EMISSIONS OF CO_2 FROM ROAD FREIGHT TRANSPORT IN LONDON: TRENDS AND POLICIES FOR LONG RUN REDUCTIONS

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Abstract

Freight transport has been receiving increasing attention in both literature and practice following the growing recognition of its importance in urban transport planning. This papers analyses historical and projected road freight CO_2 emissions in the city of London and explores the potential mitigation effect of a set of freight transport policies and logistics solutions. Findings indicate a range of policies with potential to reduce emissions in the period up to 2050. However, this reduction would appear to only be capable of partly counterbalancing the projected increase in freight traffic. More profound behavioural measures therefore appear to be necessary for London's CO_2 emissions reduction targets to be met.

Key words: freight, transport climate change, CO_2 emissions, London

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1. INTRODUCTION

CO_2 emissions generated by urban transport systems have been widely analysed in the literature in the last decade. However, most studies to date have mainly focused on the functioning of the personal transport system and attempted to identify the most effective ways to reduce emissions generated by the movements of people in and around cities. Only recently has the environmental impact of the movement of goods and services captured the attention of local authorities, academics and practitioners. This new interest has been accompanied by growing recognition of the importance of urban freight transport systems for cities' life both in economic and social terms. Freight transport is an important user of the limited and constrained urban space. Service providers and operators move across cities competing for space with other stakeholders including passenger car drivers, public transport vehicles, cyclists and pedestrians (Munuzuri et al., 2005), and a large range of different types of goods are not only transported to, from and across urban streets but also packed, stored, loaded and unloaded in these locations (Dablanc, 2007).

For all these reasons and because of the array of complex decisions that have to be taken by different types of users, organising the freight transport system in an urban area is particularly challenging. Freight system organisation has to be fully integrated with the urban land planning effort and not only has to consider the economic efficiency of operations but also respond to growing environmental and sustainability concerns. Among the environmental externalities produced by freight transport operations in cities, CO_2 emissions, air pollution and noise are particularly important. These environmental issues are common to most urban areas in the world where a considerable increase in both population and employment densities and their consequent environmental impact has made necessary a general rethinking of spatial planning and transport policies.

This study focuses on London, a large and dynamic urban agglomeration which has been experiencing profound spatial and demographic changes in recent years (GLA, 2008) and therefore represents an important and useful case study for the analysis of CO_2 emissions generated by road freight operations. The Greater London Authority (GLA) recently launched a plan which contains the details of policy initiatives aiming at the reduction of the city's carbon emissions. This plan highlights the necessity of a 60% reduction in CO_2 emissions in London by 2050 and identifies transport as one of the key areas where significant CO_2 emissions savings have to be made (GLA, 2007). The national government has since adopted an 80% reduction target by 2050 (Climate Change Act, 2008). Furthermore, following the increasing awareness of the importance of its freight transport system and the need to accommodate the projected economic and demographic growth (TfL, 2006), Transport for London (TfL) recently published the London Freight Plan (LFP). This plan sets a target of 0.7 million tonnes of CO_2/year (1.7 million with the introduction of carbon pricing) to be saved from the freight sector by 2025 (TfL, 2008a).

The purpose of this paper is to establish the likely trend and hence level of CO_2 emissions from the road freight sector in London by 2050 and the degree to which policy interventions might reduce these emissions. The key research questions are: *what is the amount of CO_2 emissions from road freight traffic operations in London and how are these emissions likely to evolve in the future?* and *to what extent can policy instruments reduce CO_2 emissions from freight?*

This paper is organised as follows. Section 2 outlines the methodology. Section 3 develops baseline projections of freight traffic emissions to 2050. Section 4 assesses potential policy interventions. Section 5 analyses the potential impact in London of a set of policy initiatives. Conclusions are drawn in section 6.

2. METHODOLOGY

First of all it is necessary to note that for the purpose of this study the definition of freight is, in accordance with the London Freight Plan (TfL, 2008a): "the physical carriage of goods by any mode. This includes the provision of services and utilities and the movement of municipal, commercial and domestic waste".

The first methodological step in this analysis concerned the decision over a method to allocate carbon emissions from freight to London. This research employs a 'source' approach (as opposed to 'end-user' approach) and allocates to London[1] the CO_2 emissions generated by freight movements within its boundary, independently of the their origin and/or destination (whether inside or outside the London administrative territory). This approach therefore considers London as a geographical unit in which carbon emissions physically take place.

This choice was mainly motivated by the limitations in data availability and enables this analysis to make use of existing information on freight traffic movements within the London boundaries and emissions datasets.

After the definition of an allocation method, the next step was an assessment of the availability of historical data for the London case. The information on traffic used for this analysis, (since published in the London Freight Data Report - TfL, 2008b), were obtained from the TfL Freight Unit. The search for more detailed data on privately-owned Light Goods Vehicles (LGVs) was particularly challenging. Anecdotal evidence suggests an increasing contribution of these vehicles to both traffic and emissions, however, the movements of these vehicles are difficult to monitor and they are often used for private purposes. McKinnon (2007a), for example, estimates that only 35% of company-owned van traffic should generally be accounted as freight; while data on company owned van traffic from the London Freight Data Report (TfL, 2008b) shows that in 2005 28% of total vehicle kilometres in London were performed for commuting and other personal use.

In this paper we have classed all van traffic as freight for three reasons. Firstly, the London Atmospheric Emissions Inventory (LAEI) (GLA, 2006) is structured by vehicle type as are other inventories and the London Freight Plan analysis. Therefore following the same assumptions facilitates comparison of results. Secondly, policies on vehicle technology are developed by vehicle type, with the European Commission proposing CO_2 targets for light commercial vehicles for the first time (Commission of the European Communities, 2009). Finally, as yet the evidence on the precise split between freight and other uses and its evolution over time is sparse. Our assumption will over-allocate van emissions to the freight sector but will be compatible with other approaches.

Data on fuel consumption, emissions, and fleet composition for all types of vehicles at London level were limited, and only information for 2002 and 2003 were available from the London Atmospheric Emissions Inventory (GLA, 2006). For this reason, for both the historical profile and the development of projections, national fleet data and the correspondent average emission factors from the National Atmospheric Emissions Inventory (NAEI) (AEA, 2007) were employed.

The information described above was employed to produce an historic profile of road freight traffic and CO_2 emissions in London in accordance with the following equation.

$$E = \sum_{n} t \times ef_i \times fc_i \qquad (1)$$

Where E represents the total emissions produced by freight vehicles in London obtained by summing the contribution of each different class of freight vehicle n. The contribution of each class is obtained by multiplying the amount of vehicle/kilometres t for the class, the specific emission factor ef_i (average grams of CO_2 per kilometre) where i represents a different sub-class according to the Euro engine technology classification and fc_i is the percentage of the specific sub-class in the fleet. The resulting emission profile was then used to produce baseline projections for both traffic and emissions based on extrapolation of trend information on traffic growth and fleet composition.

A review of the most recent literature concerning the impact of transport policies and logistics practices on traffic and emissions was then produced in order to identify suitable measures and assess their potential impact. Findings from this review were used to produce alternative projections. These projections were then compared with those in London main freight policy document (TfL, 2008a) and the results of an exploratory consultation with a small number of freight experts and practitioners.

This consultation aimed to gain expert opinion on a range of measures and their likely impact on freight kilometres and CO_2 emissions in the medium (2025) and long (2050) term. A questionnaire was distributed in April/May 2008 to around 50 experts from academia, local and national authorities and transport and environmental organisations. Responses were obtained from only 7 experts; in retrospect the questionnaire was too long and complex and some were reluctant to speculate about the future. However, although only a small sample, the findings are drawn on here where they help to illuminate issues.

3. BASELINE PROJECTIONS

3.1 Historical Trend and 2005 baseline

The traffic information mentioned in the previous section was employed to compute freight vehicles' CO_2 emissions levels for the period 1996-2005. Fleet composition data for the period 1996 to 2005 by Euro standard technology was obtained from the National Atmospheric Emissions Inventory (NAEI) (AEA, 2007). Because of lack of information on fleet composition at regional level, London was assumed to have followed the United Kingdom's (UK) average over this period.

CO_2 emission factors by Euro standard technology were obtained from several sources as the NAEI (AEA, 2007) only report factors for LGVs and Heavy Goods Vehicles (HGV) up to Euro II standard technology. Factors for LGVs Euro III and IV diesel engines were taken from AEA (2005). Factors for LGV Euro III and IV petrol engines were calculated by applying the same scaling factor as for diesel engines. Factors for HGVs above the Euro II standard were calculated by applying a scaling factor to the NAEI Euro II figures as reported in a study produced by NERA for the Department for Transport (NERA, 1999).

Table 1 shows that Pre-Euro I vehicles have lower emissions than more recent models largely due to their smaller size, lower weight and the absence of air pollution reduction technologies that can work against energy efficiency. From Euro I there are some small improvements in CO_2 emission factors. For the specific case of HGVs, data on trends in average fuel consumption show that this has slightly decreased for rigid lorries and slightly increased for articulated ones in the period 1993-2007 in the UK (DfT, 2007a). This is not only dependent on engine technology but also on other variables like load factors, driving style etc. but indeed shows that no significant progress has been made in improving fuel efficiency.

Table 1. Emission factors

Vehicle	Euro standard technology	Emission factor (grams of CO_2/km)
Petrol LGVs	Pre-Euro 1[a]	203.2269
	Euro I[a]	254.1288
	Euro II[a]	238.3001
	Euro III[c]	238.3001
	Euro IV[c]	238.3001
Diesel LGVs	Pre-Euro 1[a]	242.9466
	Euro I[a]	246.1223
	Euro II[b]	240.6000
	Euro III[b]	240.4000
	Euro IV[c]	240.4000
HGVs Rigid	Pre-1988 models[a]	581.2651
	1988 - 1993 models[a]	571.9273
	Euro I [a]	684.5428
	Euro II[a]	672.5857
	Euro III[c]	672.5860
	Euro IV[c]	652.4084
	Euro IV(+)[c]	652.4084
HGVs Artic	Pre-1988 models[a]	1273.0359
	1988 - 1993 models[a]	1263.0790
	Euro I[a]	1801.2594
	Euro II[a]	1569.3941
	Euro III [c]	1569.3940
	Euro IV[c]	1522.3122
	Euro IV(+)[c]	1522.3122

Source: [a] (AEA 2007), [b] (AEA 2005), [c] adapted from NERA (1999)

It is important to note that in June 2009 the Department for Transport published various documents (Boulter et al., 2009) which discuss and update the methodology behind the estimation of emission factors for future use in the atmospheric emissions inventories. These documents (available at www.dft.gov.uk/pgr/roads/environment/emissions) were the result of a lengthy consultation process on the way to improve testing and estimation and emissions from both regulated (including CO_2) and unregulated pollutants which concluded in October 2008. The changes outlined will apply to the next NAEI due to publish at the end of 2009 (DECC, 2009). The new emissions factors differ from those previously employed in terms of presentation as they refer to a different and considerably more detailed categorisation of vehicles with respect to weight. Their use here would therefore be complicated as the available traffic data does not distinguish vehicles in terms of weight but rather in terms of axles. However, our own calculations (deriving an average emission factor at an average speed for the different vehicles) suggest that whilst the new factors do impact on absolute emissions largely as a consequence of the lower emissions factors for HGVs, they do not produce significantly different results, in terms of policy impact. They do have an impact, however, on the figure for total emissions, as a consequence of lower emissions factors now attributed to articulated HGVs. Because of the lack of significant differences in terms of policy testing, and in consideration of the fact that an inventory (either local or national) employing these factors has not yet been officially published, we have used the original emission factors in our modelling exercise.

As shown in Equation (1) vehicle kilometre figures were then multiplied by the percentage of each Euro standard technology within the fleet and by the corresponding emission factors. The resulting emissions profile is shown in Table 2.

Table 2. Vehicle Kilometres, (000) and CO_2 emissions (Tonnes/year) in London 1996 and 2005

Vehicle	1996	% of total	2005	% of total	% change 1996 to 2005
LGV					
Traffic	3308025	76.0	3971975	78.2	+20.1
Emissions	761927	46.4	955399	49.1	+25.4
HGV					
Traffic	1041613	24.0	1108297	21.8	+6.4
Emissions	881811	53.6	989634	50.9	+12.2
Total Freight					
Traffic	4349638		5080272		+16.8
Emissions	1643739		1945034		+18.3

Source: Vehicle kilometres (TfL 2008b); Emissions - own calculations.

Table 2 shows a significant upward trend in freight vehicle traffic on London roads over the period 1996-2005, mostly as a result of increased LGV use. HGV growth occurs largely in the use of articulated lorries. Articulated 6+ axle HGV experienced the highest growth in this period with total vehicle kilometres in 2005 more than twice the level in 1996, albeit from a low base. It is likely that this sharp increase was related to legislation that increased the maximum weight of articulated (6-axle) lorries from 41 to 44 tonnes (McKinnon, 2005).

For both LGVs and HGVs growth in CO_2 emissions exceeds traffic growth. For vans this is largely due to the increase in the proportion of Euro I engine vans in the fleet at the expense of Pre-Euro I. The former have in fact a higher CO_2 emissions factor than the latter (see Table 1). In the case of HGVs, it also reflects the trend towards heavier articulated vehicles. It is possible to argue that policy should focus on HGVs because they account for only 20% of the vehicle kilometres but 50% of emissions or on LGVs because of their higher traffic growth rate. Here we focus on both types of vehicles.

3.2 Baseline Projections To 2050

The data presented in section 3.1 was employed to produce projections of CO_2 emissions in London for the period 2006-2050 which assume the continuation of the current situation and policies already in force. In order to do so, traffic projections were built through extrapolation in accordance with the trend observed in the period 1993-2005[2]. This assumption was applied to all vehicles except 6+ axle HGVs which experienced a 246% increase between 1993 and 2005, which, if projected, would have depicted a highly unrealistic situation. Growth in this sector was capped at 100% to 2025. Then the resulting trend was extrapolated up to 2050.

In order to estimate CO_2 emissions to 2050, the emission factors described previously were applied to the traffic projections. In terms of fleet composition, information on the period 2006-2025, by Euro standard technology, were taken from the NAEI (AEA, 2007). Data limitations led to the following assumptions being made:

- London was again assumed to follow the national average in terms of freight vehicle fleet composition.
- Emission factors do not change over time. Some efficiency gains are achieved in the fleet as proportion of more efficient vehicles increases over time. Although it is likely that Euro IV engines average emission factors in

2025 are going to be lower than those of today, no precise information on the likely evolution of emissions could be found[3].

- Fleet composition for the period 2025-2050 was assumed to remain as in 2025 with all circulating vehicles belonging to the Euro IV technology (and for the case of LGVs with a percentage of petrol and diesel engines of 10% and 90%, respectively). Because of the lack of information on both fleet composition and CO_2 emissions factors for Euro V and VI technology, this assumption was necessary in order to build baseline projections.
- No hypotheses were formulated about changes in terms of empty running and average load factors for freight vehicles. These variables were assumed to follow the trend they experienced in the period 1993-2005[4]. This was done in order to produce a simple baseline scenario to be used as a comparative tool.

These assumptions depict a fairly pessimistic picture in assuming no further gains in energy efficiency and the projections are likely to indicate higher emissions than might occur in reality because of this. However, this exercise does provide a clear baseline against which to test policies.

Figure 1 shows the projected growth in road freight traffic in London over the period 2006-2050 reflecting the historical trends discussed earlier. Van traffic, for example, is assumed to grow by about 50% by 2025 and up to 150% by 2050. It is useful to note that these figures are conservative with respect to national projections prepared by the Department for Transport which forecast an increase of van traffic in the UK by about 67% by 2025 (DfT, 2008). This is perhaps surprising as we might have expected the increase in LGV traffic to exceed the national average in a dense and congested urban area like London where smaller and more flexible vehicles would be expected to have a comparative advantage. However, growth may also be dampened by congestion and also the effects of the congestion charge in central London and the difficulties and expenses of parking and loading/unloading operations.

Figure 1. London freight vehicle traffic projections 2006-2050.

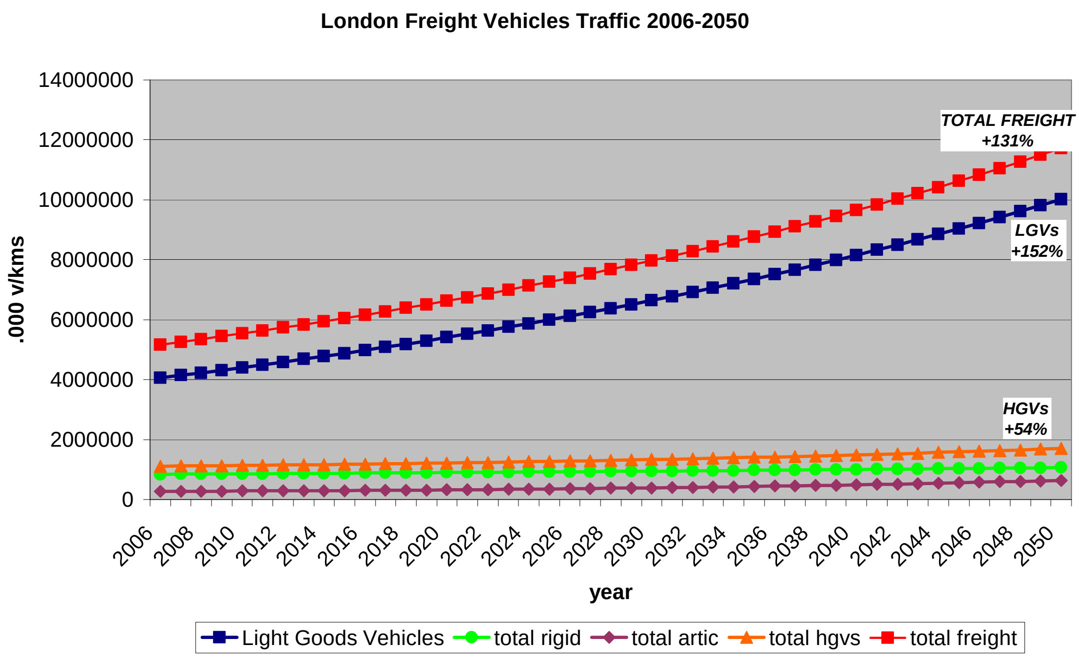
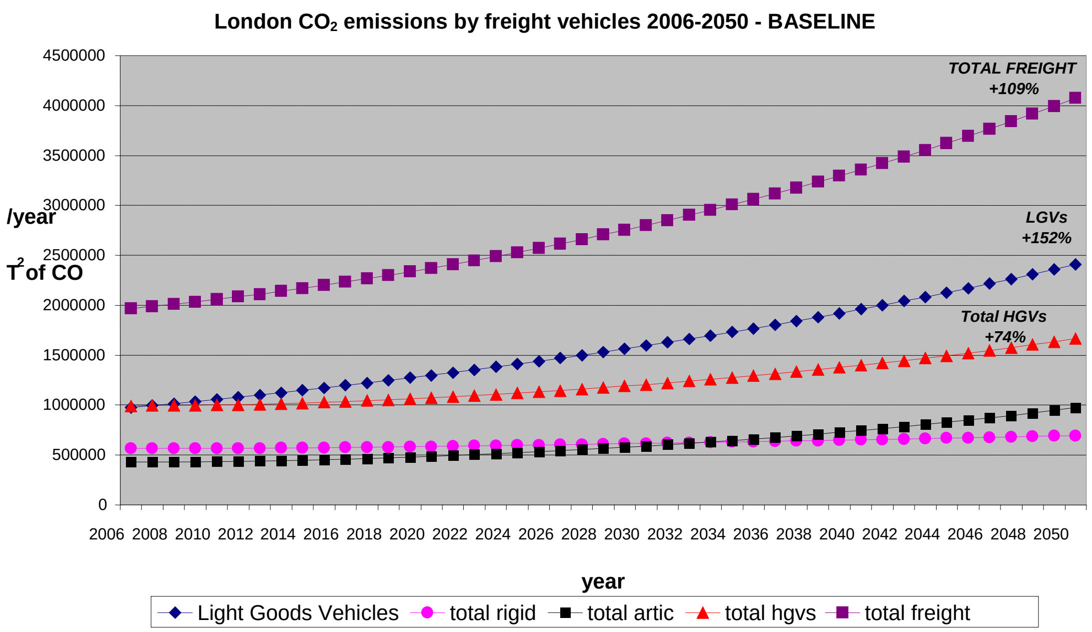


Figure 2 indicates that the total amount of CO_2 produced by road freight traffic in London in the period 2006-2050 would more than double under the assumptions made, largely driven by traffic growth.

Figure 2. London CO_2 emissions by freight vehicles 2006-2050 (tonnes).



.Although these projections have been produced following a simple assumption that past trends will continue in the future, they represent a useful comparative baseline. The resulting emission trends, shown in Figure 2, were found to be within 1 to 2% of baseline projections for London contained in both the London Atmospheric Emission Inventory to 2010 (GLA, 2006) and the London Freight Plan to 2025 (TfL, 2008a), and were thus deemed to be a consistent baseline from which to explore policy interventions.

4. INTERVENTION MEASURES

4.1 The policy context and potential measures

The London Freight Plan is a useful source of information to describe the current freight policy context and identify the policy initiatives and measures which have the potential to be applied in London in the near future, and are therefore worth investigating. In general, the plan depicts a freight policy framework which seeks practical alternatives to road transport and proposes strategies for the improvement of the efficiency of freight distribution. The plan emphasises the necessity of a strong partnership among the different stakeholders and considers four key partnership projects: a freight operator recognition scheme, delivery and servicing plans, construction logistics plans and a freight information portal. Among the carbon reduction measures contemplated in the plan we can find: modal change, fleet efficiency, out of hours deliveries, construction consolidation, retail/office consolidation, waste collection fleet, voluntary adoption of alternative fuel and low carbon vehicles, and national level road user charging and bio-fuel policies (TfL, 2008a).

An extensive review of the most recent available literature exploring the potential impact on freight traffic and emissions of lifestyle changes (such as the increasing importance of online shopping) transport policy initiatives, logistic practices and infrastructural provision was undertaken to identify the most promising policy measures. This is summarised in the Appendix (Table A1) and revealed that whilst a relatively wide range of studies exist, many fail to report a precise impact measure and/or consider different assumptions and constraints that make results referring to a single measure difficult to compare. Where present, impact figures were based either on data gathered in geographically and time limited case-study situations or as the product of simulation or modelling exercises. The challenge was therefore first to identify those studies with a focus on traffic and/or emissions that actually report the level of impact achieved for traffic or emissions. Subsequently, it was necessary to assess whether the relevant initiative was applicable to the specific case of London and whether it was possible to generalise the results found in the relevant literature.

Logistics infrastructure development

A variety of infrastructure solutions have been employed in recent years to achieve reduction in traffic and emissions in highly populated urban areas. This section briefly discusses the existing evidence on the impact of these solutions.

The increasing success of e-commerce and home shopping has received growing attention in the literature because of its consequence for both private and freight traffic (Edwards et al., 2009). Simulation studies have shown that the net gain between the reduced number of car journeys and the increased number of van deliveries could result in a reduction of vehicle/kilometres of up to 70 to 80% (Cairns, 2005; McLeod et al., 2006). In a case study in the German city of Cologne, over a three-year period, e-commerce generated a reduction in car traffic of about 14%, while, over the same period, freight traffic increased by 3% (Esser and Kurte, 2005).

City logistics solutions such as Collection Delivery Points (CDP) have been devised with the specific purpose of reducing the magnitude and impact of the internet-generated increases in delivery traffic. CDPs are locations, attended or unattended, where couriers can deliver goods when recipients are not at home. Unattended CDPs take the form of delivery boxes in high density residential or business areas where final customers can collect their parcel at their convenience. Attended CDPs can take the form of a new infrastructure development or make use of existing locations such as post offices, petrol stations or supermarkets, where parcels are first delivered and then collected by the recipients (McLeod et al., 2006; Song et al., 2009). In particular, CDPs have been identified as a possible solution to the increasing phenomenon of missed first-time home deliveries as they are estimated to have the potential to achieve saving in total shopping driving distance varying from 16 to 53% (Song, 2007; Song et al., 2009).

Urban Consolidation Centres (UCC) have also been employed to reduce freight traffic in urban areas. Various types of logistic solutions are considered within this category, and their differences are not always straightforward (Marcucci and Danielis, 2008). In general, UCCs are facilities located inside or close to target areas in which deliveries can be consolidated in order to optimise both route and load utilisation for subsequent deliveries (Browne et al., 2007). Here we consider three specific types of UCC: Urban Distribution Centres (UDC), Construction Consolidation Centres (CCC), and Vehicles Reception Points (VRP).

UDCs are normally publicly-owned logistics infrastructure, serving the whole or part of a city centre, in which deliveries to both home and business are consolidated. UDCs normally serve retailers, small manufacturers and the tertiary sectors. Two centres in operation in France have achieved considerable results in terms of reduced traffic, noise and CO_2 emissions (Patier, 2007).

A specific type of UCC dedicated to the construction sector, the Construction Consolidation Centres (CCC) have been widely used in recent years to consolidate deliveries to construction sites in urban areas in order to minimise traffic and waste. In London and Bristol, for example, they have led to a considerable reduction in freight traffic and CO_2 emissions (Browne et al. 2005a; TfL 2007). Additional CCCs are planned to be built in London in the near future in order to further extend their capacity in terms of traffic and emission reduction (TfL 2007).

Reductions in carbon emissions within the delivery sector have also been generated by the use of VRPs. These are locations normally serving a specific area of town and/or city centre, generally smaller than in the case of UDCs, in which drivers are assisted in parking and unloading. Goods are then delivered to their final destination on foot using handling equipment, and for this reason they generally serve a small area (which is increasing due to the utilisation of improved equipment and small electric vehicles). They are normally implemented either through a private initiatives of businesses and operators or in partnerships with local authorities. The economic sectors normally using these facilities are small retail organisations, shops, and other services, for which delivered goods are normally smaller and can be loaded/unloaded and handled with smaller equipment. These centres are making their way in various cities in France and in some cases achieved CO_2 emissions reduction of up to 80%. (Patier, 2007).

Traffic restrictions and regulations

Few studies attempt to estimate the impact on both traffic and emissions of traffic restriction and regulation. Delivery restrictions in Athens were investigated by Yannis et al. (2006), while Musso and Corazza (2007) explored the provision of loading/unloading bays in Rome. However, neither study provides estimates of the amount of traffic or carbon emission reduction achieved. Vehicle weight access restrictions in operation in certain urban areas have been estimated to generate an increase in total distance travelled by freight vehicles and a consequent increase in carbon emissions of up to 7% (Anderson et al., 2005). Impact estimates are also reported in a study on the freight vehicle usage of bus lanes in the Portuguese city of Porto (Melo et al., 2007) where the authors conclude that relaxing restrictions on the usage of bus lanes by freight vehicles could reduce carbon emissions from freight up to 50%. However, in London bus preferential lanes may be already too heavily utilised to allow a long-term gain in terms of traffic and congestion reduction. The implementation of dedicated freight routes has also given interesting results elsewhere (Finnegan et al., 2007; Hsing-Chung and Meyer, 2009).

Driver training and Information and Communication Technologies

There are various ways of optimising transport and logistic operations within the freight sector in order to increase their efficiency. These can target the drivers and/or the vehicles (both in terms of utilisation and capacity).

The development of driving skills has been identified as one of the most important factors that freight operators can employ to order to reduce both fuel consumption and emissions and for this reason the Safe and Fuel Efficient (SAFED) scheme was adopted in 2003 for HGV drivers and extended to LGV drivers in 2006. This scheme is based on achieving both fuel efficient driving and a reduction in accidents but also covers training for other related operations like refuelling, maintenance and data recording and monitoring. Thus far the scheme has generated savings of up to 10% in fuel and CO_2 emissions per vehicle (DfT, 2006a).

Considerable progress has been made through the use of Information and Communication Technologies (ICT) at the vehicle level. Computerised routing, scheduling and vehicle tracking systems for example, has allowed operators to increase the efficiency of their operations (Hubbard, 2003; McKinnon, 2007b). As the available software has improved and the price has fallen (McKinnon, 2007b) more companies have adopted such systems and achieved both cost reduction and savings in carbon emissions of about 10% (Ando and Taniguchi, 2005; DfT, 2007b, c).

Savings have also been obtained by improving load factors (Taniguchi and van der Heiden, 2000) and reducing the proportion of empty running (McKinnon and Ge, 2006). Load factors have been improved by more efficient choice of loading methods, the modification of the size of pallets, the utilisation of the entire vehicle inner height, the utilisation of modular loads and changes in the shape of packaging. Initiatives boosting the collaboration and the exchange of information between operators, freight procurement services, real-time tracking systems and reverse logistics have all been used to attempt to diminish the proportion of empty running by assuring a more efficient match between capacity and demand (McKinnon, 2007b).

Vehicle efficiency

Measures targeting vehicles' aerodynamics and tyre inflation control have the capacity to achieve fuel consumption reduction of about 30% (Ang-Olson and Schroeer, 2002).

A key measure is the development and adoption of low emission vehicles. Improved carbon efficiency of freight vehicles has been estimated to have the potential to generate a reduction in total UK freight emissions of between 3.2 to 6.4 million tonnes by 2030 (Banister and Hickman, 2006). Various technologies have been trialled, and Compressed Natural Gas (CNG) powered vehicles, for example, have achieved reductions in CO_2 emissions (DfT, 2007c). However, to date, as can be seen from the emissions factors little progress has been made.

It is also useful to remember that some of the measures discussed above, in particular those at the vehicle and driver levels directly affecting fuel consumption, would be additive to a degree, and, therefore, policy packages containing a set of these measures might achieve fuel consumption saving of about up to 60% (McKinnon, 2007a).

Measures specific to London

Finally, London-specific studies are not numerous. Apart from the above mentioned studies on the impact of construction consolidation centres, other studies have investigated the impact of two of London specific transport policies, the existing congestion charging scheme and the Low Emission Zone (LEZ). The LEZ is expected to have a negligible effect on transport and logistic operations (Browne et al., 2005b), and hence carbon emissions (Bush, 2006). The congestion charging scheme has had a significant impact on freight traffic within the charging zone during the time in which it has been in force. Between 2002 and 2007, the number of vans entering the charging zone fell (in terms of numbers of vehicles measured by manual traffic counts) by about 13% and HGVs by 5%. However, from 2005 the number of lorries entering the zone has started to increase again. In terms of vehicles/kilometres within the charging zone while van traffic figures remained the same between 2006 and 2007, lorries experienced a 9% increase in traffic in the same period. This is likely to be due to the increased number of vehicles entering the zone in these two years (TfL, 2008a) Furthermore, it could also be the case that lorries entering the zone and paying the relevant charge carry out a higher number of deliveries and services before leaving the zone.

4.2 Measures for Further Testing

The next step was to apply the evidence to the case of London in order to produce sensible policy tests. The lack of data at national and London levels concerning, for example, the amount of traffic for different sub-sectors (like construction) was a particular obstacle. Also, the lack of adequate information on the proportion of privately-owned vans complicated this task[5]. For these reasons informed assumptions were made about the potential penetration of the policy initiatives of interest on the total freight traffic in London.

Six policy initiatives were selected for further analysis as they were identified to be those with the highest potential to be applied (in terms of political feasibility) and to succeed (in terms of evidence of impact either already in London or elsewhere). These are detailed below.

Promotion of Low Emission Vehicles and other efficiency measures

The promotion of the purchase and use of low or no emissions vehicles is an important policy initiative which could have a considerable potential in reducing CO_2 emissions from freight vehicles. The European Commission proposals for target reductions in new van emissions (CEC, 2009) should have an impact here. The Committee on Climate Change (CCC, 2008), identify improvements in carbon efficiency not requiring a change in energy sources, and the usage of electricity as an energy sources as the main ways[6] to reduce carbon emissions from transport (for cars, vans and HGVs). We therefore consider for the purpose of our studies both technological measures such as improved aerodynamics, tyre inflation control, wide base tyres, tare-weight reduction, low-friction lubricants, reduced engine idling, start and stop technology, and the potential diffusion of electric-powered freight vehicles.

Existing studies give evidence of considerable potential for such initiatives. At the UK level, for example, Banister and Hickman (2006) suggest that the improved carbon efficiency of freight vehicles has the potential to save from 3.2 (25% reduction from the base 2000) to 6.4 (50% reduction) million tonnes by 2030. The Committee on Climate Change, under different scenarios, finds that stop and start engine technologies and non-engine measures could achieve savings in vans' emission of about 0.4 Million tonnes of CO_2 by 2020. Non-engine efficiency technologies, the usage of hybrid powered lorries and electricity for smaller HGVs could achieve savings of 1 Million tonnes of CO_2 by 2020.

Although there are studies providing information on likely penetration of low vehicles in the future freight fleet, like Selwood and Seymour (2001), and the Committee on Climate Change report which contains figures on the technology uptake rates (as a percentage of new vehicles up to 2025 for stop and start diesel engines (for vans) and hybrid-diesel engines (for lorries), no studies exist, to our knowledge, on the likely proportion of traffic that could be attributed to these vehicles. The following assumptions were made in order to explore the potential effect of this policy initiative:

- low emission vehicles are defined as vehicles that can achieve (through various technical specifications and/or using alternative fuels) carbon saving of 20% over current diesel or petrol powered vehicles
- no emission vehicles are defined as vehicles whose CO_2 emissions at the tailpipe is zero (these can therefore be electric plug-in or fuel cell hydrogen vehicles),

- the penetration of low emission vehicles in London's HGV traffic is set as 35% of total in 2025 and 75% in 2050,
- in the case of LGVs, 20% of traffic in 2025 is allocated to no emission vehicles, while the figure for 2050 is 60%.
- of the remaining LGV traffic in 2025, 25% is allocated to low emission vans. In 2050, the corresponding figure is 75%.

These are optimistic assumptions for LGVs and depend on technological improvements taking place and offering reliability standards and costs that lead to rapid diffusion through the fleet. Conversely, the HGV fleet remains diesel based with a maximum saving of 20%.

Drivers' Training and ICT

It is well documented in the literature that more efficient training of freight vehicles' drivers and increased performances can achieve savings in CO_2 emissions (DfT, 2006a, 2007d; McKinnon, 2007a). Following the introduction in the UK of the mandatory driver Certificate of Professional Competence (CPC), all HGVs drivers should receive training by 2014, and safe and fuel efficient driving techniques are likely to be an important part of this training (CCC, 2008; DfT, 2008). On the other hand, improving driving skills should also consider the use of information and communication technology (ICT - Optimised vehicle routing, automated vehicle locations systems, vehicles information communication systems) to help both freight managers and drivers in making the most efficient use of resources (Baumgartner et al., 2008). All these (and other) initiatives have been promoted in recent years within the DfT "Freight Best Practice" programme (DfT, 2008). In accordance with the evidence, it was assumed that schemes improving drivers' training and performance, and the widespread adoption of ICT could achieve an average 10% reduction in CO_2 emissions (as a consequence of fuel efficient driving techniques, reduced waiting time at both origin and destination, and improved route selection avoiding more congested areas) and 2.5% reduction in traffic (as the consequence of the improved routing facilities). This was applied to our projections according to the following assumptions:

- savings are allocated to 10% of HGV traffic in 2010, 30% in 2015, 60% in 2025 and 100% in 2050,
- the same assumption is made for LGV, but corrected using a 0.75 factor. The correction was applied as there is no compulsory driver training schemes or certification for vans, equivalent to the recently introduced Certificate of Professional Competence required for HGVs drivers. For this reason saving in emissions generated by improved driving skills are likely to be smaller and require more time in the van sector (CCC, 2008) also in consideration of the wider range of usage and the high proportion of privately-owned vans in London (TfL, 2008b).

Construction Consolidation Centres

Evidence of the benefit of these centres is available as there are currently two centres operating in London, and several more are planned to serve the increasing number of construction sites within the capital (TfL, 2007). The existing centres have achieved savings of up to 75% in vehicle trips for the relevant traffic directed to the construction sites served by the centre (Browne et al. 2007).

It is more difficult, however, to quantify the potential savings from construction consolidation centres on total traffic as no precise information on the proportion of traffic relative to the different sectors of the economy is available. For these reasons the following assumptions were made in order to test the potential of these measures for the construction sector:

- construction consolidation centres are assumed to generate 50% saving with respect to the situation in which construction traffic vehicles do not use a centre,
- the saving figure indicated above is applied to 15% of London total HGV traffic in 2025 and 25% in 2050 (these figures broadly take into consideration the increase in construction traffic both in absolute and relative terms as a consequence of the projected increase in the number of construction sites in London (TfL, 2007))
- in the case of vans, evidence (TfL, 2007) shows that these represent about 40% of traffic directed to the centres but only 2% of traffic from them. For this reason, saving figures were applied to LGVs as well, but they were assumed to apply to a lower percentage of their v/kms, 2.5% and 7.5%, for 2025 and 2050, respectively.

Urban Distribution Centres

As indicated in the previous section this centre may serve an entire city centre and target deliveries for manufactures and retail organization. Experiments in various cities across Europe have achieved CO_2 emissions reduction of up to 60% of the target traffic in congested urban areas (Dablanc, 2007; Patier, 2005). In a simulation study conducted in Italy (Marcucci and Danielis 2008), urban distribution centres were found to be capable of attracting a share of up to 50% of goods delivered in a small urban area.

Various sources at national (DfT, 2003, 2004, 2006b) and London (Browne et al., 2004; TfL, 2008b) levels were consulted in order to estimate the likely proportion of delivery traffic in London which could potentially employ these centres. Although no precise figures were available the data was sufficient to build the following broad assumptions for the testing of the impact of this initiative:

- urban distribution centres were assumed to be capable of generating a 25% saving in the relevant delivery traffic
- this saving figure was applied to 7.5% of HGV traffic in 2025 and 15% in 2050
- in the case of LGV, the figures for 2025 and 2050 were 20% and 35%, respectively (this reflected the higher usage of vans, rather than lorries, for deliveries within urban areas).

Collection Delivery Points

As for the previous initiatives, Collection Delivery Points have been devised in order to reduce home delivery traffic. These are locations in which parcels are delivered and then collected by the final recipients.

The following assumptions were formulated:

- collection delivery points are assumed to be able to generate savings in traffic terms of up to 20% for the relevant delivery traffic with respect to the situation in which these points are not used.
- the saving figure is applied to 20% of LGV traffic in 2025 and 40% in 2050.
- the impact on HGV traffic is considered as negligible in both 2025 and 2050 as the relevant home deliveries are more likely to be carried by LGVs (Edwards et al., 2009) as items normally carried by lorries (like larger appliances and furniture) have to be delivered at home (normally by more than one person) and cannot be collected by customers.

Vehicle Reception Points

The experimentation of Vehicle Reception Points (VRPs) in France achieved important savings in traffic and up to 80% reduction in CO_2 emissions for the operators using them (Patier, 2007). As for the two previous cases, these logistic solutions have been devised to reduce delivery traffic and, in particular, to improve the efficiency of delivery in the "last mile" (Edwards et al., 2009). As stated in the previous section VRP are locations in which deliveries are consolidated before being delivered on foot or using low or no- emissions handling equipment to their final destination, normally a business in a high density urban area. As noted in the previous section these centres are normally the product of private initiatives and serve small retail organisations, shops, and other services which handle smaller goods. The following assumptions were made in order to test the potential of these centres to achieve CO_2 emission savings in London:

- vehicle reception points were assumed to generate a 15% saving in delivery traffic in the relevant area,
- in the case of HGVs, saving figures were assumed to apply to 2.5% of traffic in 2050 and to 5% in 2050,
- in the case of LGVs, the corresponding figures for 2025 and 2050 were 10% and 25%, respectively.

Relaxing delivery times

The last initiative treated in this paper is the relaxation of restrictions on delivery time/windows. This initiative has been explored in the literature (Anderson et al., 2005; Holguin-Veras, 2007; Yannis et al., 2006) and it appears that under certain conditions relaxing restrictions and, in particular, allowing goods to be delivered at night, could achieve noticeable saving in both traffic and emissions. This is however a sensitive issue as night deliveries require an extensive amount of flexibility for carriers and their customers (Brom et al., 2009) as well having to comply with noise regulation, especially in residential areas.

The following assumptions were made in order to test the potential of this policy initiative in London:

- the relaxation of delivery times could achieve savings in traffic of up to 15% if implemented
- these savings could apply to 15% of total freight traffic in London in 2025, and to 30% in 2050 (for both HGVs and LGVs)

5. POLICY IMPACTS

This section reports the results of the policy impact analysis which was carried out according to the assumptions discussed in the previous section. It is important to note that the assumptions made remain debatable and were adopted in order to assess the potential of the single initiatives and test 'what might be achieved if' rather than provide a precise measure of the impact of the single policy in London. The first two measures we have considered the promotion of low and no-emissions vehicles are initiatives that are likely to be taken at national or international level. The remaining measures are more likely to be the result of effort at local level in London. The development of logistics infrastructure to accommodate and manage delivery traffic and changes in regulations will require a deep collaboration between local authorities, businesses, operators and potential users.

It is also important to note, before presenting the results of the policy analysis, that the set of policy initiatives considered in this study is not comprehensive and there are other schemes that could also achieve important emission reductions results. The London Freight Plan (TfL, 2008a) for example, also considers the implementation of various projects which intend to boost collaboration and partnership between businesses and operators in London. Measures to improve modal change, the efficiency of the network and of the waste fleet are also considered in the Plan. There are also initiatives that could be taken at national level, like the implementation of a road users charging scheme (Hensher and Puckett, 2008) and the promotion of bio-fuels (CCC, 2008), which are forecast to have a considerable impact on freight carbon emissions in London. The logistics and transport literature also suggests other possible measures like the usage of underground trains for the transport of freight in high density urban areas as well as computerized on-line loading zone reservation systems (Munuzuri et al., 2005). Lorry-only lanes and tollways are also discussed in the literature (de Palma et al., 2008) and have recently being used in Dublin (Finnegan et al., 2007). However, we have limited our tests to measures where some evidence was available and that appeared to be adaptable and feasible in London.

Results of the tests on the policies considered in this study are summarised in the Table 3 where they are compared with the baseline projections and the 2005 emissions figures which were presented in Table 2.

Table 3 Impact results – single policy tests

Policy	CO_2 emissions 2025	% change from 2025 baseline	% change from 2005	CO_2 emissions 2050	% change from 2050 baseline	% change from 2005
Baseline	*2572156*		*32.2*	*4073101*		*109.4*
Low Emission Vehicles	2147451	-16.5	10.4	2235125	-45.1	14.9
Drivers' Training	2277853	-11.4	17.1	3382953	-16.9	73.9
Construction Consolidation Centres	2469190	-4.0	26.9	3636124	-10.7	86.9
Urban Distribution Centres	2478955	-3.6	27.5	3660207	-10.1	88.2
Vehicle Reception Points	2546320	-1.0	30.9	3929435	-3.5	102.0
Relaxing Delivery Times	2514282	-2.3	29.3	3802290	-6.6	95.5
Collection Delivery Points	2514590	-2.2	29.3	3792091	-6.9	95.0

Table 3 shows that no single measure leads to a fall in emissions relative to 2005 levels. However, the optimistic vehicle efficiency and technology assumptions almost completely offset the emissions growth in the baseline – with emissions up only 15% by 2050 as opposed to over 100% in the baseline.

There is potential for drivers training and information and communication technology and Construction Consolidation Centres to help deliver savings in terms of CO_2 emissions. In the latter case, this is borne out by the performance of two Construction Consolidation Centres operating in London (TfL, 2007). On the other hand, these centres, as well as measures aiming at increasing the share of low emission vehicles, and logistic solutions for the delivery sector will require a wide effort from the urban planning point of view which has to be taken into consideration in discussing their potential.

Measures targeting delivery traffic have potential to help in reducing freight emissions, however, their impact needs to be sufficient to offset the projected increase in delivery traffic as a result of the growing success of online commerce (Cairns, 2005; Esser and Kurte, 2005; Taniguchi and Kakimoto, 2003; Weltevreden and Rotem-Mindali, 2009).

Each measure has been assessed separately and it is difficult to draw conclusions on additionality. Clearly if vehicles emit less CO_2 per kilometre the savings from measures to reduce vehicle kilometres or to encourage more energy efficient driving practices will be reduced. It is reasonable to assume that a policy package including the measures tested above might generate savings of about 25% by 2025 and 50% by 2050 with respect to projected baseline figures.

It is also important to note that there are a number of reasons for avoiding excessive dependence on policy initiatives mainly relying on technological solutions. Firstly, there is a need to start to reduce emissions in the short-term to avoid further increases in emissions. Secondly, the ability of technology to deliver efficiency changes is uncertain. Thirdly, there is the possibility that efficiency gains, which will make delivering goods and services cheaper, would in turn be offset by traffic growth. This is what is normally now in the energy consumption literature as ‘rebound effect’, when gains in efficiency are offset by a consequent increase demand for energy (Sorrell et al., 2009). Last but not least, zero emission vehicles would be dependent on the total decarbonisation and indeed probable expansion of the energy supply sector.

We now compare our estimates with those obtained by the consultation of a small number of freight experts, (discussed in section 2), and those contained in the London Freight Plan (TfL, 2008a).

A small number of experts in freight and environmental matters (seven experts including two academics, three transport authority officials, one local authority official and one transport consultant) were consulted in order to gather information about their expectations on the likely impact of a number of policies on London. The results of the expert consultation (Table 4) indicate a lack of general consensus about the potential of most initiatives. In the case of low emissions vehicles most experts considered 20% and 30% as potential savings for 2025 and 2050 respectively (only one expert indicated higher figures). In the case of Construction Consolidation Centres most indicated a figure of around 3% for both 2025 and 2050 apparently revealing a lower confidence in the potential of these centres to reduce the growth in construction traffic.

Table 4. Comparison of Emissions Projections

Measure	**Impact (% change from baseline projections 2025 and 2050)**					
	Our calculations		**London Freight Plan[1]**		**Experts Consultation[2]**	
	2025	**2050**	**2025**	**2050**	**2025**	**2050**
Low Emissions Vehicles[3]	**-16.5**	**-45.1**	**-11.7**	**n.a**	**-20/50**	**-30/80**
Drivers' Training[4]	**-11.4**	**-16.9**	**-11.3**	**n.a**	**-3/30**	**-5/35**
Construction Consolidation Centres	**-4.0**	**-10.7**	**-5.5**	**n.a**	**-1/15**	**-1/15**
Urban Distribution Centres	**-3.6**	**-10.1**	**n.a**	**n.a**	**n.a.**	**n.a.**
Vehicle Reception Points	**-1.0**	**-3.5**	**n.a**	**n.a**	**-1/10**	**-1/20**
Relaxing Delivery Times	**-2.3**	**-6.6**	**-0.4**	**n.a**	**0/-40**	**0/-45**
Collection Delivery Points	**-2.2**	**-6.9**	**n.a**	**n.a.**	**0/-40**	**0/-40**

Source: Own calculations and (TfL 2008a)

[1]Figures reported in this table are the most optimistic ones included in the plan, those relying on a high degree of collaboration within the freight transport sector and have been calculated using information contained in Appendix D (TfL 2008a).

[2]This column reports ranges

[3] Voluntary adoption of Low Emission Vehicles in the London Freight Plan

[4]Fleet efficiency in the London Freight Plan

A direct comparison with the Freight Plan for all policies is not possible as assumptions are different and some initiatives are grouped together. The plan reports two impact figures for each policy, according to two possible levels of collaboration, high or low, between operators, users and local authorities, and the figures considered for comparison in this paper were their most optimistic ones. Table 4 shows that the plans' figures for drivers' training and construction consolidation centres are generally in line with our figures, albeit slightly higher for the latter. In the case of low emission vehicles and the relaxation of delivery times, however, the plan reports less optimistic figures. The plan is clearly reflective of policies that are under the influence of TfL/ GLA and what is politically feasible (with the maximum level of collaboration) whereas this research is looking at the maximum possible policy impacts.

6. CONCLUSIONS

This paper has briefly analysed the historical, current and future situations in terms freight transport sector in London, focusing on its road movements activities and CO_2 emissions. Data limitations have forced the application of a relatively simple model based on existing literature and assumptions on the scope of policy measures in London's total freight traffic. Nevertheless, this analysis has enabled us to provide illustrative scenarios for CO_2 emissions from freight in London.

Analysis of historical emissions shows that from 1996 to 2005 emissions from HGVs and LGVs in London increased by around 18%. Projections of these trends reveal that if the growth in freight traffic continues, and in the absence of further policy intervention these CO_2 emissions may increase by an additional 109% by 2050.

Analysis of the most recent literature has reveals a range of potential policy interventions for reducing CO_2 emissions from freight transport in London. However, the policy tests indicate that even with optimistic assumptions the selected policy interventions cannot deliver absolute reductions from 2005 levels only a slower rate of growth.

The most effective policy development would be the entry and success of low and no carbon vehicles into the fleet. Under our assumptions emissions growth could be held to around 6% to 2050. However, relying on technical developments to deliver emissions savings is risky as such vehicles may enter the fleet at a slow rate and zero carbon vehicles would be dependent on a larger and decarbonised energy generation sector.

A successful package of technological, logistical and behavioural policy could be capable of achieving savings of about 50% with respect to the projected baseline in 2050. This will certainly require high levels of collaboration between planners, operators and their customers, both business and final consumers. Thus the road freight sector is unlikely to be able to deliver an even minimal contribution the 60% London reduction target. Interventions that not only attempt to make freight and logistics operations more efficient but also deeply influence behaviour are therefore critical to the success of carbon reduction measures in the this sector. This will be important to achieve further reductions and, especially, to avoid any rebound effects.

Finally, this research has highlighted the gaps in the availability of data concerning traffic and emission from freight in London and the necessity of further research and more formal modelling of these in order to draw more precise conclusions on their likely evolution. Better information on van use is a particular requirement to guide the development of appropriate policies.

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Footnotes

[1] This research considers the Greater London Authority area which comprises a surface of around 1,600 km^2 and a population of around 7.5 million (GLA, 2008).

[2] Data on fleet composition were available from 1996 only and for this reason Table 2 compares traffic and emissions information from 1996 to 2005.

[3] For example, Euro I LGVs are expected to cease their contribution to traffic beginning from 2013, and in 2025 all vans are going to be Euro IV powered AEA. (2007).

[4] The proportion of empty running by lorries has been steadily declining in the UK in the last 30 years and more (McKinnon and Ge, 2006) whereas average load factors declined in the period 1990-2004 (McKinnon, 2007b).

[5] Traffic data by business sectors are only available for company-owned vans for the year 2002. In number of vehicles terms, privately-owned vans registered in London are around 123,000 (54% of total) (TfL, 2008b)

[6] The Committee also consider the diffusion of bio-fuels as energy source among the fleet (CCC, 2008). However we do not consider this initiative in our analysis.

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Table A1. Summary of literature review

Evidence based, case studies		
Authors and location	*Policy – Logistic initiative*	*Impact on Traffic and/or CO_2 emissions/fuel consumption*
(Esser and Kurte, 2005) Cologne	*E-commerce, home shopping* Note: For a review of studies on the impact of e-commerce and home deliveries on traffic, transportation and logistics operations also (Browne 2001; Browne et al. 2001; Mokhtarian 2004)	The increase of B2C E-commerce between 2003 and 2006 generated a reduction in car traffic of about 14% (7.6 M v/kms) and an increase in commercial vehicle traffic of about 3%. (1.75 M v/kms).
(Patier, 2005, 2007) France	*Implementation/provision of Urban Distribution Centres (UDC)*: Public transhipment depots which serve a part of an urban area. From these depots, goods are delivered in a consolidated way.	Potential to generate 3hours/day/truck saving for freight operators. This resulted in a 61% decrease in overall fuel consumption (if it is assumed that 10 to 20% of urban goods deliveries pass through these centres).
(TfL, 2007) London	*Construction Consolidation Centres (CCC)* Note: There is no clear consensus in literature on the effect of consolidation centres on traffic as it appears that this effect strongly depends on the sector and geographical characteristics of the urban area under study. For a recent extensive review on the effect of consolidation in freight operations see (Browne et al., 2005b).	A CCC generated 75% decrease in CO_2 emissions, a reduction in the number of construction vehicles entering the City of London (directed to sites using the centre) of 68%.
(Browne et al., 2007) Heathrow and Bristol		The Heathrow Airport Retail Urban Consolidation Centre (HARUCC) generated a 70% reduction in vehicle trips for the goods handled in the centre (a saving of 87,000 v/kms in 2003 and 144,000 in 2004). A similar centre operating in Bristol (Broadmead), used by 51 retailers, enabled a 42,722 v/km saving in 2005.
(Patier 2007) France	*Implementation/provision of Vehicle Reception Points (VRP)* Locations in which drivers are helped to park. Goods are then delivered on foot using handling equipment.	VRPs have been experimented in several French towns and, according to estimations, they generated, over a 6 month period for a single large operator (Chronopost), a 80% reduction in CO_2.
(Finnegan et al., 2007) Dublin	*Provision of dedicated freight lanes*	The freight – exclusive Dublin port tunnel generated a reduction of up to 90% in the number of 5 and more axles HGVs in traffic sensitive city centre locations
(DfT, 2007c) Transco National Logistics, Birmingham	*Use of Information and Communication Technologies (ICT), optimised vehicle routing, Vehicles Information Communications Systems (VICS)*	Optimised vehicle routing generated a saving of 360 journeys per year from 2002 for a total annual saving of 24,000 miles.
(Ando and Taniguchi, 2005) Osaka		VICS generated a reduction of 63% in delays at the delivery point and a reduction in total running time of 6.8%. It has generated a 7.6% reduction in CO_2 emissions.
(DfT, 2007c) Transco National Logistics, Birmingham	*Promotion of Low Emissions Vehicles (LEV) usage*	The trial of Compressed Natural Gas (CNG) powered vehicles (used to cover approximately 250,000 miles per year), generated an annual reduction of 42t of CO_2.
(DfT, 2007d) Thorntons plc, Derbyshire	*Driver Performance Management* This may include fuel consumption recording sheets, data loggers, performance league tables, tacographs, drivers' service levels and accidents monitoring, Automatic Vehicles Location Systems (AVLS), General Radio Packet Service (GRPS).	A fuel monitoring programme and incentive scheme generated a gain in fuel efficiency in the period 2001 to 2003 of 6.5%.
(DfT, 2007e) Marshalls, Nationwide		The use of AVLS and GRPS, and an improved fuel management generated an annual reduction 4,000 journeys, 330,000 v/kms, 515t of CO_2.
(DfT, 2007b) Yearsley Group, West Midlands		A fuel monitoring programme resulted in an improvement of fuel efficiency in the period 1999 to 2005 by 11.7%.
(TfL, 2008c)	*Congestion Charging Scheme (CCS) and other road users charging schemes*	The London CCS generated between 2002 and 2007 a 13% reduction of van traffic within

London		**the charging zone. In the case of lorries, the reduction was 5%.**
(Buhler and Jochem, 2009) Germany		**A study on the impact of road user charging on freight modal choice quantified in 1% the reduction of CO_2 emissions from freight vehicles on German motorways**
(Taniguchi and van der Heiden 2000)	***Cooperative freight transport systems:***	
Forecasts, projections, simulation and scenario-based studies		
(McLeod et al., 2006; Song, 2007) Winchester	***E-commerce, home shopping***	**A saving in total driving distance varying from 16% (in the case of 10% missed first-time home deliveries) to 53% (if failed home deliveries are around 50%). Transport emissions on a typical shopping day by around 50% with respect to the traditional high street shopping model.**
(Cairns, 2005; Cairns et al., 2004) Witney, Oxfordshire		**If 10-20% of total shoppers use home delivery shopping, the net gain between car journeys and van deliveries could reach 7-16% (70-80% reduction v/kms).**
(Weltevreden and Rotem-Mindali, 2009) Holland		**The development of b2b and c2c commerce could generate an increase of about 35 million freight v/kms nationwide**
(Song et al., 2009) West Sussex	***Collection Delivery Points***	**The usage of Collection/Delivery Points could achieve savings in CO_2 from home delivery operations of up to 40%**
(Patier, 2005, 2007) France	***Implementation/provision of Urban Distribution Centres (UDC) or Consolidation Centres (CC)***	**These logistic centres have the potential to generate 3hours/day/truck saving for freight operators. This has resulted in a 61% decrease in overall fuel consumption considering that 10 to 20% of urban goods deliveries pass through these centres.**
(TfL, 2007) London		**A reduction of driven kilometres up to 43% in the case of implementation of four or six construction consolidation centres in London (with 100% more deliveries). Savings in terms of CO_2 emissions by 2007 would be from 7,700 to 13,600t.**
(Melo and Costa 2007) Porto (Pt)	***Freight vehicles usage of bus lanes***	**The shared usage of bus lanes would generate a reduction of up to 35% in delay time per vehicle per kilometre (for vans in peak hours). The increased average speed would result in diminishing CO_2 emissions by up to about 50% (non-peak time).**
(Hsing-Chung and Meyer, 2009) Atlanta, Georgia	***Truck Only Toll Lanes***	**The implementation of truck-only toll lanes in the Atlanta (Georgia, US) highway system could achieve savings in CO_2 emissions of up to 61%% by reducing congestion and improving truck flows**
(Anderson et al., 2005) Basingstoke, Birmingham and Norwich	***Imposing weight restriction for urban areas access***	**An increase in total distance travelled from 7 to 23%. An increase in total CO_2 emissions from 4 to 7%.**
(Bush, 2006) London	***Low Emissions Zone (LEZ)***	**Changes are expected to occur in the stock profile. No significant impact on the volume of traffic. Effect on CO_2 emissions is expected to be negligible.**
(Browne et al., 2005b) London		**Negligible effect on traffic as freight companies are not likely to change their operational routes because of the scheme.**
(Banister and Hickman, 2006) UK	***Promotion of Low Emissions Vehicles (LEV) usage***	**The improved efficiency of freight vehicles could generate a reduction in CO_2 emissions by 2030 from 3.2 to 6.45 Mt.**

(Banister and Hickman 2006) UK	***Use of Information and Communication Technologies (ICT) 'in' and 'on' freight transport (teleactivities):*** **Automatic flexible freight handling and tracing, integrated logistical systems, mileage related taxes, track and intermodal nodes, optimised vehicle routing, Vehicles Information Communications Systems (VICS).**	**This package of measures is assumed to generate a total of 7% decrease in freight movement by 2030 (t/km) (in relation to base 2000), and a saving of 0.9 Mt of CO_2 emissions by 2025 (in relation to base 2000)**
(Taniguchi and van der Heiden, 2000) Kobe		**Advance routing and scheduling systems generated a reduction of 8.3% in CO_2 emissions.**
(Ang-Olson and Schroeer 2002) USA	***Trucking efficiency measures.*** **Improved aerodynamics, tyre inflation, tare-weight reduction, low-friction lubricants, reduced engine idling, speed reduction.**	**These measures together could generate an aggregate reduction in fuel consumption by about 30%.**
(DTRS 2004) Sydney (AUS)	***Promoting higher load factors***	**In a study on CO_2 abatement transport scenarios in the city of Sydney, higher load factors for freight vehicles was the logistic measure with the highest impact on freight operations, with a 17% reduction in CO_2 emissions compared to the base 1996.**
(Taniguchi and van der Heiden 2000) Kobe - Japan		**Controlling load factors of pick/up delivery trucks generated saving of up to 18% in CO_2 emissions when the demand for freight services was doubled**
(Melo and Costa, 2007) Porto (Pt)	***Implementation of Collaborative Systems (CS)*** **Collaboration agreements within shopkeepers in a specific area who cooperate to decrease costs and minimise the impact of deliveries.**	**For the case of lorries, collaborative system resulted, in the case study area, in 11% reduction in traffic (v/kms). CSs generated a 3% increase in average speed and a 13% reduction in CO_2 emissions.**
(Hickman et al., 2009) London	***Freight Policy Package including:*** **changed handling factors, reduce length of haul, improved rail share mode, reduced empty running, improved fuel efficiency and choice of fuel/power source**	**This package of measure could achieve up to 42% reduction in CO_2 emissions in London with respect to the business as usual scenario**
(Taniguchi and van der Heiden 2000) Kobe - Japan	***Cooperative freight transport systems:*** **this includes various forms of collaborations like UDCs, VCPs and other ways to reduce the number of trucks used to collect and deliver the same amount of goods**	**This cooperative solutions were simulated to the likely to achieve up to 51.8% reduction in CO_2 emissions from urban collection and delivery operation when the demand for freight services was doubled.**