planning horizons permitting greater numbers of destinations to be visited by a single vehicle. Maximising the benefits delivered by extended journey planning will involve significant inter-organisational collaboration and relaxation of vehicle access constraints.

- Collaborative interventions such as backhaul and synchronised consolidation require common standards of load description. In particular the availability of weight and cube data would enable more collaborative ventures to form. National standards for road freight data would facilitate collaboration and provide a more robust foundation for the calculation of logistics efficiency and more meaningful insights into best practice.
- Local authorities often have little data on the nature and characteristics of urban distribution operations and freight activity in their region. Volumes of freight traffic, its origins and destinations, and types of commodities moved are generally unknown. Therefore, local transport plans and land use policies do not adequately address key issues enabling more efficient urban freight solutions. UCCs can be very effective at reducing freight traffic and GHG emissions associated with freight traffic destined to urban locations. Therefore, local authorities would benefit from more guidance and advice on UCCs, with a particular focus on existing successful schemes and opportunities for most effective UCC applications (e.g. public procurement schemes). This would help to raise awareness of the potential benefits of UCCs, and help to ensure that they are considered as part of local freight transport strategies and land use policies.

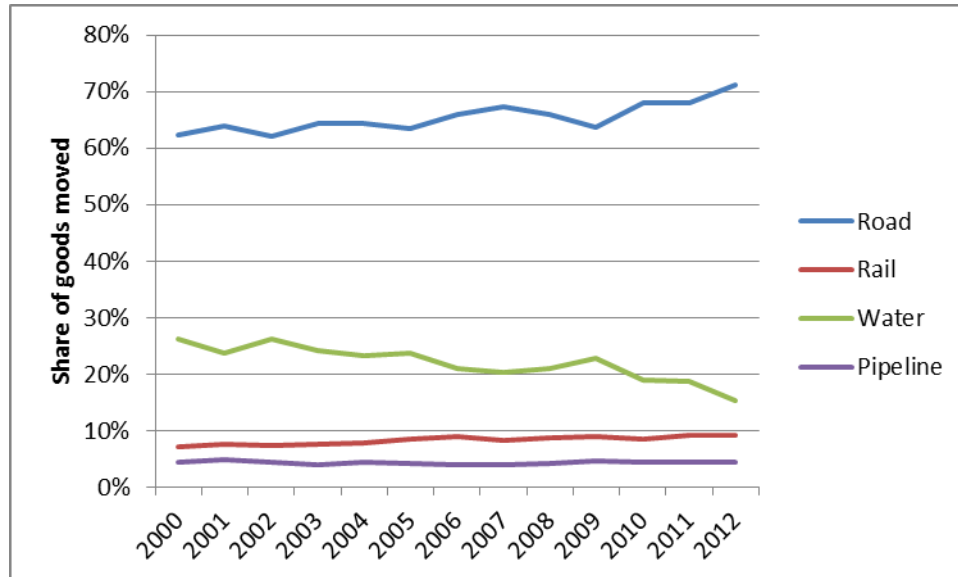
These factors highlight the need for policy makers to consider enabling actions to facilitate the transition to more efficient logistics operations. Key areas that would need to be addressed are:

- Improving the availability of relevant logistics data to facilitate collaboration and improvements in planning of freight transport operations.
- Clarification of permissible forms of collaboration in the context of anti-competitive regulations.
- The development of strategies to permit the use of Higher capacity vehicles.
- Facilitation of land use considerations for UCCs.

## 6 Modal shift

Freight movements across the UK are implemented using one of five modes: air, rail, road, pipeline, and water. The majority of domestic freight is moved by road and the share of goods moved by other modes has been relatively flat or declined in recent years (Figure 19).

**Figure 19: Share of domestic goods moved by mode, 2000-2012**



Source: DfT 2013

After airfreight, road is the most GHG-intensive freight transport mode. This section focuses on opportunities for a greater use of rail and waterborne freight transport in the UK<sup>6</sup>.

The following sections summarise the results of a literature review conducted for the purpose of this study and a focus group discussion held in Edinburgh on 7<sup>th</sup> January 2015. The focus group was attended by experts representing operators and users of alternative transport modes, trade associations, and policy makers. This was supplemented with a follow-up interview with a representative of Network Rail on 13<sup>th</sup> February 2015.

### 6.1 Rail freight transport in the UK

In the UK, volumes of freight moved by rail have been in a long-term decline since the 1950s. More recently the percentage share of rail in the freight transport market has been relatively stable at 8-9% over the last decade.

In terms of commodity grouping, coal movements accounted for the largest share of tonne-kms moved - 36% of tonne-kms moved and 44% of tonnes lifted by rail in 2013-14 (Table 10).

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<sup>6</sup> Due to a limited range of products suitable for pipeline transport, the possibilities of influencing the overall modal split figures by shifting more freight into the pipeline network are somewhat limited. Although innovative attempts to move freight via pipelines are being developed (e.g. Mole Freight Pipeline system), their long-term economic viability is still uncertain.

**Table 9: Rail tonne-kms moved by commodity group, 2013-14**

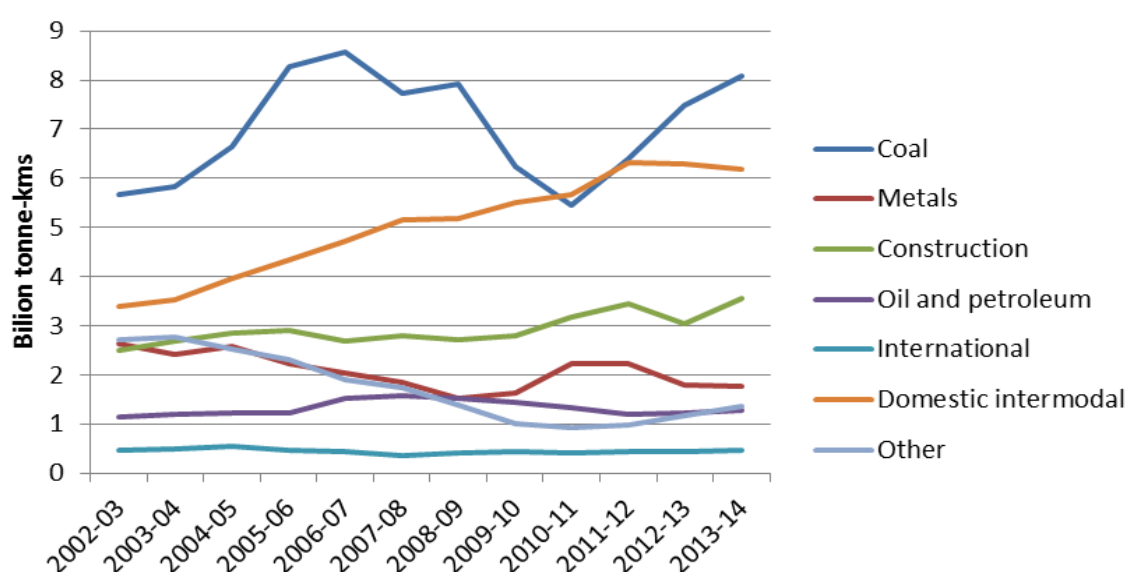
Commodity	Percentage of tonne-kms moved, 2013-14
Coal	36%
Domestic intermodal	27%
Construction	16%
Metals	8%
Oil and petroleum	6%
Other	6%
International	2%

Source: ORR (2015)

The second largest grouping is domestic intermodal traffic, i.e. domestic movements of containerised cargo, which accounted for 27% of rail freight tonne-kms, and it is the fastest growing segment (Figure 20). This growth has been primarily driven by movements of containers to and from UK ports and the Fast Moving Consumer Goods (FMCG) sector. One in four containers entering the UK is now moved by rail (Rail Freight Group, 2015). In FMCG sector, because of the distance involved, Scotland is the dominant destination for rail freight movements, typically starting from Daventry International Rail Freight Terminal (DIRFT). Recent reports suggest that rail is becoming more competitive for routes from England to Wales and even southern England to the Midlands (FTA, 2012).

The share of construction materials in goods moved by rail has been gradually increasing, and now accounts for 16%. Metals, oil and petroleum products, other good, and international freight movements constitute the remaining 22%.

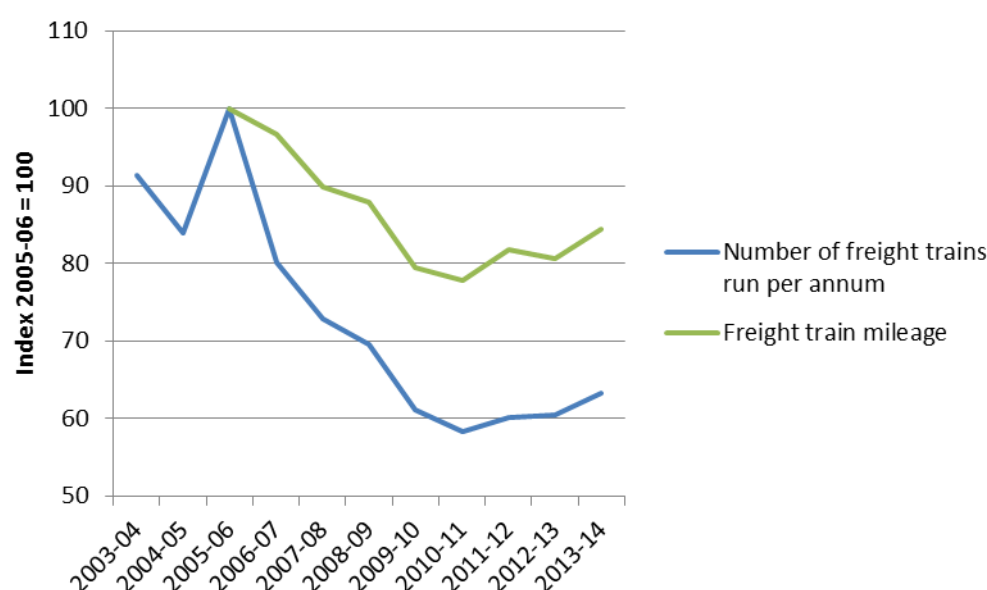
**Figure 20: Goods moved by rail, by commodity group, 2002/03-2013/14**



Source: ORR, 2015

The changing commodity mix of rail freight traffic is changing the nature of rail freight operations. Commodities traditionally serviced by rail, i.e. coal, aggregates and other quarried materials, are moved in large volumes between a few centralised points of origin and destinations, and these movements are not time-critical. For instance, coal typically commences its journey at a mine, or, more recently, at a port, and it is moved by rail to a few power stations whose locations are determined by a centralised strategy for energy generation. Furthermore, coal is not perishable and the large amount of stocks carried by the power stations mean that its delivery is not time critical. Domestic intermodal movements, however, are highly time-sensitive, prioritising the reliability, punctuality, and timeliness as performance indicators, a significant change in the way rail freight transport operates.

**Figure 21: Freight train mileage and number of freight trains per annum**



Source: ORR, 2015

In absolute terms the amount of freight tonne-kms and tonnes lifted by rail increased slightly over the last decade. At the same time, the number of freight trains run has fallen steeply since 2005-06 (Figure 21). This suggests significant efficiency improvements in the rail freight sector. Annual freight train mileage has fallen too, but less steeply than the number of freight trains, implying that the average distance travelled by a freight train has increased.

## 6.2 Rail freight forecast for the UK

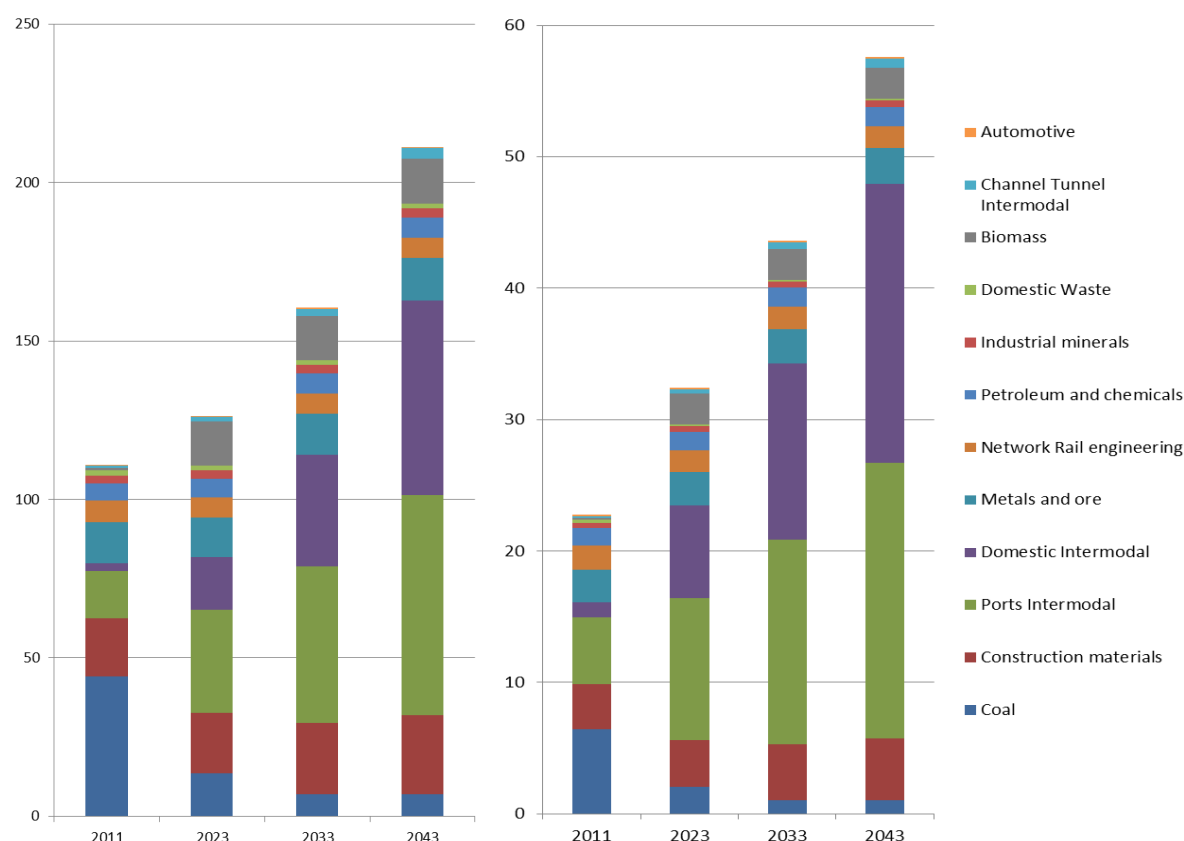
A recent rail freight forecast prepared specifically for the UK published by Network Rail (2013) is based on MDS Transmodal's Great Britain Freight Model. The central case projects a 90% increase in tonnes lifted, and 152% increase in tonne-kms moved by rail between 2011 and 2043 (Figures 22). The forecast sets out the expected changes in the commodity mix moved by rail. As a result of decarbonisation of the UK energy supply sector, the number of coal-fired power stations will be reduced, thus the amount of coal transported by rail will also decrease. Coal movements are projected to decline from 36% of all tonne-



kms moved and 44% of tonnes lifted by rail in 2013-14, to only 3% of tonnes lifted and 2% of tonne-kms by 2043.

Offsetting the decline in coal movements, four sectors are forecast to grow in the next 3 decades: container port traffic, intermodal domestic movements, construction materials, and transport of biomass.

**Figure 22: Forecast of freight lifted (left) and moved (right) by rail, 2011-2043**



Source: Network Rail, 2013

The forecast growth is underpinned by several assumptions and takes account of forecasts of wider economic trends, such as international trade, economic growth, land use planning and rail connectivity of new warehousing developments, etc. In the domestic intermodal sector, upgraded railway connectivity of ports (e.g. Felixstowe, Southampton) and new developments, such as the development of the new deep-sea container port and logistics park at London Gateway, introduce opportunities for rail and are likely to substantially increase rail's share of container traffic from ports to inland container hubs. Expansion of both new and existing rail-connected warehousing sites is expected to drive a significant growth in the transport of non-bulk domestic products.

The demand for rail movements of construction materials is expected to increase in line with forecast population growth, driving the demand for house building in the UK. This will increase the need to move bulk construction materials from remote locations to construction sites located close to population centres, most of which are already serviced by rail connections.

The volume of metals moved by rail was forecasted to experience a small increase, despite the fact that the AECOM/ITS (2010) study identified metals as one of the key markets with potential for growth for rail. However, given the recent upheavals in the UK steel industry (e.g. the closure of the Teeside Steelworks plant, and Tata Steel announcing 1200 job losses in Scunthorpe and Lanarkshire), the future of this market is uncertain. Traditional rail steel movements are likely to be replaced by import movements from ports, which may result in longer average length of haul (as it happened in the coal sector). Consequently the overall increase in steel tonne-kms moved by rail will result from longer distances travelled, rather than from greater tonnages lifted.

Future demand for biomass movements by rail was estimated based on Department of Energy and Climate Change (DECC) projections of energy use published in 2012. It is expected that 80% of the future demand for biomass movements will be satisfied by rail (Network Rail, 2013).

The focus group participants broadly agreed with the growth trends projected by Network Rail (2013). As a result of the decarbonisation of energy generation, a strong decline in the demand for rail coal movements from ports to power stations, was expected (Table 10). However, the growth in biomass movements was anticipated to more than compensate for the decrease in coal traffic. The switch from coal to biomass will require a different operating approach. Biomass is much lighter, requires covered wagons, and needs to be stored in silos at ports and power stations. An increase in biomass movements will require investment in rolling stock (covered wagons) from rail freight operators, and storage silos at ports and power stations. Limited storage capacity will make it necessary for rail to provide rapid and reliable services.

Intermodal services to and from deep-sea ports and domestic non-port intermodal services, serving mainly the retail sector, were expected to experience significant growth. Opinions varied on the future trend in aggregates traffic from stabilisation at current levels to an increase by 25% as building activity recovers and grows. Automotive traffic was expected to remain at current levels.

**Table 10: Expert opinion on future changes in rail freight demand.**

<b>Commodity</b>	<b>Projected changes in demand</b>
<b>Coal</b>	Significant decline
<b>Biomass</b>	Growth, but the extent uncertain
<b>Intermodal services to deep-sea ports</b>	Significant growth
<b>Domestic intermodal services (non-port traffic)</b>	Significant growth
<b>Aggregates</b>	Stable - ≈25% growth
<b>Automotive</b>	Stable
<b>Piggyback (semi-trailers on train)</b>	Significant potential, but incentives needed
<b>Shared-use trains (passenger and freight)</b>	Marginal

Rail freight services carrying road semi-trailers were seen as likely to offer an opportunity to significantly increase the rail's share of the freight market. This would, however, require some incentives to encourage investment. Shared-use trains combining passengers and freight were also mentioned, but there was considered to be very little potential for this type of service.

The main limitation of the Network Rail (2013) forecast is its focus on freight demand without sufficient consideration being given to the ability of the rail network to cater for it. According to Network Rail (2013), potential capacity constraints will be addressed in the follow-up studies. As discussed below, if not addressed, limited capacity of the rail network may become a significant barriers to further growth of rail freight transport in the UK. Apart from national-level initiatives, the European Trans-European Transport Network (TEN-T) strategy may also play a role in supporting the investment in the infrastructure needed to accommodate growing rail freight traffic.

### **6.3 Domestic waterborne freight transport**

Domestic waterborne freight transport consists of inland waterway, coastal shipping and one-port traffic.

- Inland waterway involves moving freight on canals, river and estuarine waterways.
- Coastal shipping involves vessels operating between two or more points of the UK.
- One-port traffic refers to movements to and from offshore installations and sea dredging.

Short sea shipping typically refers to vessels travelling by sea, without crossing an ocean. In the UK it encompasses coastal shipping, but also movements between the UK and the mainland continent of Europe or the Republic of Ireland. The data presented in this section does not include international freight movements.

Waterborne freight transport is usually given less attention than other modes, even though it still carries a greater proportion of domestic tonne-kms than rail. However, while in recent years the volumes moved by rail have been increasing; waterborne freight transport has been in a steady decline (Figure 19).

Coastwise traffic accounted for 68%, and one-port movements for 28% of domestic waterborne tonne-kms in 2013. Despite a historically well-developed canal system in the UK, inland navigation represents only a small proportion, i.e. 5% of total domestic waterborne freight moved. Petroleum products are the main cargo moved by waterborne transport, accounting for 57% of its total tonne-km (DfT, 2014).

The focus group participants expected the demand for waterborne transport to remain relatively stable or drop slightly due to a decline in the demand for coal movements and oil traffic. There is a possibility that waterborne transport can capture some of the biomass movements to compensate for the loss of coal and oil traffic. The tightening of restrictions on sulphur emissions from ships within the North Sea 'Sulphur Emission Control Area' (SECA) will increase the cost of short-sea and coastal service, possibly resulting in a in some modal shift to rail or road.

## **6.4 Factors affecting modal shift in the UK**

The key factors in the freight mode selection are cost, speed, transit time reliability, characteristics of the goods, and service. Concerns about energy use and environmental impacts are still seldom decision factors. As such, transport mode decisions are mainly viewed as a service-constrained economic choice, i.e. for a given set of service constraints the operator will choose the least cost transport solution, providing that does not negatively impact other logistics costs such as warehousing, inventory, or order processing costs.

Although in recent years the trend towards an increased use of alternative transport modes has been clearly visible in the UK, for example the use of domestic intermodal services in the retail sector, it is still uncertain how much more modal shift can be achieved as a result of current market forces. Greater government intervention may be required to drive changes in behaviour where economic incentives are inadequate.

A number of factors likely to affect the share of rail and waterborne services in the UK freight transport market were identified. These can be categorised into the following groups:

### **6.4.1 Inflexible pricing structures**

Whilst alternative transport modes are less GHG-intensive, the inherent inflexibility of alternative transport modes and limited network connectivity make it difficult for rail and waterborne transport to meet the operational requirements of modern supply chains. Traditionally, they tend to cater for journeys in excess of 300 km, preferably in sectors not tightly constrained by just-in-time operating practices. Relatively inflexible pricing structure of rail and waterborne transport results in their high cost over short distances. Further, freight transport demand in terms of tonnages and tonne-kms moved by rail and inland waterway is price elastic<sup>7</sup>, with higher elasticities for short distance movements (Beuthe et al., 2001), i.e. small changes in the price are likely to result in disproportionally large changes in demand, particularly over shorter distances.

### **6.4.2 Availability, capacity and connectivity of infrastructure**

Availability, capacity and connectivity of transport infrastructure are significant challenges to shifting more freight onto alternative transport modes. Improved connectivity of ports and greater access to inland intermodal terminals are vital to increasing rail and waterborne transport shares of the UK's freight transport market. Availability of inland intermodal terminals in the UK is quite limited, particularly in the South East of England. Major distribution parks in the UK are aligned with the motorway network and lack a direct rail connection. This generates a need for additional hinterland movements by road, thus increasing the total duration and cost of intermodal journeys. The mixed-use rail infrastructure in the UK results in timetabling priority being given to passenger trains when capacity is inadequate or disruptions occur. This may have a negative impact on the reliability of rail freight services.

Investment in gauge enhancement to W12 on strategic freight routes will allow rail to accommodate a broad range of deep-sea, larger European containers and swap bodies

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<sup>7</sup> Elasticity of demand measures the output effect, i.e. change in demand as a result of a price change.

traffic (Table 11). Intermodal routes can also be upgraded to accommodate longer intermodal trains to increase capacity of the network.

**Table 11: UK enhanced loading gauges**

Name	Height	Width
W9	9'	2.6m
W10	9' 6"	2.5m
W11	9' 6"	2.55m
W12	9' 6"	2.6m

#### **6.4.3 Operating practice and changes in commodity mix**

The long-term downward trend in rail and waterborne freight volumes has been caused mainly by the structural change of the British economy, particularly the decline in heavy industry, resulting in a contraction of the bulk freight market. In order to increase their share of the UK freight market, rail and water need to win new traffic, including intermodal, wagonload and time-sensitive business. Changes in the commodity mix moved by alternative transport modes require new management approaches. While supply chains for commodities traditionally moved by rail and water, e.g. coal, oil and aggregates, are not very time-sensitive, high levels of reliability, timeliness, and punctuality of services are vital for new segments of rail freight traffic market, such as movements to / from ports, or retail deliveries.

Greater modal shift to rail can only be achieved when alternative transport modes start to adopt 24/7 operation cycles, so freight transport can be synchronised with supply chain operating cycles. However, if rail and waterborne freight transport are to be widely adopted customer behaviour also needs to change, for instance some relaxation of delivery schedules may be required.

#### **6.4.4 Awareness, knowledge, and skills**

Many shippers are only familiar with using road transport for moving freight, and the lack of experience with alternative transport modes causes resistance to mode switch. There is also a common perception that alternative transport modes are inflexible, unreliable and difficult to use. A common view is that rail and waterborne services are only suitable for bulk, long distance freight movements. Furthermore, environmental considerations are still given too little weight in corporate mode choice decision making process.

#### **6.4.5 Innovative service offering**

Innovative solutions could help to increase rail freight traffic, for example shorter, faster and more frequent rail services carrying containers and road trailers between locations that are currently inaccessible to longer trains. Rail freight services carrying road semi-trailers (i.e. so-called piggyback) could also increase rail's share of the freight market. However, moving road semi-trailers by rail requires infrastructure enhancements, dedicated rolling stock, and handling equipment at the terminals. Even though innovative and fast handling solutions exist (e.g. CargoBeamer), rail operators would need to make a significant investment in the equipment, which is unlikely to happen without government incentives.

#### **6.4.6 Regulatory framework**

Stability of regulatory regimes and certainty in the long-term pricing strategy are vital to sustained growth in rail freight volumes. For instance, the total cost of rail offering comprises a mix of operating costs, such as equipment provision, fuel and labour costs, and the track access charge. The track access charge is revised every five years by the Office of Rail and Road, thus is highly dependent on current government policy. Within the timeframe of this report (up to 2035) there will be four control periods.

Land use planning policy should prioritise connectivity to major industrial locations to rail and waterborne freight transport networks in order to eliminate the need for feeder movements. Introduction of road-user charging for trucks could also make alternative transport modes more competitive.

#### **6.4.7 Availability of rolling stock**

Across the EU, meeting increased demand for rail freight movements will require investment in additional rolling stock. Islam et al. (2014) estimate that significantly more rolling stock, combined with improvements in rail productivity, will be needed to facilitate modal shift to rail in Europe. The focus group participants did not express concerns about asset availability to accommodate growth in domestic rail freight traffic in the UK. However, it was acknowledged that changes in commodity mix moved by rail will drive the need for investment in certain type of rolling stock from rail freight operators. For instance, an increase in biomass movements will result in greater demand for covered wagons.

#### **6.4.8 Financial incentives**

The asset life for rail and waterborne freight transport is long, and measures designed to increase the share of domestic rail and waterborne freight transport, such as using faster vessels or increasing service frequency, often increase operating costs. Public sector investment can help to overcome market distortions, and attract higher value traffic to rail and waterborne transport, thus improving their competitiveness. In the UK, mode shift to rail and waterborne transport is supported by Mode Shift Revenue Support (MSRS), Waterborne Freight Grants (WFG), and Freight Facilities Grant (FFG) (Scotland only) schemes.

#### **6.4.9 European Policy: Trans-European Transport Network (TEN-T)**

The European transport infrastructure policy aims to *'close the gaps between Member States' transport networks, remove bottlenecks that still hamper the smooth functioning of the internal market and overcome technical barriers such as incompatible standards for railway traffic. It promotes and strengthens seamless transport chains for passenger and freight, while keeping up with future technological trends'* (European Commission, 2015). Nine core network corridors will form the backbone of the unified trans-European transport network (TEN-T), and should be completed by 2030. The development of integrated transport corridors in Europe will be supported by Connecting Europe Facility (CEF) with a budget of €26 billion up to 2020.

The North Sea- Mediterranean Corridor is one of the nine core network corridors. This multimodal corridor links Ireland and the UK to the continental Europe. It stretches through

the Netherlands, Belgium and Luxemburg, and ends in the south of France. Given the country's relative peripherality and current under-utilisation of the capacity to move freight trains through the Channel Tunnel, the development of the North Sea- Mediterranean Corridor should result in rail being able to capture a larger share of long haul, cross-border movements to and from the UK.

**Table 12: CEF: pre-identified projects focused on transport links in the UK**

Link	Mode	Project
<b>Cork-Dublin-Belfast</b>	Rail	Studies and works; Dublin Interconnector (DART)
<b>Belfast</b>	Port, multimodal connections	Upgrading
<b>Edinburgh-Glasgow</b>	Rail	Upgrading
<b>Manchester-Liverpool</b>	Rail	Upgrading and electrification, including Northern Hub
<b>Birmingham-Reading-Southampton</b>	Rail	Upgrading the freight line
<b>Dublin-Cork-Southampton</b>	Ports, rail	Studies and works on port capacity, Motorways of the Sea (MoS) and interconnections

Source: European Commission (2015)

## 6.5 Modal shift scenarios

Three modal shift scenarios, low, central and high, were constructed based on findings from the literature review and the focus group discussion. The scenarios were developed based on the European Commission's mode shift target. In its 2011 White Paper, the European Commission set a target of shifting at least 30% of road freight transport moving over distances greater than 300kms onto rail or water by 2030, and more than 50% by 2050. The baseline for the target is not specified in the White Paper, and can be interpreted as related to the number of movements, tonnage (e.g. McKinnon, 2015) or tonne-kms (e.g. Tavasszy, 2011).

Input data and general assumptions underpinning the scenarios are outlined below:

- Traffic will be shifted from road to rail, i.e. no increase in the share of waterborne transport is anticipated. This is based on findings from the literature review and focus group discussion.
- Linear interpolation of the European Commission's mode shift targets between 2030 and 2050 is assumed. This translates to at least 35% road freight transport over 300kms shifted onto rail by 2035.
- The European Commission's mode shift target is applied to tonne-kms.
- GHG emission savings from moving freight to alternative transport modes in scenarios presented below are based on DEFRA emission factors for different modes (kg CO<sub>2</sub>e/tonne-km).

**Table 13:GHG emissions from road, and rail freight transport, kg CO<sub>2</sub>e/tonne-km, 2014**

Transport mode	Kg CO <sub>2</sub> e / tonne-km
Articulated HGV > 33 tonnes (average laden)	0.084
Freight train	0.028

Source: DEFRA, 2015

- The mode shift is assumed to only affect goods currently moved by articulated vehicles over 33 tonne gross vehicle weight (gvw) and the average lading factor is applied.
- Routing using rail transport modes is assumed to require some diversion from the most direct road connection reflecting the lower network density of this modes. A deviation routing factor of 1.2 is applied.
- Hinterland movements by road to and from railheads are not included in the GHG reductions estimates. These are likely to reduce the estimated savings, as not all origin and destination points will be rail connected.
- Based on the outputs of the HGV model, 175.1 billion road tonne-kms are forecasted in 2035. It is assumed that proportions of road freight traffic carried by different HGV categories will remain at current levels.
- The scenarios focus only on the effects of diverting existing freight traffic from road to rail, and do not include the effects of the overall increase in rail freight traffic volumes over the timeframe of this report.

**Table 14:Mode shift scenarios (numbers may not add up due to rounding)**

	Low	Central	High
	20% road freight transport over 300kms shifted onto rail by 2035	35% road freight transport over 300kms shifted onto rail by 2035	35% road freight transport over 200kms shifted onto rail by 2035
Freight traffic diverted from road (billion tonne-kms)	6.0	10.5	22.6
Freight traffic diverted to rail, including deviation routing factor (billion tonne-kms)	7.2	12.6	27.1
GHG emissions from moving goods by road (Mtonnes of CO <sub>2</sub> e)	0.51	0.89	1.91
GHG emissions from moving goods by rail (Mtonnes of CO <sub>2</sub> e)	0.20	0.36	0.77
GHG emission savings from mode shift (Mtonnes of CO <sub>2</sub> e)	0.30	0.53	1.14

**The low scenario** assumes that the European Commission's target will not be met in full, i.e. only 20% of road freight transport over 300kms will be shifted onto rail by 2035. This scenario takes into account the unique geography of the UK and resulting relatively low proportion of traffic with sufficiently long average length of haul for rail to effectively compete



with road. It also reflects the fact that potential for switching mode highly depends on the time-sensitivity of the traffic. A high level of supply chain timeliness is required by intermodal traffic, which is expected to be the main growth area for rail. It is therefore assumed that not all barriers to shifting more freight onto rail can be overcome by market forces or policy interventions within the time frame of this report.

**The central scenario** assumes that there is a sufficient capacity in the network to accommodate extra freight traffic, and rail can meet the operational requirements of time-sensitive supply chains, to enable the mode shift in line with the European Commission's target. The credibility of this option is strengthened by recent experience of rail capturing longer distance FMCG traffic.

**The high scenario** demonstrates savings associated with applying the European Commission's target to road movements over 200 kms. This reflects a possibility of rail capturing some chained trips that currently include some interim handling (e.g. storage or cross-docking in regional depots). In the current reporting system, these are recorded as separate freight journeys, but on a door-to-door basis the total distance travelled should be long enough to make rail economically effective.

In the low scenario, GHG emission savings from shifting more freight onto rail of around 0.30 Mtonnes of CO<sub>2</sub>e in 2035 can be anticipated. This increases to 0.53 Mtonnes of CO<sub>2</sub>e in 2035 in the central scenario. Reducing the threshold distance from over 300 kms to 200 kms more than doubles GHG emission savings resulting from the mode shift (1.14 Mtonnes of CO<sub>2</sub>e in 2035).

## 6.6 Summary

- Shifting freight to rail can result in significant GHG emission savings.
- Financial incentives to encourage greater use of alternative transport modes are available, but there are a number of non-financial barriers that have to be overcome for the anticipated modal shift to materialise.
- Intermodal rail services to and from deep-sea ports and domestic non-port intermodal services, serving mainly the retail sector, offer the greatest potential for significant growth of the UK rail freight market.

## 7 Outlook to 2050

Our analysis suggests that the impact of measures to improve operator efficiency and improve logistics operations could deliver potential carbon savings of 34% relative to baseline HGV emissions by 2035. Approximately 40% of this reduction is delivered through Higher capacity vehicles, UCCs and relaxation of time constraints, which all are dependent on significant changes in the regulatory environment.

Delivering these savings exhausts the potential for all the interventions considered in this study. It is therefore not possible to identify further carbon reduction opportunities in the period 2035-50. Without further technology breakthroughs or radical innovations in logistics practice achieving 80% reductions in road freight transport GHG emissions is highly unlikely by 2050.

This study has not included any consideration of alternative fuels, although it is possible to foresee the use of electric vehicles especially in urban contexts. Assuming decarbonisation of electricity supply in the UK, this would result in significant reductions in GHG emissions as a result of a widespread switch to electric HGVs. Furthermore, as shown in Section 6, it may be possible to increase the amount of freight moved by alternative transport modes, although this would probably require increased rail connectivity and innovative (faster) material handling technologies.

We consider 2 scenarios for demand side measures in the period 2035-50:

**Scenario 1.** A much greater availability of standardised logistics data, paired with significant improvements in processing capability could extend the reach and impact of logistics measures. This could include the emergence of open, collaborative, synchro-modal logistics networks. The developing interest in what has been termed the Physical Internet directly addresses this scenario.

Synchro- modal logistics refers to operations that synchronise operations across multiple modes of transport

The Physical Internet refers to the optimisation of logistics activity across multiple supply chains, as opposed to the current arrangements reflecting optimised corporate supply chains, which may result in sub-optimal arrangements across the system as a whole.

**Scenario 2.** With a lack of further decarbonisation opportunities for road freight transport, there could be a further switch freight to rail and water.

These two scenarios help to prioritise additional measures.

**Priority 1: Data availability.** The availability of more data to plan and organise logistics will always improve efficiency of the freight transport system, regardless of mode and modal split strategies. Moreover, this is a relatively low cost intervention. There are, however, some barriers to its implementation. These include: the unwillingness of the companies to share data, concerns about data security and commercial sensitivity of data, integrity of collected data, and the efficiency of planning algorithms.

**Priority 2: Modal switch.** As shown in Section 6, additional GHG emission savings from modal shift would require a significant proportion of journeys to be done by rail. This, in turn, would require great improvements in rail capacity and connectivity, necessitating significant capital investment. The de-carbonisation of electricity supply coupled with electrification of the rail network could deliver the required reductions with lower levels of connectivity. Due to the long investment lead time for rail infrastructure, investment in this intervention needs to start immediately if improvements in rail connectivity are to be achieved to guarantee significant GHG savings from modal shift.

There are three important issues that need to be mentioned here. Most estimates of carbon savings from the modal shift to rail are based on comparisons of one-way journeys for both rail and road. This is the approach adopted also in this report. While road freight transport achieves reasonably good backhaul rates, most freight trains return to base empty. Intermodal trains are the exception, as they tend to carry containers both ways (even though the vast majority of the containers on the return journey are empty, they are classed as loads). This may result in overstated carbon benefits of rail. However, since much of the future growth on rail is expected in the intermodal sector with high backloading rates, comparisons between total journeys carried out by different modes become more favourable to rail. Also, more traffic may become available to fill the containers on the return journeys, thus further increasing the carbon benefits of rail.

The second point relates to the electrification of the railway network. In the UK, 40% of rail traction is electrified, but electric traction accounts for only around 5% of freight train mileage (DECC, 2010). To date, the take-up of electric traction has been relatively limited, even on electrified routes. This is likely due to two main factors. Investment cycles for locomotives are long, and it takes time for infrastructure upgrades to be reflected in the composition of the UK freight locomotives stock. Also, in order to maintain flexibility diesel engines are preferred, as they can be used on electrified and non-electrified routes. As increasing proportion of the UK traction gets electrified, the proportion of electric freight trains should rise, resulting in greater carbon benefits.

The final point relates to a potential for electrification of long distance road freight. At the moment, electric vehicles have applications mainly in urban and regional distribution. It is, however, possible that within the time scale of this report new, viable solutions to long distance road transport electrification will be developed. Some trials are already underway, e.g. Siemens' eHighway system in California. If the national road network was fully electrified, this would negate the environmental benefits of shifting more freight onto rail.

## 8 Summary

This project aimed to improve the evidence base on demand-side measures to reduce fuel consumption and GHG emissions in the HGV sector, in order to inform advice on the fifth carbon budget (2028-2032).

Three types of demand side interventions were considered:

- Technological improvements to existing vehicles, for example technologies to improve aerodynamics.
- Measures to promote more efficient driving styles, which can reduce the carbon intensity of a given HGV km, for example eco-driving.
- Improvements to logistics operations from measures such as improved routing, use of consolidation and distribution centres, higher lading factors, a reduction in empty running and use of computerised technologies. These measures reduce emissions by reducing overall distance driven by HGVs.

Modelling results suggest that GHG emissions from the HGV sector would decrease by 8% between 2015 and 2035 as a result of supply-side improvements, i.e. due to the introduction of new more efficient vehicles (the baseline scenario).

In the central commercial scenario, GHG emissions reductions from demand side interventions of 34% relative to the baseline emissions could be achieved. 42% of that would result from improved driving style, 42% from improvements to logistics operations efficiency, and the remainder from aftermarket improvements to vehicles.

Improvements to driving styles have the lowest cost of implementation and offer the biggest opportunity for improvements in operator efficiency. The use of UCCs, relaxation of delivery times and the use of higher capacity vehicles generate the most significant improvement in logistics efficiency by 2035. However, these measures have significant implementation barriers that need to be overcome for the savings to materialise. The extent to which potential carbon and cost savings from improvements to logistics operations are realised in practice will depend on a range of factors such as the way the road freight transport industry will evolve or developments in future collaboration practices.

The social cost-effectiveness of the vehicle-level measures is broadly aligned with commercial cost-effectiveness considerations. This is because lower discount rate and introduction of carbon prices into the analysis partially offset lower fuel prices and longer payback period in the social cost-benefit analysis.

Shifting freight to alternative transport modes can result in significant GHG emission savings (between 0.3 and 1.1 MtCO<sub>2</sub>e) in the freight transport sector. Intermodal rail services to and from deep-sea ports and domestic non-port intermodal services, serving mainly the retail sector, offer the greatest potential for significant growth of the UK rail freight market in the coming years. However, even though businesses are gradually increasing their use of alternative transport modes, and financial incentives are available, there are also a number of non-financial barriers that have to be overcome for significant modal shift to materialise.

The study identified a number of key areas that policy makers might consider to facilitate the transition to more efficient logistics operations. Key areas that would need to be addressed are:

- Improving the availability of logistics data to facilitate collaboration and improved planning of freight transport operations.
- Clarification of permissible forms of collaboration in the context of anti-competitive regulation.
- The development of strategies to permit the use of Higher capacity vehicles.
- Facilitation of land use considerations for UCCs.

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## Appendix 1 Model Description

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- Introduction

The model developed for the Committee on Climate Change (CCC) is an adapted version of the Carbon for Money model which was originally developed by the Centre for Sustainable Road Freight, in conjunction with the Freight Transport Association, for use by individual companies to assess the implications on carbon emissions on various vehicle and driver fuel saving measures. It uses an NPV based analysis to identify those fuel saving measures that are most cost effective.

The CCC model has been developed using an Excel spreadsheet to allow ease of data input, and incorporates various macros which perform the analyses. It has been designed with three essential characteristics which are ease of use, quick to set up and run, and aesthetic appeal. Buttons can be selected on the major worksheets which allow the user to perform analyses or move to other worksheets.

The aim of the model is to use summarised data from the DFT's CSRGT database to calculate the carbon dioxide emissions associated with the UK's road freight transport operation. A total of 29 vehicle and driver carbon-reducing measures have been identified using existing research and company experience. This has been supplemented with 7 additional operational measures which are currently happening, and will continue to happen, in the supply chain, and will affect the distances driven by road and fuel consumed. The model uses a net present value (NPV) calculation for the vehicle measures to assess the cost effectiveness of each measure before it is selected for use.

By modelling the effects of these measures over a 25 year period between 2010 and 2035, the tool will help to identify potential CO<sub>2</sub> emissions in the UK for freight transport.

The tool generates two reports with the following outputs:

- For each year by type of vehicle
  - Total GHG emissions
  - Fuel consumed
  - No of vehicles
  - Kilometres run
- Dominant measures adopted by type of vehicle

An outline of the model structure is shown in Appendix 1.

- Model Main Menu

The first screen shown on loading the model is the main menu. It consists of three direct inputs and a number of buttons to perform various actions. The three input values are the year in which the model is to start, the business sector on which to perform the analysis, and the scenario to be modelled. This business sector input has a drop down list from which one of 19 business sectors can be selected, or alternatively all business sectors can be analysed if required. There are currently three scenario options that can be modelled.

The model contains six sets of input data selected by pressing one of the buttons on the main menu. They are:

- Data derived from the CSRGD database
- UK parameters relating to the future cost of fuel, manufacturing output, congestion and new vehicle purchases
- The characteristics of vehicle and driver fuel saving measures to be considered
- The characteristics logistics measures to be considered
- A table showing the likely adoption rate for each fuel saving measure over a 21 year period
- The vehicle input data used by the model

The main menu also contains buttons for five actions that can be performed with this data. They are

- Running the model
- Displaying the annual results of the model run
- Displaying the measures adopted
- An iteration of a single year on a selected business sector
- A display of the measures adopted by each vehicle ranked in descending order of NPV

A final button on this screen allows the user to close the model.

When any of these buttons are selected macros are run in the VBA Project Module called MenuButtons. A description of each button macro is given below:

Button Name	Linked Macro	Description
<b>CSRGD Data</b>	btnCSRGDData_Click()	Displays the CSRGD Data worksheet
<b>UK Database</b>	btnInputUKData_Click()	Displays the InputUKData worksheet
<b>Set Up Sector Vehicle Data</b>	btnInputData_Click()	Runs a macro which extracts data from the CSRGD Data for the business sector requested and displays the InputData worksheet. If All business sectors is selected in the Main Menu then a blank InputData worksheet is shown.
<b>Characteristics of Vehicle Measures</b>	btnInputMeasures_Click()	Displays the InputMeasures worksheet
<b>Characteristics of Logistics Measures</b>	btnInputLogMeasures_Click()	Displays the InputLogMeasures worksheet
<b>Percentage Take up of Measures</b>	btnInputTakeUpData_Click()	Displays the InputTakeUpData worksheet

<b>Run Model</b>	btnReport_Click()	
<b>Display Annual Report</b>	btnTabularResults_Click()	Displays sheet Report if an individual business sector has been selected in the main menu, or sheet AllCoResults if all business sectors has been selected in the main menu
<b>Display Measures Report</b>	btnDisplayMeasuresReport()	Displays sheet MeasuresReport if an individual business sector has been selected in the main menu, or sheet MeasuresAllCo if all business sectors has been selected in the main menu
<b>Annual Iteration for a Single Sector</b>	btnNextIteration_Click()	
<b>Display Measures by Vehicle Type</b>	btnDisplayFilter()	
<b>Close Model</b>	Auto_Close()	Closes model

**Table 1: Main Menu Buttons**

- The CSRGT Data

The DfT's data from the Continuing Survey of Road Goods Transport (CSRGT) contains some key input parameters for the model. The dataset represents a detailed analysis of road transport flows in the UK. A general description of each parameter is provided in Appendix 2. The CSRGT data was initially validated by checking grossed up km and tonne km for each year against the values shown on the DfT Road Freight Statistics report. The fuel type information provided in the CSRGT data came from the DVLA so an additional dataset was provided by the DfT which showed the number of licensed HGVs in Great Britain by propulsion type as at 30 June 2014.

Additional parameters were calculated and added to each record namely, average length of haul, percentage empty running and percentage load fill by weight. These were also validated against the DfT Road Freight Statistics for each year.

The fuel consumption values in the CSRGT data are likely to be inaccurate. In some instances there are no entries, perhaps because a vehicle has not been filled with fuel during the recording period, and in others the fuel consumption rate for the vehicle is well outside of expected ranges. This could be due to a vehicle being filled with fuel at the beginning and end of the recording period, which would mean the fuel consumption rate could be significantly lower than the actual rate. Consequently an estimated average mpg value was calculated for each vehicle type based on either a rigid or artic, the gross train weight, and number of super single tyres. This typical mpg value was derived from averaging four sources namely Motor Transport, Commercial Motor, FTA and RHA cost tables, all related to diesel fuel only which represented 99.6% of the CSRGT records. Applying these values to the gross km travelled produced an estimate of total litres of diesel fuel consumed.

The same four sources were used to calculate an estimate of the number of vehicles by type. The average annual km travelled by different types of vehicle were obtained and applied to the total km in the CSRGT data. However this only produced about half the known number of licenced vehicles on the road. Using additional DfT data obtained on licensed vehicles a factor was calculated for each type of vehicle in each year and applied to the annual km travelled per vehicle type. This produced a more realistic estimate of vehicle numbers.

The key data requirements for the model are shown in the table below.

Summarised from the CSRGT dataset	Comment
Vehicle type – possible values are: Small rigids Large rigids Artics	The CSRGT data has been appended with this data for each record based on whether an artic or rigid, and the gross train weight. To be compatible with the AEA (2012) study a rigid less than 15,000kg is classified as a small rigid and 15,000kg and over is a large rigid.
Type of operation Urban Distribution Regional Distribution Long-haul Distribution	The length of haul has been derived by dividing the Tonne km / Tonnes for each record in the dataset. If the average length of haul in the CSRGT data is less than 25km then it has been classified as urban. Less than 100km has been classified as regional and 100km or over is long haul.
Fuel Type	Extracted directly from CSRGT

Number of vehicles	Calculated as described above
Fuel consumed per year (litres)	Calculated as described above
Total km in year being considered	Extracted directly from CSRG

- The UK Input Data

This set of data informs the model of expected changes in the price of fuels and carbon, plus predicted changes in km and congestion levels, over a 25 year period.

The costing information has been derived from a set of tables that supports the September 2014 version of the DECC/HM Treasury Green Book supplementary appraisal guidance on valuing energy use and greenhouse gas (GHG) emissions. The cost of a litre of diesel has been split into a commercial cost and a social cost. The commercial cost has been obtained from the central value of table 8 in the DECC spreadsheet named 20141001\_Supporting\_Tables\_for\_DECC-HMT\_Supplementary\_Appraisal\_Guidance. The social cost has been obtained from the central value of table 13 in the same spreadsheet, as has the non-traded carbon pricing value which has been obtained from table 3.

The changes in kilometres travelled by small rigid, large rigid and artic, over the 25 year period, have been supplied by CCC and are consistent with those used in the AEA (2012) study. They also reflect expected changes to congestion levels.

This input sheet also contains expected fuel efficiency improvements to new vehicle diesel engines, over the 25 year period, via a series of specific technical measures such as:

Mechanical Turbocompound  
Electrical Turbocompound  
Heat Recovery (Bottoming Cycles)  
Controllable Air Compressor

- The Vehicle Measures Input Data

Twenty nine vehicle and driver related carbon saving measures have been identified.

Information about fuel savings and costs for each measure are input on this sheet. None of the measures will have any effect on the kilometres travelled by vehicles.

The fuel savings are split into the types of operation which have been derived based on average length of haul. Thus percentage fuel savings have been added to urban, regional and long-haul distribution based on research from various sources, most notably the report by AEA (2012), and these have been included on this input sheet.

The per vehicle costs for each measure include the capital cost, annual maintenance cost and resale value plus the lifespan of the measure. Again the source of this information is included on the worksheet.

- The Logistics Measures Input Data

Seven logistics measures have been identified that will impact kilometres travelled and fuel consumption. Most of these measures have been put into operation to a greater or lesser extent, and are expected to be implemented more significantly in the coming years. Whilst the use of longer heavier vehicles is currently prohibited in this country, others in Europe permit this type of vehicle, and research has shown they can be beneficial on UK roads.<sup>8</sup> It is therefore prudent to include the possibility that a vehicle of this type may be accepted in a trial form initially, but may then become an accepted vehicle, before 2035. Collaboration to reduce empty running by filling vehicles on both the outward and return legs of a journey has been around for many years. Vertical collaboration started in the mid 90's with factory gate pricing, typically operated by FMCG retailers and their suppliers. More recently, since the mid 2000's, horizontal collaboration, whereby companies operating at the same level in the supply chain work together, has started to become more widespread among companies. Horizontal collaboration to maximise vehicle fill (synchronised consolidation) has also gradually become an accepted way of reducing the kilometres travelled. Although still in the early adopter phase, pressure from customers to be more sustainable, and government policies, are likely to encourage this form of logistics practice, and is therefore likely to be more prevalent in the future.

There have been many research projects, typically sponsored by the EU, into the use of urban consolidation centres. There are many examples of these in the UK, currently in operation, such as Broadmead in Bristol, Meadowhall in Sheffield, Heathrow, and a construction consolidation centre operating successfully in Silvertown serving construction sites in London. The purpose is to limit the number of vehicles operating in a city, thereby easing congestion and improving air quality and living conditions. As with collaboration, pressure from local and regional government is likely to encourage the further use of these types of facilities. However, the past has shown that for these facilities to be economically viable, subsidies have to be in place initially, until there are sufficient companies using the centre. Even now, there are still doubts about future viability unless other forms of value added activities can be included such as shelf ready and waste disposal functions.

Supply chain networks are constantly being changed to reflect new market conditions. Whether it is the drive to reduce costs, improve or maintain service levels, achieve greater sustainability or customer demands, networks are being adjusted in an effort to achieve an optimum performance. Over the years, the tendency has been to centralise stockholding meaning greater distances travelled by transport. With the increased amount of importing activity a greater focus has been placed on port centric logistics. Whichever network is adopted there will be an overall impact on the kilometres travelled by road and fuel consumed.

Within the EU and in the UK there is a desire to move goods from road to alternative forms of lower carbon of transport such as rail, canal or coastal shipping. In the UK there has been little change in the proportions of these transport modes being used for freight over the last 15 years. However, with the pressure to be more sustainable, there is now a greater awareness of other modes, rail in particular, with some companies such as Tesco

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<sup>8</sup> Knight, I., Newton, W., McKinnon, A., Palmer, A., Barlow, T., McCrae, I., Dodd, M., Couper, G., Davies, H., Daly, A., McMahon., Cook, E., Ramdas, V. and Tylor, N. 'Longer and/or Longer and Heavier Vehicles (LHVs): A Study of the Likely Effects if Permitted in the UK – Final Report' *TRL Ltd. Crowthorne*, 2008



significantly increasing their use of this type of transport. It is likely greater use will be made of rail in the future.

The demands for more rapid response rates to customer orders has increased over the years. In the FMCG sector for instance, it was the norm for order day 1 for delivery day 3. This has now changed to delivery day 2 and increasingly it is becoming delivery day 1. With the increasing use of the internet for home deliveries and the many alternative channels for ordering, fragmented supply chains are the outcome, resulting in inefficient use of road freight transport. Many of the logistics measures already outlined can help to ease this problem but a further option might be to slow the rate at which orders are fulfilled in order to achieve a more efficient vehicle load. In particular “just in time” deliveries can have a negative cost and environmental effect on the overall efficiency of an operation.

The data required by the model includes an estimate of the kilometre and fuel savings that might occur from implementing these measures. They have been derived from a number of sources including the Starfish study<sup>9</sup> and the Tesco freight transport profile<sup>10</sup>.

It is unlikely that all these measures will be applicable across business sectors, types of operation or vehicle types. This input screen allows specific combinations to be selected for each measure.

- The Percentage Take up of Measures

This input screen represents the estimated percentage take up of each of the measures over a 25 year period. Clearly, some of the vehicle related measures will be more applicable to certain sizes so the input screen has been split into four sections, namely the percentage take up of measures for small rigids, large rigids and artics, and logistics operations measures. The figures shown on the input screen indicate the maximum percentage for each measure in a particular year, and have been derived from a questionnaire circulated to a wide range of industry members. This input sheet also includes a table showing the expected new vehicle uptake of each measure, over a 25 year period.

A further table in this worksheet automatically adjusts the figures in these two tables to reflect the extra percentage of measures being taken in a year. This means that the actual uptake percentages used in the model only apply to older eligible trucks, and it also avoids double counting the proportion of kilometres considered for each measure.

- The Vehicle Input Data

When this option is selected in the main menu a macro is run which extracts data from the CSRGT input screen for the business sector selected. It then automatically populates the fields headed:

- Vehicle category
- Type of operation

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<sup>9</sup> Palmer, A., McKinnon A. ‘An Analysis of the Opportunities for Improving Transport Efficiency through Multi-lateral Collaboration in FMCG Supply Chains’ *LRN 2011*, Southampton, September 2011

<sup>10</sup> IGD Supply Chain Analysis 2014 <http://supplychainanalysis.igd.com>

- Fuel type
- Number of vehicles
- Fuel consumed per year
- Total distance per year

In addition a formula automatically calculates the fuel economy from the distance run and fuel consumed. Where diesel fuel is used, the macro routine sets the percentage of diesel used to 100% reflecting a 5% use of biofuels.

Based on the year being examined a formula extracts, for the appropriate vehicle type, the proportion of extra kilometres travelled in the next and subsequent year, by referring to the data stored in the InputUKdata worksheet. This is automatically added to the two columns requiring the percentage increase in distance over the next two years, in the vehicle input screen.

A maximum of 12 different vehicle type, operation and fuel type combinations can be added to this input screen.

Note that if All Business Sectors has been selected in the main menu then this part of the screen will not be populated with any figures.

At the bottom of this screen there is data about the costs of different types of fuel, and a carbon cost. A formula automatically extracts this information from the InputUKData worksheet depending on the year being examined, and the scenario to be modelled.

There are two direct inputs required on this screen. The first represents the discount rate to be used for the NPV calculations. This is used to discount future cash flows to the present value. The second input is the maximum payback period commercial companies might accept. Thus a capital investment and annual cost for the lifespan of a measure should have a payback period less than the figure in this input cell for the model to accept the measure. Values entered in this worksheet automatically/dynamically updates cells in worksheets AH Model Calc, Select Options, Payback period Calculation, and NPV. The results of the NPV are also dynamically added to cells AN1:BC349 in the NPV Priority worksheet.

- Running the Model

As stated in the previous paragraph, much of the spreadsheet model uses formulae to automatically/dynamically update the calculations, but for certain actions a macro is required. Each of the working worksheets in the model are described in section □. When RunModel is selected on the Main Menu worksheet a macro called btnReport\_Click() is activated. The operation of this macro follows the structure outlined in Appendix 1, and performs a number of steps as follows:

1. In the first instance the main menu input screen is checked to see what business sectors are to be examined.
2. For each sector in turn, or for a specific business sector if requested, the model clears any contents from the vehicle input data worksheet and extracts the relevant data from the CSRGD data worksheet
3. A subroutine called btnPriorityMeasures() is run which copies and sorts the NPV measures into descending order of value into the Filter worksheet. Any NPV values less than zero or are greater than the maximum payback period identified in the InputData screen are excluded.

4. The pivot tables are then updated in the Pivot worksheet, and the results for business sector for the year being examined are output to the Report and the MeasuresReport worksheets.
  5. The pivot table results are also used to change the vehicle InputData worksheet to the next year's values. As each year is analysed the formulae in the vehicle InputData worksheet automatically updates the price of fuel for the corresponding year and formulae also update the kilometres run entries by the year on year km increase factor, all extracted from the InputUKData worksheet.
  6. The macro then repeats the process from step 3 for each of the 25 years being examined and then ends if a specific business sector has been selected in the Main Menu
  7. If All Business sectors have been selected in the Main Menu, after 25 years analysis have been completed, the macro copies the results from the Report worksheet to a section reserved for each business sector in the AllCoResults worksheet. The AllCoResults worksheet contains a formula accumulating the results of each business sector into a single report.
- Displaying the Annual Report

As the model runs annual results are added to the Report worksheet for a specific business sector. This is split by vehicle type, and a total. The results output each year show the baseline CO<sub>2</sub> emissions, fuel consumed and kilometres run, and the same values again with all the accepted fuel saving measures. The number of vehicles is shown together with predicted tonne km for the year. There are two final calculations in the report which show the grams of CO<sub>2</sub> per kilometre with measures, and percentage change in fuel/CO<sub>2</sub> over the baseline start year. After 25 years have been completed, the model stops if a specific business sector has been selected for analysis, and displays this complete report.

If the option to analyse All Business Sectors has been selected in the Main Menu, the results on the Report worksheet are then copied to one of 19 tables in the AllCoResults worksheet, one table for each business sector. The report displaying the results for all business sectors is identical to the report for individual business sectors, but contains formulae summing up the appropriate values in each of the 19 tables. Additional columns have been included in this report to show the total emissions savings split by savings from new vehicle improvements, savings from improved operator efficiency and savings from reduced kilometres travelled.

In both the Report and AllCoResults worksheets there are buttons to allow the user to save the results, return to the main menu or display the measures report. In addition the Report worksheet for a specific business sector allows for a single annual iteration, if required (see section 12)

- Displaying the Measures Report

As with the annual report, the measures report is held in two worksheets depending on whether All Business Sectors or a single business sector has been selected, in the Main Menu.

If a single business sector has been selected, when the model completes a year, the CO<sub>2</sub> and fuel consumed for each positive NPV measure are added, by vehicle type, for the year being examined, to the table, located between cells S4:BT91 in the MeasuresReport

worksheet. This table includes two columns that calculate the average CO<sub>2</sub> and fuel consumed for each measure. At the completion of the 25 year analysis the model macro copies the measures containing positive values into the main display area and sorts by vehicle type and descending order of CO<sub>2</sub> emissions.

A similar process exists for all business sectors. If this option is chosen, when a single business sector has been analysed, the results from the single sector MeasuresReport worksheet are copied to the MeasuresAllCo worksheet table in S4:BF91. After all business sectors have been analysed the model macro copies all the measures containing positive values into the main display area and sorts by vehicle type and descending order of CO<sub>2</sub> emissions.

- Running an Annual Iteration

This option is only available if a single business sector has been chosen. It steps through the Run Model logic, one year at a time, so that specific parameters can be checked and analysed. This is useful to see how the selected measures are chosen and updated for each year.

When this option is selected, the model initially shows a list of prioritised measures, by vehicle/operation/fuel type combination, in the Filter worksheet. As well as NPV, cost and CO<sub>2</sub> savings, and payback period, this worksheet shows the effect on fuel consumption of combining measures for a vehicle category as defined on the InputData worksheet. This updated fuel consumption figure is then used for the following year's analysis.

A second iteration of this option displays the first year's results in the Report worksheet. There is an option to run a subsequent year by selecting the Annual Iteration button either in the Report Worksheet or the Main Menu. This then displays the next year's results, and so on until the completion of a 25 year analysis for the business sector.

- Displaying the Ranked NPV Measures

At any point in the Annual Iteration process this option can be selected. It displays the current position of the Filter worksheet. It contains data extracted from the NPV Priority worksheet for those measures that have a positive NPV with less than maximum payback period for each vehicle category. It also displays additional data important for combining measures and calculating new fuel consumption. There are no methods or sources anywhere that have shown an accurate way of combining vehicle fuel saving measures. The approach adopted in this model is based on the same method used by AEA (2012), which is combining the fuel savings of the chosen vehicle technologies in a multiplicative way.

- Description of Other Worksheets in the Model

These additional worksheets support the calculations being made. Each of worksheets contain formulae and perform calculations to support the final results. Macros are used to extract specific information from these worksheets to support the output.

Sheet Name	VBA (shtName)	Summary
<b>AH Model Calc</b>	shtAH	<ul style="list-style-type: none"> <li>Calculation related to the user input</li> <li>Conversion factors</li> <li>DEFRA carbon emission factors</li> <li>Fuel cost of each vehicle type</li> <li>Carbon emissions of each vehicle type</li> </ul>
<b>Payback Period Calculation</b>	ShtPaybackPeriod	<ul style="list-style-type: none"> <li>Contains financial input</li> <li>Calculations related to cost savings, payback period and fuel savings</li> <li>Collects input for maintenance cost, lifespan and resale value from the InputMeasures sheet</li> <li>Calculation for alternate-fuel vehicles</li> </ul>
<b>Select Options</b>	shtSelectOptions	<ul style="list-style-type: none"> <li>Carbon-reducing measures implementation matrix</li> <li>Carbon emission calculations for each measure</li> </ul>
<b>NPV</b>	shtNPV	<ul style="list-style-type: none"> <li>Calculation of 'Net Present Value' of all 29 carbon-reducing measures</li> </ul>
<b>NPV Priority</b>	shtNPVP	<ul style="list-style-type: none"> <li>Displays NPV from NPV sheet</li> <li>Identifies measures that have a positive NPV and less than maximum payback period for each vehicle category</li> </ul>
<b>Filter</b>	shtFilter	<ul style="list-style-type: none"> <li></li> </ul>
<b>Logistics Measures</b>	shtLogMeasures	<ul style="list-style-type: none"> <li></li> </ul>
<b>Pivot</b>	shtPivot	<ul style="list-style-type: none"> <li>Creates a number of pivot tables to summarises the ranked NPV data and measures adopted from the Filter worksheet, and adds additional information relevant to the new vehicle operation in the subsequent year</li> </ul>

**AH Model Calc** worksheet – this worksheet takes the vehicle input data and calculates the current year, and following 2 years, kilometres and fuel consumption by vehicle type assuming no interventions have been applied. This worksheet also contains DEFRA CO<sub>2</sub> conversion units for a range of fuel types. These figures are then used in the Select Options worksheet.

**Select Options** worksheet – this worksheet takes the percentage savings and take up rates for each vehicle and driver measure, for up to 12 vehicle types, and calculates the baseline fuel consumed assuming no measures applied, and with measures applied. These are then used in the Payback period Calculations worksheet.

**Payback period Calculations** worksheet – this worksheet applies the costs of measures to each of the 12 vehicle types and estimates the savings potential, payback period, litres of fuel and kilometres saved, the percentage of vehicles taking up each measure, maintenance cost, resale value and CO<sub>2</sub> savings. The calculations in this worksheet are in preparation for input to the NPV process.

**NPV** worksheet – this worksheet extracts information from the Payback period Calculations worksheet and applies them to the NPV formula which is as follows:

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \dots + \frac{C_T}{(1+r)^T}$$

–  $C_0$  = *Initial Investment*  
 $C$  = *Cash Flow*  
 $r$  = *Discount Rate*  
 $T$  = *Time*

The NPV calculation is applied to each of measures for up to 12 vehicle types.

**NPV Priority** worksheet – This worksheet brings together all the key information from each of the other worksheets for each measure and vehicle type. A macro then extracts only those measures and vehicle types that have a positive NPV, and fall within the maximum payback period as defined in the InputData sheet. Elements from this sheet are then added to the Filter worksheet

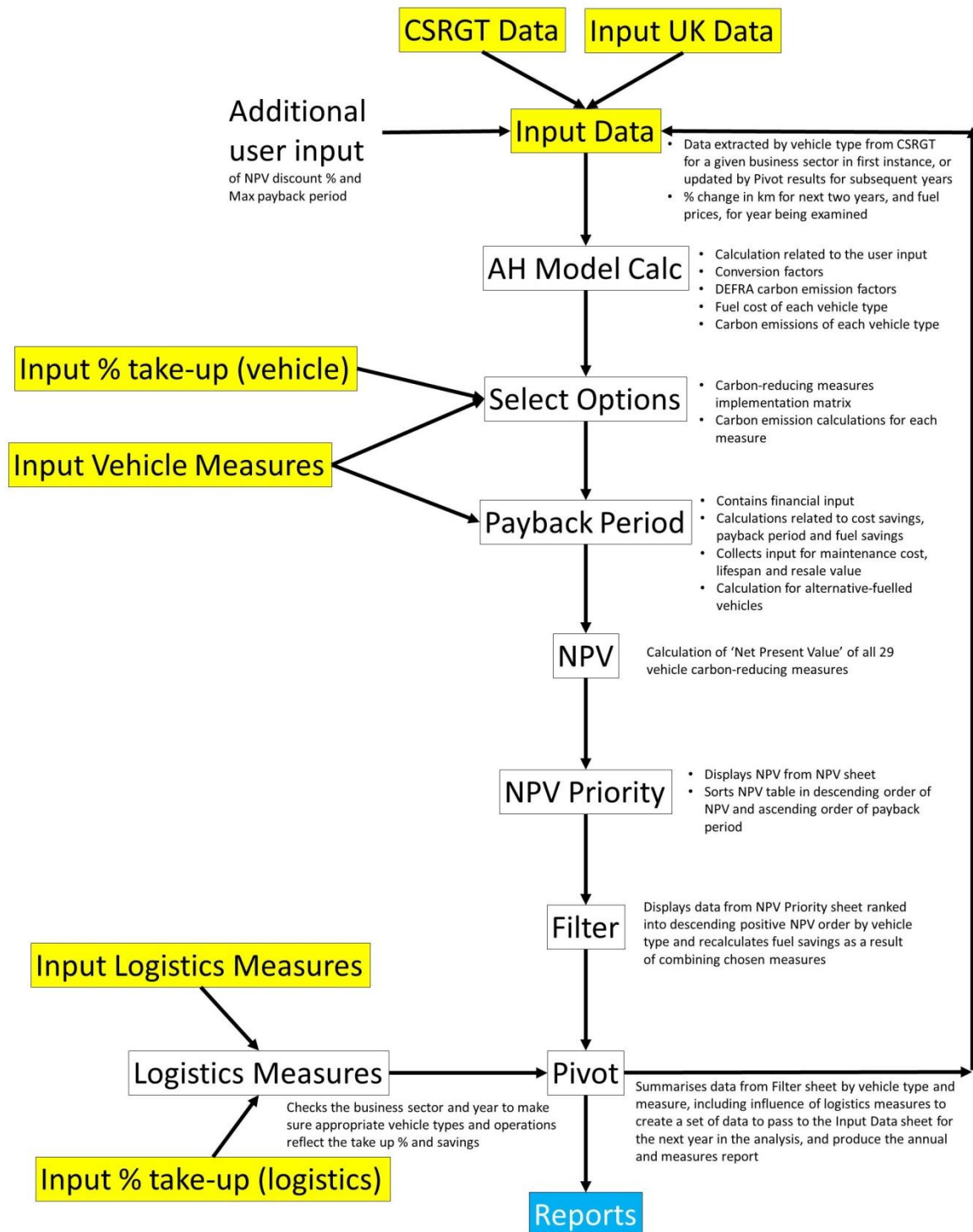
**Filter** worksheet – this is described in section 13 above

**LogisticsMeasures** worksheet – This worksheet takes data from the InputLogMeasures worksheet and performs a range of calculations to estimate the kilometres run, number of vehicles and fuel consumed, depending on the type of vehicle being used, the type of operation and the business sector being considered. The results are input to the Pivot worksheet

**Pivot** worksheet – this worksheet contains 2 pivot tables which summarises the data held on the Filter worksheet. The first pivot table extracts the CO<sub>2</sub>, fuel savings and the percentage of fuel saved for each vehicle type used in the particular model run. This is then expanded to include a range of calculations for the logistics measures and arranged for displaying in the annual report. The second pivot table summarises all the measures from the Filter worksheet with a third worksheet used on this summarised data to arrange the data for displaying in the measures report.

## Appendices

### Appendix 1: Structure of the Model



## Appendix 2: Description of CSRGT data



**General Description**

This dataset comes from the Continuing Survey of Road Goods Transport - Great Britain (CSRGT-GB), which surveys UK activity of GB registered HGVs over 3.5 tonnes in weight. It is a stratified sample survey, recording a weeks worth of activity from a sample of vehicles each week, and covering about 1-2% of the GB HGV population annually.

The data provided cover the period 2004 to 2010, and are provided in a Microsoft Access database, called "CSRGT\_GB\_Vehicle\_level\_data\_2004\_2010.accdb".

The table contains vehicle attributes and activity aggregated to the vehicle level. Each row of the table therefore corresponds to a single vehicle surveyed for a single week. The activity measures however are not the observed values for the single vehicle in a single week, but are already "grossed" (multiplied by a weighting factor) so that when activity is summed up over the sampled vehicles sharing certain characteristics, the quarterly activity of the entire GB population of similar vehicles is estimated (see note 2 below)

Variable Name	Type	Units	Range of values	Description and comments
SurveyYear	Long Integer	Years AD	2004 to 2010	Survey Year
SurveyQuarter	Long Integer	N/A	1 to 4	Survey Quarter. 1 = Jan -Mar; 2 = Apr - Jun; 3 = Jul-Sep; 4 = Oct-Dec
GrossTrainWeight	Decimal	Kilograms	3501 to 65000	Maximum permitted laden weight of vehicle (i.e. vehicle + trailer + load) , obtained from DVLA database
ArticRigid	Text, 5 characters	N/A	"Artic" or "Rigid"	Flag distinguishing rigid ("Rigid") and articulated ("Artic") HGVs.
OperatingMode	Text, 14 characters	N/A	"Hire or reward" or "On own account"	"Hire or reward" means that the company or individual owning the vehicle use it to carry goods belonging to other people - i.e. they specialise in transport. "On own account" means that the company or individual owning the vehicle use it to carry goods that belong to them (i.e. have been grown, extracted, manufactured, bought, etc. by the same company)
NatureOfBusiness	Text, 111 characters	N/A	One of the 19 business categories listed below	These 19 codes are specified by the CCC, and aggregated from the NACE revision 1 codes used in the source dataset. Note, vehicles with code 60 in the source data (Land transport; transport via pipelines) have been incorporated into the "Hire or Reward Transport

				(Public haulage)" category, after inspection of the business names being labelled with code 60.
NumSuperSingleTyres	Long integer	Number of tyres	0 to 61	Number of "Super Single" tyres on the trailer used by the vehicle. Applies to both articulated and rigid vehicles. Note there are some implausibly high values, and that the number of vehicles with 0 is likely to be an overestimate, as non-response to this question was coded as 0.
DoubleDecker	Text, 3 characters	N/A	"Yes", "No" or "N/A"	Does the vehicle possess a double decker trailer? Articulated vehicles only. "N/A" values refer to rigid vehicles. Note that the proportion of "Yes" values is likely to be an underestimate - see note 1
GPS	Text, 3 characters	N/A	"Yes" or "No"	Does the vehicle possess a GPS unit? Note that the proportion of "Yes" values is likely to be an underestimate - see note 1
FleetMan	Text, 3 characters	N/A	"Yes" or "No"	Is the vehicle under fleet management? Fleet management is a slightly ambiguous term, so may have been interpreted in different ways by different respondents, but the intention was to monitor use of vehicle tracking systems. Note that the proportion of "Yes" values is likely to be an underestimate - see note 1.
Computer	Text, 3 characters	N/A	"Yes" or "No"	Does the vehicle possess an onboard computer? Note that the proportion of "Yes" values is likely to be an underestimate - see note 1
FuelType	Text, 10 characters	N/A	"Petrol", "Electric", "Petrol gas", "Diesel" or	Fuel type at registration, obtained from the DVLA database. Conversions to other fuel types aren't recorded.

				"Gas"
GrossingFactor	Decimal	N/A	98 to 29198	<p>The multiplication factor used to scale up weekly samples to quarterly population estimates - see note 2. Note that if you want to obtain estimates of the size of the GB population of vehicles having a certain attribute, rather than population activity, you should divide the grossing factor by 52. However, the total you then estimate will be the population of ACTIVE vehicles in that stratum, not necessarily the total number. Fuel purchased or taken from storage for the surveyed vehicles. Grossed figures are obtained by multiplying recorded fuel purchased/ taken from storage by each vehicle's grossing factor (see note 2). The distance travelled by the HGV during the survey week, grossed up to reflect its contribution to population level activity. Obtained by multiplying sampled distance by the grossing factor (see note 2) The loaded distance travelled by the HGV during the survey week, grossed up to reflect its contribution to population level activity. Obtained by multiplying sampled loaded distance by the grossing factor (see note 2) The empty distance travelled by the HGV during the survey week, grossed up to reflect its contribution to population level activity. Obtained by multiplying sampled empty distance by the grossing factor (see note 2) The weight of goods lifted by the HGV during the survey week, grossed up to reflect its</p>
GrossedFuelPurchasedL	Decimal	Litres	0 to 11021985	
GrossedTotalKMs	Decimal	Kilometres	323 to 36780282	
GrossedLoadedKMs	Decimal	Kilometres	0 to 30850006	
GrossedEmptyKMs	Decimal	Kilometres	0 to 18390141	
GrossedTonnes	Decimal	Tonnes	0 to 12695159	

GrossedTonneKMs	Decimal	Tonnes * Kilometres	0 to 441697486	contribution to population level activity. Obtained by multiplying sampled weight of goods by the grossing factor (see note 2) The weight of goods multiplied by distance moved by the HGV during the survey week, grossed up to reflect its contribution to population level activity. Obtained by multiplying sampled weight of goods by the distance travelled on a trip level basis, and multiplied again by the grossing factor (see note 2) The maximum achievable tonneKMs if the vehicle had been filled to its carrying capacity on all loaded trips. Calculated on a trip level using trip distance* carrying capacity. Already "grossed" up - see note 2.
PotentialGrossedTonneKMs	Decimal	Tonnes * Kilometres	0 to 559823579	Unique identifier for each record in the table, corresponding to one vehicle surveyed in one week. Vehicles could appear more than once in the sample, but not more frequently than once every 3 years. This column has a primary key constraint, meaning that duplicate values are not permitted.
UniqueID	Long integer, unique constraint	N/A	1 to 80493	

## NOTES

1. **Technologies.** The variables showing the use of GPS, onboard computers and fleet management software should be treated with caution. The respondents were asked to tick a box to indicate a "Yes", and "No" is assumed if the box is left unticked. Therefore, deliberately unticked boxes (when the haulier wishes to indicate that the vehicle does not have these features) are impossible to distinguish from non-responses, where the question was ignored. A similar issue applies to the variable indicating use of a double-decker trailer: although a specific "No" tick box is also available for the respondent, when neither box is ticked "No" is assumed, and we did not distinguish between these options when entering data onto our system. Additionally, we have not published any figures using these variables, so there has been no validation to check their accuracy. The practical implication for interpretation is that the actual proportion of vehicles in the "Yes" category is likely to be

lower (and "No" concomitantly higher) than the true values in the population. As such, while comparisons of differences in prevalence of the use of technologies among groups or across years may be valid (using "presence-only" based statistics), the actual prevalence values recorded in our survey should not be quoted as estimates of national-level prevalence.

**2. Grossing factors.** CSRG-GB is a sample survey, where sampling is stratified by a vehicle's size and regional provenance. In order to estimate national level activity by HGVs in each stratum, the sampled quantities, such as distance, weight of goods moved, and weight of goods lifted are multiplied up on an individual vehicle basis using a "grossing factor". The multiplication factor for each vehicle is  $(N/n) * 13$ , where  $N$  is the GB population of vehicles of the same size and regional provenance, and  $n$  is the achieved sample for vehicles of that size and regional provenance. The multiplication by 13 is to scale up from 1 week's activity sampled from each vehicle to a whole-quarter total, because we draw our sample of vehicles quarterly, but we record activity of each vehicle for only one week falling in the quarter for which it was sampled.

In order to obtain observation level (rather than grossed) activity, you must divide the grossed figure by  $GF * 1.031396459$ , where  $GF$  is the grossing factor given in the table. The extra scaling factor of 1.031396459 accounts for the time-lag between the sample of vehicles being drawn from DVLA data, and the DVLA database being updated with new information about a vehicle's status (e.g. being sold, scrapped, SORN etc.).

**IMPORTANT:** The achieved sample ( $n$ ) is made up of two parts; forms returned with activity, and forms returned with no work. So, grossing factors are calculated as  $N / (\text{active} + \text{no work})$ . However, only active vehicles are recorded in the dataset, and no information is supplied regarding the vehicles having no work. This means that if the active sample size is multiplied by the grossing factor in an attempt to estimate the vehicle population having certain attributes, only the active portion, will be estimated. For example, if the vehicle population is 1000, and 20 forms are returned, 10 active and 10 having no work. The grossing factor will be  $1000 / (10 + 10) = 50$ . Multiplying activity by this grossing factor to estimate population level activity is valid, as our expectation is that the sampled proportion having no work is equal to the population proportion. However, if you want to estimate the total number of vehicles in the population, multiplying the active sample (10) by the grossing factor (50) results in an estimate of 500, which is half of the true number, because only half of the vehicles were active, and entered into our database.

**3. Fuel economy.** There were many non-respondents to the question concerning fuel purchased during the survey week, represented by missing values in this column. When calculating fuel economy as  $\text{sum}(\text{distance}) / \text{sum}(\text{fuel used})$ , all DfT tables exclude the distance travelled by vehicles who were non-respondents to the fuel use question from the total distance figure.

**Business type categories:**

Manufacture of chemicals and chemical products

Manufacture of Wood, wood products, paper and recorded media

Manufacture of coke, refined petroleum products and nuclear fuel

Motor vehicle sales, storage and communication and utilities

Other

Manufacture of Rubber, Plastics and Non-metallic mineral products

Manufacture of office machinery, electrical machinery, radio and television and medical and precision equipment

Manufacture of transport and electrical equipment

Hire or Reward Transport (Public haulage)

Manufacture of basic metals and fabricated metal products

Recycling

Agriculture, forestry and fishing

Manufacture of wearing apparel, textiles and leather

Manufacturing of food products & tobacco

Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods

Construction, Mining and Quarrying

Other business and public services

Sewage and refuse disposal, sanitation

Wholesale trade and commission trade, except of motor vehicles and motorcycles