THE IMPACT OF SUSTAINABILITY POLICIES ON URBAN FREIGHT TRANSPORT AND LOGISTICS SYSTEMS

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Abstract

This paper considers existing urban freight transport operations within the context of the recent discussion about the sustainability of towns and cities. After examination of the importance of freight transport and logistics (both in terms of its role and its impacts) and the way in which it could be incorporated into urban sustainability strategies, a case study of freight transport in London is presented. The case study is designed to illustrate the environmental impacts caused by freight in a large city and also to model the effect of a range of strategies that could make freight transport more environmentally sustainable.

INTRODUCTION

This paper begins by considering the importance of urban freight transport in maintaining the economic vitality of the city, and the negative impacts that it imposes. The concept of sustainability and the development of sustainability strategies are then discussed. The paper then addresses the means and measures by which freight transport could be made more sustainable. The results of the modelling of freight transport and its impacts within London are then presented, together with modelling of how different sustainability strategies could alter the level of these impacts.

THE IMPORTANCE OF URBAN FREIGHT TRANSPORT

Traffic levels and their impacts in British towns and cities have received growing attention in recent years, much of this has been directed at public transport and private car traffic while relatively little consideration has been paid to road freight transport.

However, urban freight transport is important for many reasons (Meyburg and Stopher,1974; Hassell et al, 1978; Ogden, 1992). Among the most significant are:

- the environmental effect of urban freight movements (in terms of energy use and environmental impacts such as pollution, noise, visual intrusion etc.);
- the total cost of freight transport and logistics is significant and has a direct bearing on the efficiency of the economy;
- the effect of freight transport and logistics costs on the cost of commodities consumed in that region;
- it is fundamental to sustaining our existing life style;
- the role it plays in servicing and retaining industrial and trading activities which are essential major wealth generating activities;
- the contribution that an efficient freight sector makes to the competitiveness of industry in the region concerned.

IMPACTS OF URBAN FREIGHT TRANSPORT

Road freight vehicles operating in an urban environment generally emit a greater proportion of certain pollutants per kilometre travelled than other motor vehicles such as cars and motorcycles. This is due to their higher fuel consumption per unit of distance travelled and the fact that many of them use diesel as a fuel. This is illustrated in Table 1.

Existing freight and passenger transport systems in urban areas create a variety of economic, environmental and social impacts. These include (UK Round Table on Sustainable Development, 1996):

Economic impacts: (i) congestion, (ii) inefficiency and (iii) resource waste.

Environmental impacts: (i) pollutant emissions including the primary greenhouse gas carbon dioxide, (ii) the use of non-renewable fossil-fuel, land and aggregates, (iii) waste products such as tyres, oil and other materials and (iv) the loss of wildlife habitats and associated threat to wild species.

Social impacts: (i) the physical consequences of pollutant emissions on public health (death, illness, hazards etc.), (ii) the injuries and death resulting from traffic accidents, (iii) noise, (iv) visual intrusion, (v) the difficulty of making essential journeys without a car or suitable public transport, and (vi) other quality of life issues (including the loss of greenfield sites and open spaces in urban areas as a result of transport infrastructure developments).

Table 1 - Emissions for road vehicles (per vehicle kilometre) in urban conditions (Index: pre 1993 petrol car = 100; for particulate emissions pre 1993 DERV car = 100)

		Carbon monoxide	Hydro-carbons	Oxides of nitrogen	Partic-ulates	Carbon dioxide
CARS	Petrol car without three-way catalyst: pre 1993	100	100	100	-	100
	Petrol car with three-way catalyst	42	19	23	-	108
	DERV car: pre 1993	2	3	31	100	85
VANS	Petrol van without three-way catalyst	59	50	83	-	86
	DERV light van	3	11	60	97	101
GOODS VEHICLES	Goods vehicles: 3.5-7 tonnes	10	23	302	655	256
	Goods vehicles: 7.5-17 tonnes	17	17	424	528	325
	Goods vehicles: over 17 tonnes	20	19	650	524	514

Source: adapted from Department of Transport, 1996a.

According to the UK Round Table on Sustainable Development: "there is no magic solution to the many problems caused by present land transport patterns and trends. But there is much that a co-ordinated, sustainable transport strategy can do to minimise current and anticipated future adverse impacts, and their associated costs, efficiently and equitably while continuing to deliver or improve on existing benefits.....The most efficient policy decisions, following sustainability criteria, are likely to be those that meet economic, environmental and social needs simultaneously; and so minimise trade-offs between objectives to reduce associated losses and costs. These are win-win-win options." (UK Round Table on Sustainable Development, 1996, part I, paragraph 26).

As Plowden and Buchan note (1995) "Freight transport is essential to the modern economy. An efficient system must provide the customer with a good service at a reasonable cost." However, increasing congestion in urban areas has called into question our ability to achieve high levels of efficiency and as the Freight Transport Association have observed: "While industry has achieved significant success in improving vehicle productivity and utilisation, urban congestion imposes major constraints on further improvements" (Freight Transport Association, 1996).

DEVELOPING A SUSTAINABILITY STRATEGY

The concept of "sustainability" and "sustainable development" has become increasingly influential in policy considerations in recent years. The most widely accepted definition of sustainable development is "development that meets the needs of the present without compromising the needs of future generations to meet their own needs" (World Commission on Environment and Development, 1987). This was the definition used by the World Commission and then endorsed by the United Nations at the Earth Summit in Rio in 1992. This conference led to a focus on the policy action required to bring about sustainability, known as Agenda 21, which, whilst having no force in international law, has been adopted by many national governments (Mazza and Rydin, 1997). In the UK, as a result, many local authorities have been preparing environmental strategies.

The first step in moving towards a more sustainable system involves deciding on the geographical scale over which sustainability will be considered (i.e. global, international, national, regional or local) and identification of existing economic, environmental and social impacts within this defined area. It is then necessary to establish target levels by which it is intended to reduce these impacts - if this is to be rigorous it requires statistical evidence of a link between two variables. For instance, it is necessary to demonstrate that a link exists between say, nitrous oxide emissions and public health. The target level should then be based on scientific research (e.g. establishing what constitutes a safe level for these emissions). This step is proving difficult as it requires a thorough knowledge of the level of existing impact (e.g. the current level of pollutant emissions - which will be dependent upon a number of factors) and the relationship between the impact and its harmful consequences. In the case of many impacts, their short and long term consequences are not yet well understood.

These problems make it difficult to establish which impacts should be addressed and what would constitute an appropriate reduction target. If suitable targets can be established, then the next stage requires actions to be devised that will reduce the current level of impacts to the target level. Given that most impacts emanate from several or many different activities it is necessary to consider the contribution of each of these activities to the impact and decide whether actions should aim to reduce the level of impact caused by each activity by the same proportion, or whether the impact of certain activities should be reduced more than others. This could be influenced either because of the proportion of the overall impact that the activity is responsible for, or because it is easier to reduce the impact emanating from one activity compared with another activity.

Once it has been decided which activities are to be subject to actions it is necessary to formulate appropriate measures (e.g. bans, restrictions, fiscal approach etc.), and to determine how stringent these measures need to be achieve its required target (e.g. the level of the tax, the extent of the restriction, the duration of the ban etc.). We are currently at a stage where even if the level and importance of an impact is well understood, the measures needed to bring about actions that will result in specific reductions in the level of impacts are not so clear. For example, in the case of road traffic accidents, their number, location and severity are well understood. However, the measures needed to bring about a change in driver behaviour so as to reduce accident levels by a specified amount remains uncertain. In addition, any new measures that are introduced may well result in other changes in behaviour in addition to the desired one, thereby altering the intensity of other impacts.

The third stage requires resolution of conflict between objectives. These could involve a conflict between impacts (i.e. reducing one impact may increase another). It could also involve a conflict between economic and environmental objectives, or social and environmental objectives. In the case of freight transport, for example, it is essential to the economic functioning and life of the city but is also responsible for a number of environmental impacts that threaten the city's environmental sustainability.

Not surprisingly it is extremely difficult to achieve a workable, acceptable set of targets, actions and measures which will result in more sustainable cities, and a more sustainable urban freight transport system within that city.

SUSTAINABILITY STRATEGIES FOR URBAN FREIGHT TRANSPORT

The aim of a sustainable transport strategy is "to answer, as far as possible, how society intends to provide the means of opportunity to meet economic, environmental and social needs efficiently and equitably, while minimising avoidable or unnecessary adverse impacts and their associated costs, over relevant space and time scales" (UK Round Table on Sustainable Development, 1996). Since freight transport is part of the transport system it follows that the issue of sustainability must be addressed with regard to freight transport.

Urban freight movement can be improved so as to make it more sustainable in various ways. It is important to distinguish between two different groups who are capable of changing the urban freight system and the rationale for their doing so:

- *changes implemented by governing bodies*. This occurs through the introduction of policies and measures that force (or encourage in the case of new taxes) companies to change their actions and thereby become more environmentally or socially efficient (i.e. changing the way in which they undertake certain activities). In these cases there is unlikely to be any internal gain to the company from this adaptation in their behaviour and there may even be a reduction in economic efficiency. Strategies available include traffic management schemes, zoning of land use, infrastructure developments and improvements, licensing and regulations, road pricing, and terminals and transhipment centres (Ogden, 1992).

- *company-driven change*. Companies (freight transport companies and/or their customers) tend to implement measures that will reduce the impact of their freight operations because they will derive some internal benefit from this change in behaviour. This could occur because the company can achieve internal economic advantages from operating in a more environmentally or socially efficient manner, either through improved economic efficiency or through being able to enhance market share as a result of their environmental stance. Instances of company-led initiatives include increasing the vehicle load factor through the consolidation of urban freight, making deliveries before or after normal freight delivery hours, the use of routeing and scheduling software, improvements in the fuel efficiency of vehicles, in-cab communications systems, and improvements in collection and delivery systems (including materials handling technology, unitisation of loads and co-ordination between shipper, carrier and customer). As this list illustrates, some of these initiatives are technology-related, some are concerned with freight transport companies reorganising their operations and some involve change in the supply chain organisation.

Although, in several instances, efficiency in operations and reduced environmental impacts go together it must also be recognised that individual freight transport operators will not by themselves be able to achieve adequate system-wide improvements in urban freight efficiency. In some instances there may be a lack of concern about freight costs by the customers of the distribution companies since these costs may be only a small proportion of total product cost. In other cases there may be a reluctant acceptance by the freight industry of current levels of congestion, since there is no competitive advantage to any one firm as a result of a lower congestion level. This implies that a combination of company initiatives and government policies will be necessary in developing a sustainable urban freight system.

Given that the demand for freight transport is a derived demand, in order to consider how freight transport can be made more sustainable it is also necessary to understand the nature of commodity and goods flows. The driving forces behind these flows are factors such as the geographic location of activities, the costs of transport and related activities, land prices, customer tastes and required service levels and existing policies governing freight transport and land-use. Therefore in order to change freight transport patterns and reduce their impacts it is necessary to influence some of these factors that determine goods flows as well as simply focusing attention on goods vehicle movements.

Sustainable development strategies are likely to require national policies together measures taken at a more local level. A national sustainability strategy could help to ensure that urban sustainability policies do not result in some urban locations becoming less economically attractive than others. It will be necessary to find suitable measures for the town or city in question and these are likely to vary from one urban area to another.

Given the current lack of knowledge about the existing level of environmental impacts caused by freight transport in urban areas, we decided to undertake a case study of London to establish the scale of road freight activity in the city (in terms of trip numbers and vehicle kilometres performed), the fossil fuel used in these operations and the associated pollutant emissions. We then attempted to compare and contrast this road freight activity and its environmental impact with that of other road transport users in London in order to obtain an indication of the relative importance of different road vehicles in transport activity, fossil-fuel use and pollutant emission. The contribution of road transport to all pollutant emissions in London was also considered in order to put the importance of road transport in context when considering the environmental sustainability of London. The case study then provides the basis for us to consider the implications of various sustainability strategies.

A CASE STUDY OF ROAD FREIGHT TRANSPORT IN LONDON

Road is by far the dominant mode for goods movement in London. In 1994 the split between freight lifted by road and rail in Greater London was 96%:4%. Data from the most recent London Area Transport Survey (LATS) estimates that there were 1.15 million road freight vehicle (including light van) movements into, out of and within Greater London on a typical weekday in 1991 (DoT/LRC, 1994).

Cordon surveys of road traffic in London by the Department of Transport indicate the split of freight vehicle traffic between light vans, medium goods vehicles and heavy goods vehicles (Department of Transport, 1996b). This split between these three categories can be applied to the LATS data to derive an estimate of the number of freight vehicles of different type/size operating in London on a typical weekday (see Table 2).

Table 2 - Road freight vehicle movements in London on a typical weekday in 1991

Vehicle type	Percentage of goods vehicle movements in London	Road freight vehicle movements in London (000)
Light vans	65%	744
Medium goods	30%	344
Heavy goods	5%	57
TOTAL	100%	1,145

N.B. Light vans defined as having a gross vehicle weight of 3.5 tonnes or less; medium goods vehicles defined as being 2-axle rigid vehicle with 3.5 tonnes to 17 tonnes gross vehicle weight; and heavy goods vehicles defined as having 3 or more axles with up to 38 tonne gross vehicle weight.
Source: adapted from data in DoT/LRC, 1994 and DoT, 1996b.

Combining this macro weekday traffic data with operational data regarding average trip length, road freight vehicle movements at weekends, and the fuel efficiency of the vehicles, it is possible to produce: (i) estimates of the annual number of trips and the vehicles kilometres performed by all road freight vehicles in Greater London in 1991, (ii) the total energy these vehicles used in performing these trips and (iii) the pollutant emissions that this resulted in. The results are shown in Table 3.

Table 3 - Estimate of vehicle activity, energy use and pollutant emissions from road freight vehicles in London in 1991 (figures in brackets are percentage of total)

	Light vans	Medium goods	Heavy goods	TOTAL
Average trip length (km)	10.0	12.6	26.0	-
Fuel consumption (km per litre)	11.7/13.2*	4.6	2.6	-
Annual trips (000s)	205,146 (65%)	94,683 (30%)	15,780 (5%)	315,609 (100%)
Annual vehicle kilometres performed (million km)	2,056 (56%)	1,190 (33%)	410 (11%)	3,656 (100%)
Annual petroleum consumed (million tonnes)	0.14 (29%)	0.22 (46%)	0.12 (25%)	0.48 (100%)
Annual CO_2 emissions (thousand tonnes)	373.1 (24%)	749.8 (49%)	408.6 (27%)	1,531.5 (100%)
Annual CO emissions (million tonnes)	18.8 (69%)	5.9 (22%)	2.4 (9%)	27.1 (100%)
Annual HC emissions (million tonnes)	2.8 (70%)	0.9 (23%)	0.3 (7%)	4.0 (100%)
Annual NO_x emissions (million tonnes)	3.3 (16%)	11.4 (55%)	6.0 (29%)	20.7 (100%)
Annual PM emissions (million tonnes)	0.3 (11%)	1.8 (67%)	0.6 (22%)	2.7 (100%)

N.B. (i) Average trip lengths not calculated for the 1991 survey, so data from the 1981 survey used (GLC, 1985).
(ii) Fuel consumption data from Gover et al, 1994.
(iii) *11.7 for petrol-fuelled vans, 13.2 for diesel fuelled vans.

Although heavy goods vehicles were only responsible for 5% of all freight vehicle *trips* in London, they performed an estimated 11% of all freight vehicle *kilometres*. This is due to the greater average trip length of these vehicles. These heavy goods vehicles are also estimated to have consumed 25% of all the fuel used by freight vehicles in London. This is caused by the greater fuel consumption per kilometre travelled by a heavy vehicle compared with smaller, less powerful freight vehicles (this does not take into account the carrying capacity of the vehicle).

Using National Travel Survey data for Londoners' personal travel patterns (DoT, 1996c) it has been possible to estimate the vehicle kilometres performed, energy used and pollutant emissions from other motorised road traffic in London in 1991 and then compare these results with London's road freight traffic. This is shown in Table 4.

Our calculations suggest that road freight vehicles consumed approximately 18% of all energy used by motorised road transport in London in 1991. These calculations reflect the relatively higher fuel consumption rates of road freight vehicles in comparison with cars, taxi and motorcycles as, from our estimates, road freight vehicles performed 12% of all vehicle kilometres in London. These results indicate the importance of road freight vehicles in road transport energy use in London and emphasise the need to include road freight in urban transport energy use assessments.

The calculations show that road freight vehicles were responsible for 22% of carbon dioxide emissions, 26% of nitrogen oxide emissions and 68% of particulate emissions from road transport in London in 1991. Again, these estimates illustrate the importance of road freight vehicles in certain road transport-related pollution emissions in London.

Table 4 - Comparison of annual vehicle kilometres, energy use and pollutant emissions for road freight and other motorised road traffic in London in 1991

	Annual vehicle kilometres (million km)	Annual petroleum used (million tonnes)	CO_2	CO	HC	NOx	PM
Light vans	2,056 (7%)	0.14 (5%)	5%	3%	3%	4%	7%
Medium goods	1,190 (4%)	0.22 (8%)	11%	1%	1%	14%	47%
Heavy goods	410 (1%)	0.12 (5%)	6%	0%	0%	7%	16%
Cars & taxis	26,089 (86%)	2.04 (78%)	72%	95%	94%	68%	16%
Buses & coaches	315 (1%)	0.09 (3%)	5%	1%	2%	6%	13%
Motorcycles	277 (1%)	0.01 (0%)	0%	0%	0%	0%	0%
TOTAL	30,337 (100%)	2.63 (100%)	100%	100%	100%	100%	100%
All freight vehicles	3,656 (12%)	0.48 (18%)	22%	4%	4%	26%	68%
Total pollutant emissions (thousand tonnes per annum)			6,942	735	111	81	4

N.B. It should be noted that the our calculations are based on 1991 emission data and there have been improvements in vehicle engines since this date as a result of EU legislation (Euro I for cars, Euro I and II for goods vehicles, buses and coaches).

Our emission estimates are similar to estimates of carbon dioxide and nitrogen oxide levels made by London Transport; they estimate that road freight vehicles are responsible for 21.5% of all CO_2 emissions and 25.9% of all NO_X emissions from road transport in London (London Transport Buses, 1996). However, it should be noted that in the case of carbon monoxide and hydrocarbon emissions our estimates are lower than those made by London Transport, whilst in the case of particulates our estimates are higher. Few studies of pollutant emissions from freight vehicles in London have been conducted, and this topic is clearly worthy of further investigation and estimation in future.

ALTERNATIVE ROAD FREIGHT SUSTAINABILITY SCENARIOS IN LONDON

Introducing new policies to alleviate one environmental impact of urban freight movement can result in worsening others. For example, a major concern often cited by individuals and environmental pressure groups is the size of lorries operating within the urban area. Banning all lorries above certain dimensions/weights from operating within the city would immediately remove the concerns and problems caused by large lorries. However, the goods previously transported within the urban area by these large lorries will now have to be moved in smaller vehicles, and several of these smaller vehicles will be required to replace each large lorry that has been banned. As a result of the ban, total lorry trips, total energy used in freight transport and total road freight pollutant emission levels would be likely to increase. Therefore, in considering suitable approaches and remedies to specific environmental problems caused by urban freight transport it is necessary to consider the wider implications of any such action.

Considering the effects of a range of scenarios on trips, kilometres and fuel use

It has been possible to consider a range of operational changes that could potentially reduce trip numbers, vehicle kilometres and fossil fuel energy use in road freight transport in London. These are three key factors in the environmental impacts caused by road freight transport.

The scenarios that have been included in the modelling are:

1. 1991 actual road freight activity (referred to as the base case)
2. Improving vehicle load factors through load consolidation

3. Banning heavy lorries
4. Reducing empty running
5. Use of transhipment centres

The reasoning underpinning each of these scenarios, together with the assumptions used in the modelling are discussed below.

Scenario 1 - 1991 actual road freight activity (base case). The estimates of actual road freight transport activity, energy use and pollutant emissions in London in 1991 were presented in the previous section of this paper. This is the base case against which the other scenarios are compared.

Scenario 2 - Improving vehicle load factors through load consolidation. Load consolidation improves the efficiency of freight transport by increasing the vehicle load factor on each trip (i.e. the quantity of goods carried). Consolidation, whereby a vehicle will either carry goods to several different destinations or will carry several suppliers goods for one destination, is especially appropriate for urban freight transport as it reduces the total number of trips that are necessary. Urban areas are generally highly suitable for multi-drop operations, given the short distances between drops. A significant degree of load consolidation has already been implemented in the UK. Much of this has taken the form of in-company consolidation, in which a company centralise their stockholding and reorganise their transport operations to facilitate consolidation and thereby reduce total trips and hence transport costs. Examples of external consolidation (i.e. in which two or more companies combine their transport and warehousing operations) are less common in the UK; this approach offers the opportunity to significantly improve load consolidation. Load factor improvements of 50% have been achieved in a pilot scheme involving ten freight companies in Basle, Switzerland; this indicates the scope for greater load factors through load consolidation (European Freight Management, 1995).

In the modelling, we have assumed a 20% higher vehicle load factor in the improved load consolidation scenario than in the base case (i.e. 60% of the vehicle payload is assumed to be used on loaded trips in this scenario, compared with 50% of the payload in the base case).

Scenario 3 - Banning heavy lorries. In many French towns and cities, freight vehicles above a certain size or weight are banned at certain times of day. The same is true in some German towns and cities such as Heidelberg (Schmidt, 1996). Banning heavy lorries removes the noise, vibration and visual intrusion problems that they cause. However, their work would have to be conducted by smaller vehicles, which are only capable of carrying a proportion of the goods that a heavy lorry can carry on each trip. Therefore the use of smaller vehicles would be expected to lead to increases in total trip numbers, total vehicle kilometres and total fossil fuel use.

For the purposes of the modelling, it has been assumed that all goods vehicles with three or more axles (i.e. with gross vehicle weights of 17 tonnes and above - defined as heavy vehicles in the base case) are banned from operating within London, and the work of these vehicles is undertaken instead by medium vehicles (2-axle rigid vehicles with a gross weight of 3.5 to 17 tonnes). However, the goods carried by small and medium vehicles in the base case are still carried by these same vehicles in this scenario.

Scenario 4 - Reducing empty running. Road freight vehicles run empty (i.e. carry no goods) on a significant number of trips; this tends to occur especially on trips when the vehicle is returning to its base from a delivery. Official statistics show that 29.4% of all goods vehicle kilometres are run empty in Britain (DoT, 1996d). Empty running is a form of inefficiency as the vehicle capacity is not being fully utilised. Reducing the proportion of empty running yields both economic and environmental benefits and is therefore very desirable from all perspectives. The level of empty running in Britain declined from approximately 33% of total goods vehicle kilometres in 1982 to 29% in 1993 (McKinnon, 1996) and has remained stable since then.

In the modelling we have assumed that in a reduced empty running scenario, the number of trips that are run empty will be 20% lower than in the base case (i.e. 30% of all trips were assumed to be run empty in the base case, compared with 24% in this scenario).

Scenario 5 - Use of transhipment centres. A recurring theme in the discussion of ways to solve urban freight problems has been the creation of urban transhipment centres. At these centres, freight destined for city centres would be sorted into consolidated loads for final delivery into the city in smaller vehicles. A particular advantage of transhipment centres is the increased scope to consolidate goods flows destined for delivery to several customers in the urban area, and thereby reduce the total number of trips. It also replaces heavy lorries with smaller ones within the city, thereby removing, or at least reducing some of the environmental impacts associated specifically with heavy lorries. In the UK, retail distribution strategies and the desire to operate dedicated services, where lorries are used only for one retail customer, have tended to work against the development of common-user transhipment centres.

Some have argued that transhipment centres could lead to increased congestion in urban areas as more (albeit smaller) vehicles would be required to deliver the same volume of goods (Freight Transport Association, 1996). A key question that needs to be considered in much greater depth is whether the use of a transhipment centre would have to be made compulsory for the idea to succeed. Within Britain there is little recent evidence of the likely consequences of a change to a distribution strategy based around transhipment and it has been broadly accepted that some practical case studies would provide useful insights into the likely impacts.

In the modelling, it has been assumed that only small and medium freight vehicles would be allowed to continue to operate within London after the introduction of transhipment centres. The goods carried by heavy lorries in the base case are now conveyed from the transhipment centre to their final destination in London by medium lorries (and of course, this same system for goods being sent out of London). It is assumed that the load factor on these medium vehicles operating from the transhipment centres is 20% better than in the base case due to load consolidation. We have also made the simplifying assumption that the average trip length is the same when using urban transhipment centres as it was prior to its introduction (in reality the effect on trip length will be related to the number of transhipment centres established, their location and the rules governing their use). Table 5 shows the results of the alternative scenarios for freight transport in London that were examined.

Discussion of the results

The improved vehicle load factor scenario (scenario 2) can be seen to have the most beneficial effect on trip numbers, vehicle kilometres, fuel use and CO_2 emissions; achieving a 17% reduction in each compared with the base case. The reduction in empty running scenario (scenario 4) can also be seen to result in significantly fewer trips, kilometres and fuel use than the base case (8% lower than the base case in each instance).

Banning heavy lorries (scenario 3) increases the number of trips (9% higher than base case), vehicle kilometres (20% higher than base case), fuel use (16% higher than base case) and CO_2 emissions (21% higher than base case). However it is important to note that the removal of heavy lorries from London would bring environmental benefits not shown in the table in terms of reductions in noise and vibration levels and less visual intrusion.

Table 5 - Alternative scenarios for road freight transport in London (Scenario 1 base case - actual road freight activity in 1991 = 100)

	Annual freight vehicle trips	Annual freight vehicle kilometres	Annual petroleum consumed by freight vehicles	Annual CO_2 emissions by freight vehicles
Scenario 1 - 1991 actual road freight activity (base case)	100	100	100	100
Scenario 2 - Improving load factor through load consolidation	83	83	83	83
Scenario 3 - Banning heavy lorries	109	120	116	121
Scenario 4 - Reducing empty running	92	92	92	92
Scenario 5 - Transhipment centres	107	115	109	113

The use of an urban transhipment centre at which vehicle load factor improvements are achieved (scenario 5) is estimated to increase trips by 7% in comparison with the base case, increase vehicle kilometres by 15% and increase fuel use by 9%. It is worth noting that by its nature an urban transhipment centre may attract and generate a large number of trips each day so that even if the overall impact is environmentally beneficial, there may be negative local impacts from the concentration of vehicle movements.

These findings should obviously be treated with caution as the results are sensitive to the assumptions made. However, they are useful in indicating the broad manner in which key factors such as trip numbers, vehicle kilometres and fossil fuel use are likely to change under different operating conditions.

Determining the measures necessary to achieve fuel use reduction targets

In the previous section a range of freight transport scenarios were selected, assumptions about how such scenarios would alter operations were made and their impact upon trip numbers, vehicle kilometres and fossil fuel use modelled. This therefore represents a "best guess" at what could be achieved by different measures. However, as discussed previously, it is unlikely that sustainability strategies will be developed in this way. Instead, the approach taken is more likely to focus upon a specific impact such as fossil fuel use, establish a reduction target and then consider strategies that would be capable of bringing about this reduction.

We have taken a number of the scenarios defined in the previous section, together with several other actions and measures and, using the same 1991 data for road freight in London, calculated the extent to which operations would have needed to be changed in order to bring about a 20% reduction in fossil fuel use in road freight operations. The results are shown in Table 6.

Although the results in Table 6 help to indicate how different strategies could bring about reductions in fossil fuel use by road freight transport in London, they need to be treated with caution as they are obviously highly dependent upon the assumptions used in the modelling. Also, even if the numbers shown in the table were reliable, it is important to recognise that there has to date been no research that identifies whether some of these scenarios would be easier to achieve than others. For example, would it be easier to reduce empty running to 12.5% of all trips or to increase the average load factor to 62% of vehicle payload? Further research would be required to establish the ease with which different measures could be implemented and their intended outcomes achieved.

Table 6 - Strategies to reduce fossil fuel use by road freight transport by 20% in London

Strategy	Extent of change required
i) Improve average load factor	from 50% to 62%
ii) Reduce average empty running	from 30% to 12.5%
iii) Reduce average trip length	20% reduction in trip length
iv) Reduce total tonnage carried by road freight	20% less tonnage
v) Improve vehicle fuel efficiency	20% improvement
vi) Perform a proportion of light goods vehicle trips with alternatively powered light vehicles	74% of light goods vehicle trips
vii) Perform a proportion of medium goods vehicle trips with alternatively powered medium vehicles	44% of medium goods vehicle trips
viii) Perform a proportion of heavy goods vehicle trips with alternatively powered heavy vehicles	72% of heavy goods vehicle trips

It should be noted that some of the strategies shown in the table are managerial and operational in nature (such as improving vehicle load factors and reducing empty running), others are largely dependent upon technological developments (such as improvements in fuel efficiency and the availability of alternatively powered vehicles), whilst some would have to be taken by government (e.g. reduction in trip lengths through land-use planning and zoning policies). Reduction in the total tonnage carried could either be achieved through a reduction in the demand for goods (which is somewhat unlikely without major political and economic change) or through modal shift (i.e. a greater proportion of goods being carried by rail and water rather than by road).

In the case of a number of the strategies it can be seen that a 20% reduction in fossil fuel use would require a proportional change in a particular variable (such as trip length, tonnage carried, fuel efficiency and use of alternatively powered vehicles). By combining several of the strategies considered it would be possible to achieve a 20% reduction in fossil fuel without such significant change in each strategy by itself.

In the case of some of these strategies it would be necessary to change decisions and actions far beyond that of the freight transport industry. For instance trip lengths are dependent upon where manufacturing, warehousing and retailing activities are located, this in turn depends upon a number of factors such as land prices, the cost of transport, economies of scale in production, the location of the target consumer market and final consumer requirements. Therefore, in order to influence freight transport trip lengths, a wide range of other issues would need to be addressed through land-use planning and industrial/commercial policies and actions.

CONCLUSIONS

Urban road freight transport plays a key role in the functioning of towns and cities, and is a vital facilitator in the urban life that we currently enjoy. However, these vehicles are also responsible for a significant number of environmental impacts in urban areas. The goal is to find a suitable balance between economic and environmental pressures. There is a need to both improve the efficiency and quality of urban freight transport and logistics systems whilst at the same time reduce the social and environmental costs of these services. Both objectives remain of fundamental importance to the future sustainability of our cities.

In addition, the urban economy and the amount of freight movement it generates are closely linked. This has important implications for current policies aimed at regenerating towns and cities.

Regeneration implies increased demands for goods and services leading in turn to more freight movement - much or all of which will probably have to be met by the lorry. As a result if we want economically prosperous towns and cities together with fewer freight-related environmental impacts, it is clear that there is a role for public policy since the link between planning legislation and the way in which operations are carried out is very evident.

Thought needs to be given as to how measures that combine improvements in operational efficiency with reductions in environmental impact (such as improving load factors and reducing empty running discussed and modelled in this paper) could best be achieved. Measures such as these have the advantage of being attractive to freight transport companies and industry as a whole (as they can result in lower transport costs) as well as to the wider urban community, and initiatives to bring about improvements through such means can be undertaken by industry, or by industry in conjunction with policy makers.

In the case of measures that result in environmental benefits but at the expense of higher total transport costs (such as the banning of heavy lorries and the use of transhipment centres examined in this paper), it will be necessary for policy makers to take the initiative in these areas if they are deemed necessary. But, whatever initiatives are introduced, in order to succeed they will require more sophisticated planning and better co-operation than has traditionally existed between town and city authorities, traders (retailers and manufacturers) and the distribution companies responsible for collections and deliveries. Instead of an adversarial approach these organisations need to work together to solve the problems.

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