DAVID SIMMONDS CONSULTANCY

URBAN, REGIONAL AND TRANSPORT PLANNING

What is the environmental value of investment to increase the use of buses?

How the bus can help to deliver the Government's CO_2 reduction targets

Report

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Document control

Project: Greener Journeys' Buses and Environment Study

DCS reference: p75.1

Version	Date	Main author	Other author(s)	Reviewer(s)
0	12/05/12	David Simmonds		
1	18/05/12	David Simmonds		Andy Dobson, Derek Halden
2	22/05/12	David Simmonds	Derek Halden	for client review
3	26/06/12 – 02/07/12	David Simmonds		Derek Halden, Lee Woods
4	06/08/12	David Simmonds (following client review)		

SUMMARY

This report examines how the bus industry can contribute to meeting the Government's targets for reducing carbon dioxide (CO_2) emissions, particularly in the medium term up to the year 2020.

It first reviews the targets set by the UK Government, the contribution of local bus services to present CO_2 emissions, and the existing national interventions aimed at increasing the use of buses by passengers and at reducing emissions from buses. It then considers present and possible interventions under three headings:

- reducing emissions from the operations of the existing bus fleet;
- the introduction of greener buses (ie those which emit less CO_2 than existing buses, when used in the same operations); and
- the indirect contribution that improved bus services can make to reducing total emissions by reducing the use of other modes (in particular, by attracting passengers from car to bus).

From the review of these different topics, the report considers where investment in better bus services will make the greatest contribution to reducing CO_2 emissions. Given that buses are inevitably larger and heavier than cars, and generally cannot match the door-to-door (or at least door-to-car-park) convenience that car travel often offers, the environmental benefits of better bus provision are greatest where

- the number of passengers per bus is reasonably high, and where
- car users are liable to encounter significant congestion, parking problems etc.

The environmental benefits of better bus provision are therefore greatest in urban areas where passengers per bus are likely to be higher and when congestion, parking problems and other disadvantages of the car are most acute. The best-used bus services in the major urban centres may well be reducing carbon emissions by 75% or more, if one compares the emissions from the bus operations with the emissions which the bus passengers would generate by using cars if the bus services was not available.

Where there are high-frequency bus services which make use of busways or well-designed bus lanes for significant parts of their routes, thus avoiding much of the road congestion, buses can be an attractive alternative to travelling by car. This requires high standards in the buses themselves, the operation of the service (including bus priority) and the provision of information. However, active marketing is required get car users onto bus services; simply offering a good bus service is not sufficient.

The report finds that buses can play a useful role in helping to achieve the Government's targets for reductions in carbon emissions. This of course is in addition to the role of the bus in supporting the working of the economy (which is the subject of a separate study) and its social role in providing transport for many people who would otherwise be seriously deprived by a lack of independent mobility

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ABBREVIATIONS

Abbreviation	Meaning
BBA	Better Bus Areas
BSOG	Bus Service Operators' Grant
BTEC	Business and Technology Education Council (and vocational training qualifications awarded by the Council)
CCTV	closed circuit television
CfIT	Commission for Integrated Transport
CILT	Chartered Institute of Logistics and Transport
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CPT	Confederation for Public Transport
DEFRA	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
DHC	Derek Halden Consultancy Limited
DSC	David Simmonds Consultancy Limited
EPSRC	Engineering and Physical Sciences Research Council
GBF	Green Bus Fund
GHG	greenhouse gases
HGV	heavy goods vehicle
iBUS	TfL Automatic Vehicle Location system
LCEB	Low Carbon Emission Bus
MLTB	Millbrook London Transport Bus (drive cycle)
Mt	megatonne (one million metric tonnes)
NO_x	oxides of nitrogen
NTS	National Travel Survey
PM	particulate matter
PSV	Public service vehicle
PTE	Passenger Transport Executive
PTEG	Passenger Transport Executives Group
RTPI	real time passenger information
SPT	Strathclyde Partnership for Transport
TfL	Transport for London

Abbreviation	Meaning
TSGB	Transport Statistics GB
TTR	Transport & Travel Research Ltd
WebTAG	DfT web-based Transport Appraisal Guidance

1 INTRODUCTION

1.1 Background

1.1.1 This Report has been prepared by David Simmonds Consultancy Ltd (DSC) for Greener Journeys. It has been carried out in parallel with (and independently of) a study on the economic value of the bus being carried out by the University of Leeds Institute for Transport Studies.

1.2 Greener Journeys' requirements

1.2.1 Greener Journeys is seeking to improve its evidence base regarding the environmental benefits of increasing bus travel, and of the economic value of those benefits. This particular piece of work has attempted, using existing sources, to consider the degree and the value of improvement that can be expected from attracting more people to use buses under different circumstances.

1.2.2 The analysis considers the scope for change, the potential impacts of change and includes a brief exploration of the mechanisms that will deliver the required changes.

1.2.3 The analysis of different circumstances needs to include consideration of what people would have done if they were not attracted to bus travel. This is important, because running buses itself involves producing emissions; however, if the bus services can be used to attract people from driving cars on congested roads into using buses without increasing the bus operations, the effect is both to eliminate the emissions from the car trips that are no longer made **and to** reduce congestion; by allowing traffic to flow more freely, this will reduce emissions from the remaining cars and from other road vehicles.

1.2.4 The environmental value of the bus must of course be considered in conjunction with its economic and its social value. Decisions about bus investment and operation will often involve trade-offs between these – the greenest option might have highly undesirable economic and social consequences. We recognize the importance of these trade-offs, but resolving them is outside the scope of this Report.

1.3 Approach to the study

1.3.1 The contribution of increased bus use to the protection of the environment depends on estimating what the additional bus users would have done if they hadn't travelled by bus – as already mentioned, the implications are very different depending how many of the additional bus passengers would have travelled by car and how many would have walked or stayed at home. This is partly within the control of bus operators who can develop business plans to grow their greenest markets and manage decline in their least sustainable markets – which are also often the least profitable parts of their operations.

1.3.2 Both the alternative to bus use and the implications of changes in travel behaviour will differ according to the type of journey and the circumstances in which it is made. If the shift to bus occurs in an area with major road congestion problems, the reductions in emissions from reduced car use will be higher than in an uncongested area.

1.3.3 Our approach has therefore involved thinking about three sets of linkages, as illustrated in Figure 1:

- first, how will increases in bus use, resulting from increased investment in buses, bus facilities, etc, affect other aspects of travel behaviour – how many people will switch from car travel, in particular?
- secondly, how those changes will affect the vehicle operations on the road which produce emissions – what will be the associated changes in bus operation (eg additional miles, additional boarding time) and the impacts on traffic congestion (ie the effects of fewer car trips and/or more/slower buses on the roads), etc;
- thirdly, how will those changes in vehicle operation (including changes in traffic congestion) impact on emissions and other aspects of the environment, and what values can be put on those impacts?

1.3.4 Our analysis is presented in the following three chapters in terms of

- the scope for greener operation of the existing (or any) bus fleet;
- the scope for greener buses;
- the potential impacts of changes in bus services and their use on the use of other modes and the resulting emissions from other modes of transport.

1.3.5 Our proposal was to look at the travel effects of bus investment, and hence at the impacts on vehicle operation and emissions, in terms of a small number (about half a dozen) "typical bus corridors". Following discussion with Greener Journeys, the list of corridors was defined as follows:

- an urban corridor within a large town or small city (eg Cambridge - large enough to have its own urban services rather than being served wholly by stops on inter-urban routes);
- two contrasting corridors in a medium-sized city (eg Leicester);
- three contrasting corridors within in a large city or conurbation (eg West Midlands or Greater Manchester).

1.3.6 The corridor analysis is described in Appendix B. In the event it became clear that in many respects, answers to the questions we were addressing could be identified without the need to look in detail at example corridors the corridor analysis confirms some of the points made in the text, but the details of the corridor examples are not central to the conclusions.

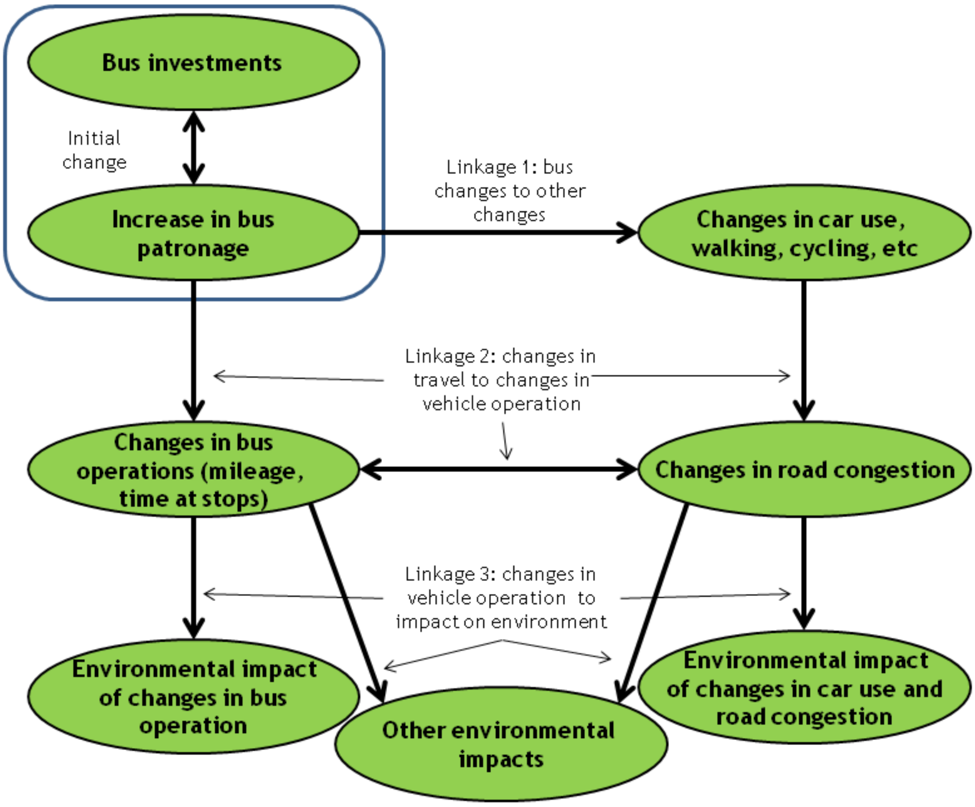

Figure 1 Linkages from bus investment and increased bus travel to environment

1.4 Report structure

1.4.1 The Report is structured as follows.

1.4.2 Chapter 2 summarises the UK Government's targets for reducing carbon emissions, and some of the related policies and interventions relevant to buses.

1.4.3 Chapter 3 considers the scope for greener operation of existing bus fleets ("greener" being taken, here, to mean "emitting less carbon dioxide").

1.4.4 Chapter 4 considers the trends in the bus fleet and the scope for greener buses.

1.4.5 Chapter 5 onsiders the impacts of bus travel and operations, and of changes in these, on emissions from other modes of transport.

1.4.6 Chapter 6 looks at the impact of investing in better bus service provision in different contexts.

1.4.7 Chapter 7 offers some conclusions.

1.5 Acknowledgements

1.5.1 We are grateful to Greener Journeys for the opportunity to prepare this report, and in particular to Katie Allister, Senior Policy Advisor, for her help and encouragement.

1.5.2 We would like to thank all of the following for information, comment and discussion:

- Pedro Abrantes, PTEG;
- Rebecca Fuller, PTEG;
- Professor Nick Hounsell, University of Southampton;
- Tom Parker, TTR;
- Claire Haigh (Greener Journeys) and members of the Greener Journeys Steering Group, particularly for their contributions at and after the meeting on 29 May 2012.

1.5.3 The DSC team remains responsible for all errors of commission, omission or interpretation.

2 THE UK GOVERNMENT'S TARGETS

2.1 Introduction

2.1.1 In this Chapter we consider the policy context – the UK Government's overall target for reducing greenhouse gas emissions, and how this influences government policy towards buses and bus services.

2.2 Overall targets

2.2.1 The UK target for reducing greenhouse gas emissions is summarised in the Executive Summary to the Carbon Plan 2011[1] as follows:

> *"The Climate Change Act established a legally binding target to reduce the UK's greenhouse gas emissions by at least 80% below base year levels by 2050, to be achieved through action at home and abroad. To drive progress and set the UK on a pathway towards this target, the Act introduced a system of carbon budgets which provide legally binding limits on the amount of emissions that may be produced in successive five-year periods, beginning in 2008. The first three carbon budgets were set in law in May 2009 and require emissions to be reduced by at least 34% below base year levels in 2020."*

2.2.2 This report is concerned with the potential for investment in bus services to contribute to that 34% reduction (from 1990 levels) by 2020.

2.3 Carbon Plan 2011

2.3.1 The Carbon Plan 2011, already referenced above, is the most recent statement of how the government intends to reach those targets. The transport chapter of the Carbon Plan 2011reports [Chart 13, p47] that in 2009,

- transport accounted for 24% of emissions (137 $MtCO_2e$, – roughly the same as in 1990, according to paragraph 2.75)
- buses accounted for 4% of those [and hence just under 1% of total emissions].

2.3.2 The only further explicit reference to buses in the Carbon Plan 2011 is a mention of the Green Bus Fund (2.102), which is considered further below. Apart from this, buses are simply included in "local sustainable travel", along with cycling and

1 http://www.decc.gov.uk/en/content/cms/emissions/carbon_budgets/carbon_budgets.aspx

walking (2.101): "sustainable travel measures, such as encouraging the use of local public transport, cycling or walking, will enable people to make lower carbon travel choices". There is no comment on the difference between a bus and a cyclist or pedestrian.

2.3.3 It could be assumed that emissions from buses are considered too small to matter in this context – but there is a specific section in the Carbon Plan 2011 on rail, which accounts for an even smaller proportion (3% rather than 4%). It therefore seems more appropriate to assume that Government does not see GHG emissions from buses as a major problem, but rather as part of the solution, although the logic for this position is not set out in the Carbon Plan 2011, and is not immediately evident from the Government's own figures on emissions per passenger kilometre considered in section 2.6 below.

2.4 Green light for better buses

2.4.1 The Government's March 2012 paper "Green light for better buses", an offshoot of the 2011 White Paper "Creating Growth, Cutting Carbon: Making Local Sustainable Transport Happen", does not set any particular targets for reducing carbon emissions from buses.

2.4.2 The interventions mentioned in "Green light for better buses" include further funding for "Better Bus Areas" which are intended "to promote passenger growth through collaboration between bus companies and local councils". The kinds of measures being pursued with BBA funding are illustrated in the example in the Green Light paper:

> *"South Yorkshire PTE will be making a number of improvements to tempt people onto buses and then keep them there. This will include improved road layouts, bus stops with real-time information about when the next bus is due, better bus shelters, measures to reduce waiting times at traffic lights and smarter tickets that can be used on more than one company's buses."*

2.4.3 Although none of these measures are directly or uniquely linked to GHG emissions in the way that the Green Bus Fund is (see below), all of these are relevant to the processes by which the bus can contribute to achieving GHG reductions, as will be discussed later.

2.5 Green Bus Fund

2.5.1 The main intervention directly addressing carbon emissions from buses, the Green Buses Fund (GBF), provides a subsidy for the purchase of low-carbon emission buses. There are two separate schemes, one in England and one in Scotland.

2.5.2 The GBF is not intended as an ongoing subsidy, but as an intervention to help establish a viable commercial market for low-carbon emissions buses in which, ideally, they would become the standard form of new buses in the UK, at least for urban bus operations. This would involve

- on the supply side, the sales of such buses reaching levels where economies of scale in production are comparable with those for conventionally-powered buses; and
- on the demand side, sufficient numbers of operators achieving savings in fuel costs from the use of more efficient buses, such that they are willing to pay more to purchase them
- the decrease in prices demanded by builders meeting the increase in prices that operators are willing to pay, so that the purchase of low-carbon emissions buses can be become routine without government subsidy.

2.5.3 The context is of course changing: as fuel prices rise, technologies offering better fuel efficiency (or the use of cheaper fuels) become more attractive.

2.5.4 The Green Bus Fund, and progress towards a self-sustaining market in low-carbon buses, are discussed further below – see chapter 4.

2.6 Buses in present Government guidance on GHG emissions

2.6.1 One of the issues raised in discussion of the plans for this project is that published Government figures do not actually show buses as particularly "green". For example, the DEFRA guidelines on calculating emissions show total direct GHG emissions of

- 0.18588 Kg CO_2e per passenger Km for non-London bus travel,

which is comparable with, for example

- 0.18110 Kg CO_2e per vehicle Km for use of an "upper medium" diesel car. (The overall average for a car of unspecified fuel is 0.20459 Kg CO_2e per vehicle Km.)

2.6.2 (For completeness, other relevant figures in the same dataset are

- 0.08630 Kg CO_2e per passenger Km for London bus travel
- 0.14877 Kg CO_2e per passenger Km for average bus travel, London and non-London
- 0.03064 Kg CO_2e per passenger Km for coach travel[2].)

2.6.3 These averages are presumably correct in the sense that if multiplied by total passenger-Km or vehicle-Km they would account for total emissions. They are however misleading if used to inform choices whether for individual journeys or for company travel policies. This has been highlighted by other commentators, eg Goodwin (2011). A firm's "reported" CO_2 emissions will fall if its staff switch from using buses (outside London) to "upper medium" diesel cars, and even more

[2] The coach figure is referenced by DEFRA as taken from data published by National Express. The other figures are attributed to DfT analysis from administration of BSOG.

so if they switch to smaller cars. These figures are of course a nonsense for a marginal change: if one bus passenger decides to make one journey by driving her car rather than using the bus, the emissions from the bus are only minutely reduced, but the emissions from the car are entirely additional.

2.6.4 Bus operations face the problem that buses are large and heavy [and heavier than they might be because of requirements to improve physical accessibility and to reduce emissions affecting local air quality], and hence necessarily use large amounts of fuel per Km travelled. Perhaps most importantly, their average load is currently low, at about 10 passengers per bus[3]. Much higher loadings are needed for buses to become a green mode. The typical bus could readily carry twice as many people with modest effect on its fuel consumption and the resulting emissions[4].

2.6.5 There seems to be a case for pressing Government to issue distinct guidance for marginal choices which would make it clear that for individual journeys, the immediate impact on the bus emissions is much less than the average. This is already implicit in the Carbon Plan's view that buses are part of the supply of "local sustainable travel", as mentioned above.

2.6.6 At the same time there is a growing need for the bus industry to demonstrate its green credentials with better information on the carbon footprint of each individual bus service. This could be achieved through better management of information about bus operations and emissions – perhaps a condition of registering public bus services should be that the carbon footprint of the individual services should be stated based on the bus fleet to be used to deliver the service.

2.6.7 It must also be recognized that bus service provision is sensitive to demand, so in the medium term (possibly months rather than years) any significant pattern of increase in bus use may well be translated, by managers' (or competitors') decisions, into an increase in bus service provision with a consequent increase in emissions. For the present project, it is important to keep this effect in mind – and hopefully to establish the circumstances where a virtuous cycle of improving bus provision and increasing bus patronage could be achieved whilst still, in less direct ways, contributing to reducing emissions **and** contributing to the other economic and social objectives of better local public transport.

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[3] see Appendix A, section A.1

[4] The impact of an additional passenger on bus emissions will be due to the very slight increase in the gross laden mass of the bus, plus the effect of an additional stop (see section A.6) if the marginal passenger boards or alights at a stop which the bus could otherwise pass without stopping. If a bus is initially carrying very few passengers, it is quite likely that an additional passenger will require at least one additional stop per journey (typically to pick him/her up on the way to the town/city centre, and to drop him/her on the way back). The higher the initial loading on the bus, the less likely it is that an additional stop will be needed.

2.7 Overview

2.7.1 To summarise:

- buses account for a very small part of UK GHG emissions;
- there are no specific targets for reducing their emissions, though the three rounds of the Green Bus Fund are evidence of a government desire to achieve such reductions;
- government clearly sees the bus as part of the solution rather than part of the problem.

2.7.2 We note in passing that, coincidentally or otherwise, **if** the whole bus fleet was to be replaced by 2020 so as to meet Green Bus Fund (Low Carbon Emission Buses) standards, **if** nothing else changed, and **if** the reduced emissions from LCEBs applied uniformly to all bus routes, then the bus industry would be very close to achieving a one-third reduction in GHG emissions in line with the overall target for the UK as a whole.

3 GREENER OPERATION OF EXISTING BUSES

3.1 Introduction

3.1.1 This Chapter is concerned with what can be done to reduce emissions from operations using the existing bus fleet. (The following chapter considers changes in the fleet, and the chapter after that considers the impacts of bus improvements on emissions from other modes.)

3.1.2 It needs to be kept in mind that the need for greener operation is being considered in a context where the mandatory standards for new engines, intended to improve local air quality, have tended to reduce fuel efficiency and to increase GHG emissions.

3.2 Traffic management

3.2.1 Most of the analysis of buses' fuel consumption and emissions is based on fixed profiles of speed against time (and hence of acceleration and deceleration, and of idling). For example, certification of bus designs as Low Carbon Emissions Buses for Green Bus Fund approval is done using a profile based on detailed recording of the operation of one bus making one journey on one particular route.

3.2.2 The potential benefits of reducing the amount of idling time in the working cycle, either by eliminating delays at the worst intersections or by switching off the engine at stops and termini, are discussed below (section 3.5). What is rather curious is that there does not seem to have been any similar study of the fuel (and emissions) savings that could be achieved by removing the need to accelerate away from stops (or slow movement) at intersections. Given that the speed profile for LCEB certification is very much a stop-go pattern, basic physics would suggest that a high proportion of the fuel used into moving the bus goes into acceleration, and very little (in urban situations) into coasting. This in turn suggests that traffic management measures to reduce the number of times that each bus has to slow, or stop, at junctions or in queues would significantly improve fuel economy[5].

3.2.3 This would also be a benefit for hybrid buses (for explanation of hybrid buses, see section 4.2). In theory, the benefit should be smaller, since hybrids obtain some of the energy for acceleration from regenerative braking; in practice, according to members of the Greener Journeys Steering Group, hybrid's fuel consumption benefits as much or more from cutting out unnecessary stops. In addition, of

[5] see also TTR (2010, page 16) for further references on this

course, such measures should (if well designed) allow faster and more reliable operation of the services, producing benefits to (and revenue from) passengers while reducing costs.

3.2.4 There is of course a risk that any fuel savings from giving priority to buses at intersections etc, may be offset by increased fuel consumption arising from the additional delays to other vehicles. However, if it is possible to design a package of interventions which is sufficiently successful in improving the attractiveness of the bus, then overall the reduction in other traffic should outweight any increase in delays which that traffic experiences from increased priority for buses.

3.2.5 In the absence of any published figures on fuel consumption per stop-go cycle, we have made our own estimates as described in Appendix A, section A.5.

3.2.6 Our estimates suggest that

- an additional halt for a bus which would otherwise be moving at a steady 40Km/h generates about 84g of CO_2, mainly of course from accelerating the bus back to 40Km/h;
- the same halt for a bus which would otherwise be moving at a steady 30Km/h generates about 58g of CO_2.

3.2.7 These figures **exclude** the additional emissions which occur while the bus is stopped and the engine is idling; they are purely the savings which would result from running at a steady speed rather than decelerating to a halt and accelerating again. (Emissions while it is halted are considered in section 3.5 below.)

3.2.8 This suggests that removing one "unnecessary" halt per kilometre could reduce emissions by approximately 5% to 10%, the effect being greater where the bus would otherwise be moving faster. The surveys carried out by TTR (2010), on an admittedly small sample of journeys and routes, show typically one to two traffic-related halts per kilometre, so there are potential delays which could be eliminated, though we recognize that doing so would be a major challenge for traffic managers.

3.2.9 We also recognize that many of the easier opportunities for bus priority have already been adopted, and that future provision for bus priority is more likely to involve additional delays for other vehicles, and resulting increases in their emissions. As already suggested, analysis of each package of interventions will be needed to ensure that the overall enhancement to bus services and the resulting shift from car to bus outweigh any increase in emissions from cars and other non-prioritized vehicles at individual intersections.

3.3 <u>Ticketing, boarding and alighting</u>

3.3.1 In driver-operated bus operations with traditional ticketing (cash fares paid for each single journey), a significant part of the idling time is spent selling tickets to passengers (or waiting while they try to find the right money, etc...). The emissions produced during the stop can be addressed in two ways:

- by switching off the engine, as discussed in section 3.5 below; and/or
- by moving to methods of fare collection and ticketing that don't involve the driver in handling money, and preferably don't involve the driver at all[6].

3.3.2 Speeding up boarding is of course preferable to trying to reduce emissions while passengers are boarding, in that it reduces the delay to the bus and all its passengers, and reduces the tendency to bunching when services are subject to delay, all of which contribute to enhancing the attraction of the bus mode. The fastest boarding (ignoring free, ticketless services) can be achieved with simple passes that only have to be shown to the driver, provided these are sold off-bus and do not require detailed checking by the driver. However, these have limitations, particularly in terms of recording who travels on which bus, and in many circumstances some kind of formal ticketing is necessary. The Government's aims for smart-card based ticketing (see *Green Light for Better Buses,* paragraph 3.19) should achieve significant moves in the right direction.

3.3.3 About one-third of buses in Britain outside London were fitted with ITSO-compliant smart-card readers by March 2011 (see section A.8); all those in London are fitted with non-ITSO-compliant Oyster card readers. It must of course be recognized that it is the use of smart tickets (paid for off-bus) that will indicate real advance and savings in bus, driver and passenger time; we have not found any national statistics on this. Arrangements that avoid even the electronic transaction time required for smart-card reading would of course be even better in terms of boarding time.

3.4 Eco-driving

3.4.1 TTR (2009) estimated, on the basis of experience in HGV fleets, that fuel savings of 5% to 10% could be achieved by training drivers in fuel-efficient driving techniques, assisted by in-cab equipment to inform drivers when they are driving most fuel efficiently.

3.4.2 TTR (2010) mentions one reported exercise in the UK which achieved reductions of up to 12%, and one in Belgium which achieved reductions of up to 30%. Aspects of eco-driving include

- changing gear at the most appropriate speeds;
- gentler acceleration and deceleration;

[6] One curiosity of the New Bus for London project is that the buses will operate with a conductor as well as driver at least "for much of the day". Within Central London passengers will have to buy tickets before boarding, but outside London they will be able to buy tickets on board – but from the driver, not from the conductor. (http://www.tfl.gov.uk/corporate/projectsandschemes/15493.aspx)

- coasting in gear, ie allowing the bus to slow down (without actually braking) in advance of an intersection or stop, rather than maintaining full road speed and then braking more sharply.

3.4.3 The 30% results from Belgium seems rather surprising, and perhaps suggests particularly bad practice before the experiment. Savings of 5% to 10% would seem a more realistic prospect.

3.4.4 Eco-driving is already becoming established as standard practice; it is for example included in the London Buses BTEC training for bus drivers as well as being adopted on an increasingly large scale by all the major bus operators.

3.5 Idling

3.5.1 One particular aspect of eco-driving is the question of when the bus engine should be switched off. Apart from its contribution to GHG emissions, it is also a local air quality problem, especially at bus stations or in streets with multiple bus stops, and in some cases a noise problem for local residents.

3.5.2 The conventional view is in effect that diesel engines should be kept running, and hence that a bus driver will only switch off the engine if he/she has to leave the bus. A report by TTR (2010) for PTEG specifically addressed the question of engine idling, and suggested that this conventional view is not entirely correct, and possibly no more than an "urban myth". They concluded that

> *The largest emissions savings are realised by immediate switch off of engines when the bus comes to a halt. There is no hard evidence to prove that turning off the engine will either damage modern engines or cause reliability issues.*

3.5.3 We understand that there is some ongoing debate about the actual emissions consequences of stopping and restarting a warm engine, with different laboratories coming to different conclusions. It also has to be recognized that the "traditional" view that the engine should be kept running is certainly correct for some, generally older diesel engines which are difficult to restart when warm.

3.5.4 On the basis of their conclusion, and having regard to practicality issues, TTR recommended the following actions:

> *At bus stops, implement a policy to achieve engine switch off after 10 seconds to reduce around 13-17% of total idling emissions (equivalent to about 3-4% of total emissions) OR if this is not feasible to aim for a 30 second cut-off, saving between 1% and 11% of idling emissions (up to 3% of total emissions);*
>
> *At termini implement a policy to achieve engine switch off, estimated at [reducing emissions by] about 2% of PM and 6% of NO_x in total on average for a 40 minute route;*
>
> *Undertake traffic management or implement selective vehicle detection technologies to provide priority to buses at key junctions and target*

specific bus stops. Tackling the three top causes of delay identified along each route in this study would remove 33% of idling emissions (equivalent to 7% of total emissions) and removing the stationary phase of a bus travelling past each average junction is estimated to reduce total emissions by 0.5%.

3.5.5 Adding these figures together (and assuming the emission reductions apply to CO_2 as well as to other pollutants) suggests that a reduction of perhaps 5% could be achieved simply by ensuring that engines are switched off (more or less) whenever possible; and a similar or larger percentage by eliminating idling at the junctions where buses spend most time stationary. The latter point leads into the next section.

3.5.6 The TTR recommendations may conflict with other changes. We were advised at the Greener Journeys Steering Group that with Euro VI engines, restart is the "dirtiest" part of the engine operation cycle, so frequent restarting would undermine the benefits of introducing these cleaner engines. If possible, the engine manufacturers should find ways to reduce the emissions of local pollutants when warm engines are restarted.

3.5.7 We note that this discussion, and these savings, probably do not apply in quite the same way to hybrid buses, where the need for the engine to continue running on a stationary bus must be determined by whether there is a need to recharge the batteries at any particular moment. There is then the question of whether the diesel engine on a hybrid bus will switch itself off, or continue to idle, when not actually needed.

3.5.8 The bus industry can perhaps take some comfort from the fact that it is doing better in this respect than the rail industry, where it was reported that in the most common class of freight locomotives, the engines are idling for 84% of the time that they are running (Haigh, 2012).

3.6 Bus stop spacing and positioning

3.6.1 In some cases there may be scope to review and revise the spacing of bus stops. Reducing the number of stops has the advantages of speeding up the bus, reducing very short journeys by bus which can be made better by zero emission active travel and improving the fuel efficiency of buses through not needing to stop more often.

3.6.2 Given that bus stop locations have generally developed over many years, are often highly constrained by a mixture of traffic and road safety considerations, and that any attempts to move them can be locally controversial, this scope is extremely limited; in addition, of course, a general reduction in the number of stops would increase the average walk to a bus stop and would undermine the social value of the bus in providing transport for those who cannot walk very far. There are however local exceptions where pairs of stops are located very close together for no detectable current reason, and one of them could apparently be abolished cutting out one unnecessary stop on some journeys.

3.6.3 One specific suggestion, from a member of the Greener Journeys Steering Group, is to consider re-positioning to avoid buses having to stop twice at an intersection and then at a bus stop. Stops are often located just downstream of intersections[7]; relocating them upstream of signalised intersections, with bus-signal communications[8] allowing the bus a clean getaway, would be preferable. Rouen (France) was mentioned as a particular example of a city which has adopted this approach.

3.7 Overview

3.7.1 To summarise: there appear to be considerable opportunities for making bus operations greener mainly through

- traffic management measures to reduce the number of times that buses have to stop and restart other than at bus stops;
- changes in ticketing to reduce boarding times;
- eco-driving, possibly including switching off idling engines whenever practical.

3.7.2 We note in passing that the kinds of interventions which the government is promoting under "Green light for better buses" (see 2.4.2 above) together with operators' own initiatives cover most of this range, though a potential bottleneck is that progress with traffic management measures to prioritise buses depend on local authorities, who have to make the difficult practical decisions about allocating and controlling the use of road space.

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7 See for example the Bus Stop Design Guide for Northern Ireland, section 3.

8 For a discussion of the issues involved in this, see the Bus Priority page on the SCOOT website (http://www.scoot-utc.com/BusPriority.php)

4 GREENER BUSES

4.1 Introduction

4.1.1 This chapter is concerned with the scope to reduce GHG emissions from buses through the introduction of greener buses.

4.1.2 Progress in the introduction of greener buses in the UK has to date been very closely linked with two policy initiatives: the Green Bus Funds operated by DfT for England and by the Scottish Government, and the moves by TfL to introduce low-carbon buses on franchised routes within London.

4.2 Hybrid buses

4.2.1 Much of this chapter is about the take-up and economics of "hybrid buses", or more specifically "diesel-electric hybrid buses". These are buses with batteries and electric motor(s)/generators as well as a diesel engine. They come in two main forms:

- **parallel hybrids**, where the bus is at different times propelled either by the diesel engine via a gear box (like a conventional diesel bus), or by the electric motor using battery power;
- **series hybrids**, where there is no direct link between the engine and wheels; the bus is propelled at all times by the electric motor using battery power, and the diesel engine is used only to drive the generator which recharges the battery.

4.2.2 In each case, the ability to apply regenerative braking, ie using the energy of the moving bus to recharge the batteries, is an important aspect of the overall energy efficiency of the bus[9]. The New Bus for London is one example of a hybrid[10]. The differences between parallel and series technologies have a wide range of implications; for example, in a series hybrid, where the diesel engine never drives the bus directly but only recharges the batteries, the recharging can generally be done by running the diesel engine at optimum output, irrespective of the road speed; the engine itself can be much smaller (about a quarter of the standard capacity); and in addition to taking up less space allows more flexibility in design

[9] For more general discussion about hybrids, see for example the article in http://www.theengineer.co.uk/urban-legend-hybrid-bus-technology/1006276.article

[10] http://www.tfl.gov.uk/corporate/projectsandschemes/15493.aspx

because it does not have to be close to the driven wheels. On the other hand, a series hybrid is dependent on the diesel engine, batteries, electric motor and control system all working all the time, whereas a parallel hybrid can in theory default to operating as a conventional diesel bus if necessary.

4.2.3 Numerous variations have been developed or are under consideration or testing, both in terms of different arrangements or combinations of electrical and mechanical components, and alternative sources of on-board power including hydrogen, compressed natural gas and petrol (gasoline) engines. One significantly different category is that of **plug-in hybrids**, which are any of the above with the facility to recharge the batteries by plugging the bus into an appropriate mains electricity supply.

4.3 Green Bus Fund and Low Carbon Emission Buses

4.3.1 The Green Bus Fund subsidises the purchase of Low Carbon Emission Buses. These are defined as buses able to achieve a 30% reduction in GHG Emissions compared to the average Euro III diesel bus of the same total passenger capacity[11]. This reduction is measured on a specific speed-time profile known as the Millbrook London Transport Bus (MLTB) Drive-Cycle which

> *...was specifically developed for use with buses and was derived from data logged from a bus in service within inner London. The drive cycle consists of two phases, a medium speed "Outer London" phase simulating a journey from Brixton Station to Trafalgar Square and a low speed "Inner London" phase simulating a journey from Trafalgar Square to the end of Oxford Street. The cycle is composed of two phases: (1) Outer London Phase, nominal distance 6.45 km, 1,380 seconds in duration; (2) Inner London Phase, nominal distance 2.47 km, 901 seconds duration.* [12]

4.3.2 There is some uncertainty about how much LCEBs contribute to reducing local air pollution[13]. LCEBs should by definition consume at least 30% less fuel in urban conditions, so one would expect reductions in air-quality related emissions (PM and NO_x) as well as in GHGs. However neither DfT nor the manufacturers appear to claim local air quality benefits for diesel-electric hybrid LCEBs, which are the most common LCEBs in the UK; neither does the Low Carbon Vehicle Partnership[14]. This would be surprising if they really did offer any significant reduction in those emissions.

[11] http://assets.dft.gov.uk/publications/certification-of-a-low-carbon-emission-bus/certification.pdf

[12] Source: Department for Transport, LCEB Accreditation Guidelines, 18 February 2011, Appendix 1. Note that what are here called "Outer" and "Inner" London are in general transport planning terminology "Inner" and "Central" London.

[13] We understand that a lot of primary and secondary evidence is due to be published in an EU CIVITAS report later in 2012.

[14] There is a useful summary of information about LCEBs at http://www.lowcvp.org.uk/lceb/

4.3.3 The few available statistics are complicated by the fact that the environmental performance of LCEBs is generally measured relative to Euro III or Euro IV, and some of the gains could equally well be obtained by introducing conventionally-powered buses to Euro V or Euro VI standard; indeed some of the advantage of LCEBs may be because their diesel engines meet those newer standards, not because they are hybrids.

4.4 Green Bus Fund: progress

4.4.1 The English GBF has to date assisted the purchase of some 952 buses (see section A.6) in three rounds over four years. Turnover in the bus fleet is estimated as typically 5.5% pa (TTR, in PTEG report[15]). The licensed PSV fleet in England includes about 39,000 buses[16], so the turnover is typically about 2,100 buses per year. This indicates that the LCEBs supported by the GBF represent possibly 1 in 9 of the new buses entering the fleet during that period –or a very slightly higher proportion of the new buses starting operation on public local bus services, since not all buses are used on these. In late 2011, the TfL fleet included 133 hybrids in operation, with a further 184 on order; only about 1 in 15 of the new buses TfL was planning to introduce in 2012-13 were expected to be hybrids[17].

4.4.2 It is not clear how many LCEBs have been purchased outside the GBF and TfL's London initiative – as far as we know, virtually none in England. It has also been pointed out (Millar, 2012) that there are no LCEBs in operation in Wales or Northern Ireland, where no GBF has been offered. The Government's decision to proceed with Round 3 suggests that there is still a long way to go before a commercially sustainable market in LCEBs is established in the UK. The only sign of commercial progress is anecdotal evidence that more operators entering TfL franchised contracts are bringing with them their own hybrids, which suggest that operators are starting to purchase them on their own accord (but in the light of TfL requirements and criteria, which have been based for some years on a policy of seeking to move to LCEBs).

4.4.3 There is also on-going debate about whether the diesel-electric hybrids that have dominated the purchases assisted by GBF are in fact a good choice of technology – with proponents of gas-powered buses, for example, arguing that these are better established in overseas markets, much simpler and more reliable, and avoid issues of battery life and disposal.

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[15] This is a somewhat slower turnover than that implies in CfIT (undated, p48/98) which gives the economic life of a bus as of 7-16 years – probably based on data from circa 2002.

[16] http://www.dft.gov.uk/statistics/tables/bus0602/

[17] http://mqt.london.gov.uk/mqt/public/question.do?id=38178. The TfL figures include some buses supported by GBF, so the two sets of figures should not be added together.

4.4.4 The 21 bio-gas buses ordered by Arriva with support from the 2012 Green Bus Fund round are reported to be "the first significant gas bus orders in the UK" (Dark, 2012). The general view of UK operators seems to be similar that of one Greener Journeys Steering Group member who reported that

> *in the UK the case for LPG/CNG buses has, to date, not been proven. This is due to various factors including the need for additional parallel fuelling infrastructure, additional capital cost, additional maintenance cost including specialist equipment and training, reduced fuel consumption, poor reliability and component life, relative inflexibility of use. Note however that at least one manufacturer has now decided re-enter this market.*

4.4.5 The fact that the GBF supports the purchase of buses but not, we understand, associated infrastructure such as fuel storage and refuelling equipment, probably creates a bias in favour of buses using conventional fuel. TfL have however been testing hydrogen-powered buses, including a technology using a hydrogen fuel cell and energy storage system, which should give zero emissions (apart from some water vapous) in operation and a greater reduction in overall CO_2 emissions than diesel-electric hybrids[18]. A small fleet of fuel cell buses is reported to be in operation on a Central London route. However, each of these technologies has involved building new refuelling facilities, which illustrates their cost disadvantage for the regular commercial operator.

4.4.6 Plans to introduce a fleet of hydrogen buses in Aberdeen have recently been announced, but this again is funded mainly by government, with over 50% of the cost coming from the European Union and Aberdeen City Council[19].

4.4.7 New developments in flywheel technology could offer an alternative to batteries as a means of regenerative braking, which is important to improving the energy and environmental performance of urban buses. It was reported in April 2012 that flywheel trials on operational buses were starting in London.

4.5 Economics of hybrid buses

4.5.1 We noted earlier that the Green Bus Fund is intended to kick-start a self-sustaining commercial market in low carbon emissions buses (LCEBs), not to provide indefinite subsidies. The potential costs and benefits of hybrid buses (to date the most common form of LCEB) were analysed by Emes et al (2009). They concluded that the life-time value[20] of the expected fuel saving from using a hybrid

[18] http://www.lowcvp.org.uk/assets/presentations/Transport%20for%20London%20-%20Finn%20Coyle.pdf

[19] http://www.lowcvp.org.uk/lceb/monitoring/details.asp?id=55

[20] Note that we understand that this estimate of the saving excludes the incentive for LCEB operation through the additional BSOG for LCEB fuel. This payment, currently 6p/Km, was introduced on 1 April 2009, only a few weeks before the Emes et al paper was presented.

rather than a conventional bus is of the order of £60,000 to £70,000, whilst the premium for purchasing the hybrid is around double that. This implies that – if there are no other variables at work - the English or the Scottish Government would need to pay a subsidy of around £60,000 to £70,000 to persuade operators to choose hybrids rather than conventional diesels. This is the approximate level of subsidy being paid in the latest round of the Green Bus Fund. This suggests that operators are not yet convinced of the other claimed benefits of hybrid buses.

4.5.2 Emes et al (2009) also quote an EU estimate, based on carbon prices, of £10,000 for the life-time value of the reduction in carbon emissions which should be achieved by the introduction of a hybrid rather than a conventional diesel bus. This tends to confirm the logic of the government view that the GBF is a pump-priming exercise, not an ongoing subsidy: even in a better economic climate it would not make sense to pay around £70,000 in subsidy to achieve benefits worth only around £10,000.

4.5.3 DfT's own analysis[21] is rather more positive, estimating the value of the fuel savings (resource cost and fuel duty) to the operator at around £114,000 over a 15 year bus life, plus a further £30,000 in the incentives paid to operators, giving a total advantage over a conventional diesel bus of over £140,000. This is double the Emes et al figure quoted above, the differences being that the DfT analysis is more recent, is in current rather than includes subsidies, and uses up to date and higher fuel price forecasts which are likely to be significantly higher than those used the 2009 paper, leading to greater savings now.

4.5.4 The figures in the preceding paragraph are for single-decker buses and discount future benefits at 3.5% per year. The additional cost of a single-decker LCEB, again compared to a conventional diesel bus, is over £110,000; this still leaves a net savings to the operator, but the pay-back period is around 10 years, which DfT recognizes as unattractive to the operator. With subsidy from the GBF, however, the average premium paid by the operators (in the 2012 GBF 3 round) was £24k for single decker buses, implying a pay-back period of around 3 years, which is commercially very attractive. For double-deckers, the fuel savings are greater (DfT assumes 35% fuel savings for double-deckers compared with 30% for single-deckers), whilst the premium on the purchase price is the same or (in the latest round) less than for single deckers. (The same £110,000 premium was separately quoted in 2010 by TfL[22], for both single and double deckers.)

4.5.5 These figures explain why there has been little interest from operators in purchasing hybrid buses without either the subsidy from GBF or incentives/pressure from TfL's franchising regime, and equally why there is considerable enthusiasm for purchasing such buses with GBF support. It also suggests that operators ought, on the DfT analysis, to be willing to purchase

[21] unpublished figures supplied by DfT for this project

[22] http://www.tfl.gov.uk/assets/downloads/corporate/Item07-Hybrid-Buses-STP-30-june-2010.pdf

hybrids with lower levels of support than those that GBF has provided, given the benefits on offer.

4.5.6 It is somewhat less clear whether progress is being made towards a situation in which operators would choose to buy hybrid buses without GBF support or other incentives. For this to happen, the premium would need to fall significantly, or the fuel price and hence the value of the fuel saving would need to increase. DfT's analysis of the submissions for GBF support suggest that the premium for hybrid double-deckers has fallen slightly from 2009 to 2012, whilst that for hybrid single-deckers has marginally risen. (The operator view expressed at the Greener Journeys Steering Group is that the premium has gone up.)

4.5.7 One group of factors which appear not to feature in DfT's analysis are the uncertainties about the reliability of hybrids (which are inherently more complex than conventional diesels), about the life expectancy of the batteries and the ultimate costs of battery disposal. Tfl reported in 2010 that reliability varied across the manufacturers who had supplied hybrids for use in London, but that it was continuing to improve as a result of modifications and upgrading.)An indication of the progress that has been made is that hybrids are now tested on a drive cycle observed in operation of a conventional bus; in 1996-97, when early hybrids were being tested, they were unable to complete standard test cycles (Martin and Smith, 2003, p36).)

4.5.8 Uncertainty about the future demand for hybrids may also be discouraging manufacturers from taking steps that would reduce the premium.

4.5.9 At present it would appear to us that continuing take-up of LCEBs, and certainly of hybrids, will depend on further support from government. A commitment to further rounds of GBF for a number of years might give greater confidence to both manufacturers and operators, and would allow time for evidence to emerge regarding the reliability of hybrids and their batteries after longer periods in service.

4.5.10 This needs to be seen in a context where the present value of the carbon savings achieved by introducing an LCEB single-decker rather than a conventional single-decker is estimated by DfT at around £16,000. (Their figures imply that the equivalent present value for double-deckers, given the greater fuel savings, is around £19,000-£20,000.) Whilst this is nearly double the value estimated by Emes et al (partly because the DfT values are in 2011 £ whilst Emes' are presumably in 2008 or earlier £), it is still a long way short of the subsidy per bus being paid under GBF. The potential benefits of hybrid buses for local air quality could be added to this. The level of subsidy appears reasonable in relation to the GBF's intended function as a pump priming exercise both for the bus operating industry and for the bus manufacturing industry.

4.6 Scenarios for bus fleet change

4.6.1 The subject of this section was examined in detail by TTR for PTEG in 2009. Their key conclusions for the fleets considered (those in the PTE areas, plus SPT) were that

- whilst "the most modern conventional diesel buses are hard to beat for reducing pollutants", they "will not reduce greenhouse gas (GHG) emissions" - "the key to high levels of GHG emission reduction is high blend and gaseous biofuel and/or diesel-electric hybrid buses";
- "the most effective way to green PTE/SPT area bus fleets, in terms of absolute costs and emission reduction, is a planned approach with high-blend biofuel and/or hybrid vehicles introduced when the technology is robust and duty rates/BSOG make them commercially attractive, together with a replacement of the oldest diesel buses with their modern low-pollution versions or targeted emission abatement via retrofit technology."

4.6.2 TTR estimated that under the most ambitious scenario (from 2009), GHG emissions circa 2015 could be reduced by about 25%[23]. This scenario involved[24]

- a 16.5% turnover in the bus fleet (about three times the rate observed circa 2009)[25];
- biofuel hybrids becoming feasible and commercially attractive;
- those hybrids using a mixture of biodiesel, bioethanol and biomethane, whilst the remaining conventional diesel fleet[26] was assumed to use biodiesel medium-blend (B20)[27].

4.6.3 It is clearly unrealistic to envisage reaching that situation by 2015, as TTR did in 2009; it would seem more reasonable to regard it as at best a possible achievement by 2020. We note also that this is a little less optimistic than our earlier observation, that moving to a 100% LCEB fleet should achieve at least a 30% reduction.

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[23] page 80. Note that we understand that the calculations for GHG emissions are "life-cycle" figures for the "life cycle" of the fuel, not of the buses themselves.

[24] TTR, 2009, p 76

[25] Note that this would mean almost complete replacement of the bus fleet between the 2009 base year and the 2015 forecast year.

[26] 37% of the 2015 fleet – see TTR page 81

[27] Regarding biodiesel blends, a member of the Greener Journeys Steering Group reported that "The increasing content of biofuel in commercial diesel is causing problems with increased (and more variable) fuel consumption due to its lower (and variable) energy content, and with increasing costs of engine maintenance (in particular fuel injectors)".

4.6.4 The reductions in GHG emissions are only part of the picture; for example, the same "most ambitious" scenario is estimated to achieve a 90% reduction in emissions of particulates from buses. The much faster introduction of new vehicles would also improve the quality of vehicles perceived by passengers (through the general newness of the buses, and specific advantages like smoother, quieter operation of hybrids), which would in turn help to greater patronage and lead to reductions in average emissions per passenger Km.

4.6.5 A report by Air Quality Consultants (2009) included scenarios for take-up of new buses but does not consider carbon implications, only local pollutants. However their Figure 2 implies that of the fleet available in 2020, about half would be buses introduced after 2012 – so by 2020 what are currently the cleanest vehicles could make up half the fleet.

4.6.6 That scenario is roughly in line with the previously quoted TTR estimate of 5.5% replacement per year – a rate of replacement which would imply 44% replacement in an 8 year period.

4.6.7 The implication of this is that by 2020 GHG emissions per bus Km might fall by around 15% if **all** the buses introduced from now on, at typical rates of replacement, were Low Carbon Emissions Buses, ie meeting the standards required for Green Bus Fund support, and if those LCEBs were deployed where they would be most effective in reducing emissions. (As noted earlier, the take-up of LCEBs to date represents only a small proportion of the buses coming into service.)

4.6.8 It has still to be kept in mind that bus emissions are a very small part of total GHG emissions. Emes et al (2009, p6) estimate that moving to an all-hybrid bus fleet in London (by around 2025) would reduce total CO2 emissions in London by 0.6%. This is not to deny the potential value of achieving that reduction, but it does emphasise that reducing emissions from buses, while still providing the bus services themselves as an element in sustainable local travel, can only make a small contribution to achieving the Government's carbon reduction target.

5 IMPACTS ON EMISSIONS FROM OTHER MODES

5.1 Attracting passengers from other modes

5.1.1 The general experience discussed in Appendix C is that better bus provision attracts additional patronage but a relatively small proportion of this is diversion from car travel. The generally low transfers from car to improved bus contrast with the more significant proportions of bus users who belong to car-owning households – though it seems likely that a lot of bus users are individuals who do not have the use of a car at the time of travel, either because another member of their household is using the car for a different journey, or because they are not personally licensed and insured to drive.

5.1.2 There appears to be an asymmetry between the proportions of new passengers that are likely to be attracted from car by improved bus services and the proportions of lost passengers that transfer to car as a result of worsening (or more expensive) bus services. We believe there are two reasons for this:

- surveys of what bus passengers would do if their bus service became unavailable or more expensive tend to focus on the very short-term response: respondents will therefore say how they would get to their current job, to their present place of study, or to a particular appointment (eg doctor, hospital) which they have to attend at the time they are interviewed, which in many cases (typically 20-33%) would be by car. These people have however by definition (they are bus passengers) originally chosen not to use the car, so there must be some reason why they prefer not to use it, eg cost of petrol and/or parking, dislike of driving, inconvenience to another household member who also needs the car. One would therefore expect that many of the people who would initially switch from bus to car would in the slightly longer term make other arrangements, eg by finding a different job, registering with a different doctor, so as not to need to use car (and similarly, some people who would initially switch from bus to other modes, other destinations or not travelling would subsequently acquire cars, or negotiate with other household members to have the use of a car);
- there seems to be a real barrier to attracting car users to bus in that most car users are often unaware of bus services, or assume that the service is inferior to that actually provided; as a result, simply providing better bus services attracts very few of them.

5.1.3 It has been reported (see Appendix C) that targeted marketing can be very effective in winning car users to bus, through the use of incentives to get the (habitual) car users to try improved bus services; once they have tried the bus service there is apparently a good retention rate. This is clearly part of a bigger picture of how the bus industry develops its relationships with its actual and potential customers (see for example recent research by DHC and others on customer relationships in shopper travel in Wigan[28]).

5.1.4 Even where car users are induced to switch their journeys to bus, it may be over-optimistic to assume that emissions from car are correspondingly reduced; for example, it is likely that some of the former car users will have been car passengers rather than car drivers, and that their driver will continue to make his/her trip by car[29].

5.1.5 The environmental benefit of reducing car trips is of course dependent on their emissions – hence the value of attracting them to bus will diminish as cars become greener. (Making cars greener is a major emphasis of the Transport chapter of the 2011 Carbon Plan).

5.1.6 There is some reason to hope that changes in consumer technology will make it easier to attract users to bus. In recent decades, car radios and hands-free car telephones have added to the attraction of travelling by car rather than bus, even if the car is stationary in a traffic jam. Newer technology involving vision as well as sound– smartphones, tablets etc – is incompatible with driving, even if controlled by speech rather than by keyboard. Considerable attention has been given to the ways in which information/communications technology allows business travellers to make more productive use of time spent travelling by train than the same time spent driving, and the contribution that this is thought to be making to the growth in train travel. A similar effect, but perhaps related more to entertainment and social networks, may work to the advantage of buses – people may be happier to travel by bus because they can use the time in ways that they enjoy or find useful.

5.1.7 This may make public transport in general, and buses in particular, more attractive to young adults, whose propensity for learning to drive has decreased in recent years. That is believed to be due mainly to increases in the requirements for passing the driving test and in the cost of insurance for young drivers; but if these people are more content to use buses than the equivalent young adults of the preceding generation, it may possibly "lock in" a continuing willingness to use bus for a proportion of trips, even if most of them do eventually acquire driving licences and cars.

5.1.8 Implications for investment in and around bus services are that

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[28] forthcoming on DHC and Technology Strategy Board websites.

[29] For example, Davison et al (2006) found that in two Quality Bus Corridors they studies, the improvements in one were tending to attract car drivers to use bus, whilst the improvements in the other were tending to attract car passengers to use bus (op cit section 7.3.1.1).

- security is important – people must feel secure while carrying expensive electronic gadgets (including at bus stops) and using them (at least on the bus);
- free, fast, quick-to-access wifi may be influential in persuading these groups to use bus. This is already available on many longer-distance express bus/coach serices. Reliable access to the internet is something where buses, nearly always operating on the surface, have an advantage over urban railways built partly or wholly underground.

5.2 <u>Holding up the traffic?</u>

5.2.1 Car drivers often see buses as "part of the problem" rather than as "part of the solution", because buses stopped for passengers to board or alight often obstruct other traffic. Bus stop designs which allow the bus to pull of the main carriageway and hence minimise delay tend to be unpopular with bus operators because of the likely delay (and resulting fuel use and emissions) waiting for an opportunity to get back into the flow of traffic. Other things being equal, more frequent buses, and/or longer dwell times due to more passengers boarding and alighting (especially if boarding involves buying a ticket), will exacerbate this problem, though much of the ticket-related delay can be eliminated by off-bus ticketing. The resulting increase in congestion from increased bus operation or increased dwell times will result in increased emissions from all the other vehicles involved.

5.2.2 This problem will tend to diminish with the introduction of greener cars and vans (which are likely to make up the majority of the delayed vehicles). The component of emissions from stopped vehicles may be eliminated altogether by vehicles which do not keep the engine idling, and the emissions associated with slowing down and accelerating away again will be reduced by hybrid or all-electric cars with regenerative braking.

5.2.3 Perhaps the most important point is that it is inefficient for a poorly loaded bus to hold up other buses or cars. The key aim must be to ensure that there are more people on the buses. This requires not just supply side measures to modernise bus routes but also demand side measures to market the bus. . Examples such as Streamline in Glasgow (see section C.2, page 51) have been successful since they combine the planning and delivery of new more efficient networks with marketing of bus travel. In such cases, the reduction in car use and associated emissions should ideally outweigh any increases in congestion and emissions caused by increased bus operation and use.

6 WHERE WILL BUS INVESTMENT BE GREENEST?

6.1 Introduction

6.1.1 There are two parts to this question:

- where will investment in buses and bus services do most to reduce emissions from buses themselves?
- where will such investment do most to reduce emissions from other modes – meaning, overwhelmingly, from cars.

6.2 Where best to reduce emissions from buses themselves?

6.2.1 Starting from the existing fleet and service patterns, there appear to be modest but useful quick wins to be achieved from the promotion of eco-driving. Eco-driving in general is a win-win possibility which will save costs for operators whilst reducing emissions; it is already being practised to some extent, so some of the savings are already been achieved. Eco-driving may extend – if the TTR analysis is correct – to switching off engines whenever the bus is likely to remain stationary for more than a few seconds, at least where the engine can be relied on to restart and where this does not undermine the local air quality advantages of Euro VI engines.

6.2.2 Bus priority measures range from simple bus lanes to sophisticated traffic control systems and dedicated busways. These would deliver significant reductions in emissions from buses if they could achieve a major reduction in the number of traffic-related stop-go cycles for buses in urban areas (see section 3.2). They should also, of course, improve the speed and reliability of bus operations, thus contributing to attracting passengers from car as well as benefiting all other bus users and the operators. In many areas, action is needed simply to maintain and improve the present operating speed and reliability, given long-standing trends of worsening conditions[30]. Many authorities have now set targets for improving bus travel journey times within their local transport plans and accessibility plans using the national statistics published by DfT for travel times by bus to local destinations,

[30] For example, Stagecoach Manchester bus operating speeds fell by 14.5% in the 10 years to 2009, according to Stagecoach's own data reported in their evidence to the Transport Committee (www.publications.parliament.uk/pa/cm201011/cmselect/cmtran/473/473we09.htm). They also reported that up to 2009, not one of the 36 Metropolitan Highway Authorities had adopted bus operating speed as an improvement target.

but accessibility targets are fairly recent being introduced as good practice requirements since 2005[31].

6.2.3 Many existing bus priority schemes have been relatively "easy wins" such as designating bus lanes where there is available road space, rather than tackling specific bottlenecks at junctions where the problems for bus operation are most acute. More needs to be done to ensure that local authorities take full account of the social, economic and environmental benefits of bus priority measures in considering proposals which may be more expensive (more sophisticated bus detection and traffic control systems) or more controversial (increasing priority for buses over private cars).

6.2.4 Managing the demand for private vehicle use by congestion pricing or more general road pricing would of course be a very effective contribution to bus priority, but this is off the political agenda for the time being; it has been suggested that new approaches could emerge quickly as part of bundled products for integrated transport (see Halden, 2008). .

6.2.5 Nearly all of the measures which can reduce the emissions from a given network and timetable of bus operations will generally be more effective in urban areas, especially congested ones, than in rural areas. This is because most of the measures hinge upon

- reducing unnecessary stops by buses – which are most frequent in congested urban areas – which produce higher emissions as well as delay;
- reducing emissions while buses are stopped, or during decelerating to and accelerating from stops – which works both on unnecessary stops due to traffic congestion, lack of bus priority, etc, and on commercial stops for passengers to board and alight, which are also more frequent in urban areas.

6.2.6 Policies to increase the take-up of Low Carbon Emissions Buses (LCEBs), such as the successive rounds of the Green Bus Fund, are likely to be the most effective ways of reducing emissions per bus kilometre, since – given the definition of an LCEB – they should reduce bus emissions by at least 30% on urban routes with very frequent stops (ie the kind of route represented by the MLTB cycle used in testing whether buses quality of LCEBs). They may also reduce the emission of other pollutants affecting local air quality. Provided the performance characteristics of LCEBs are similar to those of conventional buses, there should be no significant effect on emissions from other modes. We note however that most LCEBs in service are diesel-electric hybrids, and that unless the prices of hybrid buses fall, or the financial advantages to operators increase (eg through fuel prices rising), hybrids will continue to require subsidy.

[31] http://assets.dft.gov.uk/statistics/series/accessibility/accessibility-statistics-guidance.pdf

6.2.7 We estimated earlier (see paragraph 4.6.7) that if **all** new buses were LCEBs then by 2020 emissions from bus operation would fall by about 15% (other things being equal). The take-up of LCEBs to date is much slower, with only about one-ninth of new buses in England meeting the LCEB standard (see paragraph 4.4.1), despite incentives from GBF and BSOG.

6.3 Where best to reduce emissions from other modes?

6.3.1 The greatest environmental benefit will come from improving loadings on buses where the additional passengers have transferred from less carbon efficient modes. Demand side interventions that encourage people to use existing buses produce very little additional carbon emissions in the bus fleet, but reduce carbon emissions for other modes. Growing the greenest journeys is a virtuous cycle for the bus industry. Bus services have huge potential to be greener and developing and growing bus markets for greener bus journeys will not only help to reduce existing emissions but help to create the investment in a greener bus industry. If the bus journeys that grow fastest are the greenest choices then the buses will develop their credentials as a green mode. Demand side measures have been shown to be effective if they are personalised and targeted at promoting particular journeys (e.g. DHC et al 2011).

6.3.2 We can list the factors favouring a higher transfer from car to bus (basically wherever bus is relatively good and car is relatively bad) as shown in the following table.

Table 6-1 Factors favouring transfer from car to bus

	Bus characteristics favouring higher transfer	**Car characteristics favouring higher transfer**
pre-journey	better information on bus services	lower car ownership
at home end of the journey	short walk to bus stop short wait for bus (frequent **and** reliable service) high quality bus stop (shelter, real-time information, CCTV)	residential car parking difficulties (drivers reluctant to use cars because of difficulty of parking on return)
main part of the journey	relatively fast journey in bus: requires • competitive speed of bus itself • minimal delays for other passengers to board/alight • priority measures or dedicated busways to prevent traffic congestion delaying bus good journey experience: • clean, quiet bus • comfortable seating at least on longer journeys and for those who cannot remain standing.	traffic congestion

	Bus characteristics favouring higher transfer	Car characteristics favouring higher transfer
at destination end of journey	conveniently-located bus stops and high-quality bus stop (or bus station) for return journey	parking difficulties (queues/difficulty finding space, high charges)

6.3.3 The car-related factors that increase the propensity to transfer to bus are essentially urban:

- parking difficulties at home are an essentially urban phenomenon (particularly inner-urban, mainly in Victorian and Edwardian terraces combining high densities with lack of space to keep cars either on or off the road)
- traffic congestion and parking difficulties at the (town/city centre) destination are generally related to town/city size.

6.3.4 The parking issue means that the propensity for transfer to bus is greater for journeys to and from centres rather than between suburbs.

6.3.5 The bus-related factors are also essentially urban –

- bus stops and routes are more closely spaced in urban areas
- urban bus routes offer higher frequencies
- urban buses are more competitive in speed (largely because car speeds are lower).

6.3.6 Higher-quality stops are probably associated more with urban stops (though this shouldn’t necessarily be so on social grounds – information etc arguably more important at isolated stops on low-frequency services?)

6.3.7 Bus stations more significant for small town services and the urban end of rural services – purely urban services often work through town/city centres without using a bus station.

6.3.8 The problem issue for urban bus services is traffic congestion – this is the factor which can undermine any attempt to encourage greater bus use, particularly through its dire effect on service reliability.

6.3.9 The general answer then is that the benefits of bus investment in terms of reducing car emissions are likely to be greatest where directed to improving urban services that are already operating at fairly high frequencies and serving major commuter/business destinations where both road space and car parking are in short supply.

6.4 <u>The value of increasing bus use</u>

6.4.1 The value of investment to increase bus use depends essentially on the proportion of the additional bus passengers who transfer from car. Evidence suggests that for "typical" bus service improvements, only about 5% of the additional passengers transfer from car. In more favourable circumstances, this can rise to around 12%, and possibly higher. At the same time, marketing campaigns aimed at capturing car users in corridors where bus services are particularly good – tackling car travellers' ignorance or misperceptions of the bus service, rather than changing the bus service itself – can attract additional passengers transferring almost entirely from car. (This contrasts with park-and-ride services, which by their nature tend to promote journeys which are at least partly by car.)

6.4.2 The environmental impact of an investment attracting more bus passengers will therefore depend enormously on how the shift is achieved. For example, consider a possible national campaign of improvements which did not significantly change the environmental impact of the bus service itself – for example, improvements in physical provision, information and security at bus stops and bus stations, - uniformly applied across the country. Suppose that this achieved a 10% increase in patronage. On average, if no particular measures were taken to market the improved service to car users , we would expect only 5% of this increase, or 0.5% of the original number of passengers, to transfer from car. Assuming a car occupancy[32] of 1.25, and that for the people who did transfer from car, bus journeys replaced car journeys of equal length, the decrease in car Km driven would equal 4% of the increase in bus passenger Km, or 0.4% of the base bus passenger Km.

6.4.3 Annual travel by bus is about 45 billion passenger Km [see Appendix A, section A.2], so the 10% increase in bus travel with only 5% of the increase coming from car and an allowance for car occupancy would reduce car use about 180 million car Km per year (ie $45*10^9 * 0.1 * 0.05 / 1.25$).

6.4.4 Total annual car (and van) use is around 384 billion car (and van) Km per year, so the reduction in car traffic would amount to slightly less than 0.05% of total car traffic ($180*10^6 / 384*10^9$). Even allowing for the transfer being concentrated in urban corridors where the car emissions per Km are disproportionately high, the contribution of an undifferentiated national campaign towards achieving carbon reduction from car use would be imperceptible.

6.4.5 At the other extreme, supposing that the same 10% increase in total annual bus patronage was achieved by marketing and other measures aimed specifically at getting car passengers onto existing services. In the ideal case all of the 10% additional passengers would transfer from car. Those 10% passengers would represent 4.5 billion passenger Km transferred from car to bus, or a reduction (again assuming 1.25 car occupancy) of around 3.6 billion car Km, or something in the order of 1% of car use. Again one would expect the reduction to be concentrated in urban corridors (where bus services are relatively attractive

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[32] A lower-than-average car occupancy is assumed on the grounds that people travelling alone are more likely to switch to bus.

compared to car), so the impact on emissions from cars might be significantly higher – maybe 2%.

6.4.6 The important thing to note here is that the above calculations assume no change in bus mileage or bus emissions. If the 10% increase in bus use required, or resulted in, a 10% increase in bus Km (with unchanged rates of bus emissions per Km), then in the "untargeted" case emissions would actually increase and in the "car-user-targeted" case the net reduction in emissions would be very much smaller.

6.4.7 All this indicates that to make a worthwhile contribution to reducing CO_2 emissions, measures to increase bus patronage needs to be focussed on

- attracting people from car to bus, and
- to do so without significantly increasing the bus mileage operated.

6.4.8 It needs to be kept in mind that the absolute reduction in GHG emissions that can be achieved by reducing car will tend to decrease as the proportion of hybrid or electric cars in the urban traffic mix increases. This depends critically on the take up of low emission cars (see for example CILT 2011). If Government policy succeeds in reducing the emission rates of cars, then the environmental benefit of removing a given volume of travel from car, in terms of carbon emissions, will be less. If on the other hand a "worst case" scenario prevails where there is very little progress in reducing the emissions rates, but the upward trend in car mileage and road congestion is resumed, then the physical implications of a given reduction in car use would be much the same as at present. The value of any reduction would in addition depend on the price of carbon, which is presumably likely to go up rather than down, and more so if little progress is made towards a generally lower-carbon economy.

6.4.9 In considering the environmental benefit of the reduced car mileage, we noted that

- the average car emits about 0.2 Kg CO_2e per Km driven[33] (DEFRA/DECC, Table 6e);
- WebTAG Unit 3.3.5, para 1.2.3 provides the conversion factor that emissions expressed in tonnes of carbon (Ce) can be converted into CO2e by multiplying by the factor 44/12. So to convert CO_2e to Ce we divide by 44/12, ie divide by 3.667.
- The same WebTAG Unit lists the shadow price of carbon in 2012 as £161.25 per tonne, for the Central scenario and the non-traded sector (ie outside the scope of the emissions trading sectors). The values in the Low and High Scenarios are £80.63 and £241.88 respectively. All these money values are expressed in 2002 prices, which is the current basis for most transport appraisal work.

[33] total direct GHG emissions (ie excluding indirect emissions)

6.4.10 Using this information,

- one million car Km will emit approximately $0.2*10^6$ Kg CO_2e, or 2,000 tonnes CO_2e;
- dividing by the ratio of 3.667, that is equivalent to about 545 tonnes of carbon;
- using the price per tonne of carbon, those emissions would be priced at about £88,000 at the Central scenario prices (£44,000 or £132,000 at the Low or High scenarios respectively).

6.4.11 In the Central scenario, the reduction of 180 million car Km per year that might be expected in the "untargeted" case would be worth £15.8M, and the reduction of 3.6 billion car Km in the "targeted case" would be worth around £317M. In the Low and High carbon price scenarios these figures would be reduced or increased by 50% respectively.

6.4.12 A different perspective is provided by the DfT estimate that the external costs of congestion resulting from car use are on average about 15p/car-Km[34]. This gives rather larger figures of £27M for the traffic reduction in the "untargeted" case, or £540M in the "targeted case". Based on this DfT perspective these figures are additional to GHG savings[35]; although they are not strictly environmental benefits representing mainly the money costs and the value of delay resulting from the use of one car. Regional values for the congestion benefits vary enormously depending on the prevailing levels of congestion and hence the effect that one extra car-Km will have on other vehicles; values in London are more than 10 times the values in Wales. It is important to recognise that the urban areas with the greatest congestion are the locations with the highest existing bus loadings so additional passengers would be more likely to require additional capacity in the bus fleet with less net environmental value than the UK averages.

6.4.13 These figures again highlight two points:

- the environmental value of an increase in bus travel depends greatly on the proportion of the additional bus travellers attracted (or persuaded) from travelling by car, and the resulting reduction in car mileage driven, implying that environmentally-focussed investment in bus services should focus on urban services where bus is most competitive with car;

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[34] DfT responses to Competition Commission report "Local Bus Services Market Investigation: Provisional Decision on Remedies". Undated, but responding to provisional decision published 6 October 2011. http://www.competition-commission.org.uk/assets/competitioncommission/docs/2010/localbus/dft_pdr_response.pdf. The document refers to the WebTAG Unit mentioned in the next note as the source of the 15p/car-Km figure.

[35] This is from paragraph 3.1.1 of WebTAG Unit 3.13.2, which clearly says that reductions in congestion costs and reductions in GHG should be entered separately into Appraisal Summary Tables.

- the environmental values of increasing bus travel are only part of the overall story; apart from the important social issues of bus service , there is an economic value to reducing car use which (in current DfT appraisal methods) is larger than the value placed on the GHG reduction.

6.4.14 It should be noted that assumptions about transport and energy are changing and almost every calculation is sensitive to the local context (CILT, 2011). The overriding recommendation of previous work in this field is that carbon emissions should become a planned variable on a route by route or service by service basis. This allows the local context, competing modes, sources of energy and passenger needs to be included within the planning of greener buses.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 The environmental value of the bus – now and in the future

7.1.1 Of any mode, bus has perhaps the greatest potential for short term environmental improvement. This partly relates to a recent history of under-investment relative to other modes, but also the fact that social rather than environmental sustainability has been the focus of much recent business planning for bus services. There is substantial scope for bus journeys to be greener, and much to do to deliver greener journeys by bus.

7.1.2 The present environmental value of the bus is a mixture, with some parts of the UK bus service providing services of enormous environmental value, and others having (in purely carbon accounting terms) an adverse effect (ie emissions would be reduced by abandoning the service). At the high-performing end, the best-used bus services in the major urban centres may well be reducing carbon emissions by 75% or more compared with the emissions which the present bus passengers would generate from transferring to car use if the bus was abolished. At the low-performing end, there are many other bus services which from a narrow greenhouse gas perspective are a dead loss – if those services were abolished, it would save the emissions resulting from running the bus services, and few if any other emissions would be generated instead.

7.1.3 Planning for sustainable bus services is a complex balance between social need, economic viability, and environmental aims. Environmentally low-performing services – which in effect include a lot of off-peak commercial services as well as subsidised services – are of course extremely important as providing independent mobility for substantial numbers of people, particularly the older, the younger and those who for whatever reason do not have access to other means of transport. There may well be scope to refine how these services are provided, but it would be socially unsustainable to abandon many of these services simply to make a slight reduction in GHG emissions.

7.1.4 The way forward as we see it is that

- increasing the number of passengers per bus has the virtuous circle of increased profits, lower fares, and reduced emissions per passenger, especially if improvements in ticketing reduce the tendency for additional passengers to slow down bus operations. Achieving this virtuous circle requires demand side interventions to influence passenger choices, and supply side measures to replace some poorly-used services with more carbon efficient alternatives such as demand responsive rather than timetables public transport;

- increasing use of LCEBs will make a substantial difference to carbon emissions from the bus fleet – this should deliver a 30% reduction compared with the same use of current conventional buses);
- improvements in driving practice ("eco-driving") should achieve a further improvement, both with conventional vehicles and LCEBs (though the techniques of eco-driving may differ according to the technology in use);
- our analysis indicates, unsurprisingly, that the most urban services are generally likely to offer best scope for investments which will reduce emissions both from the buses themselves and from private cars (by attracting car drivers to become bus passengers).

7.2 Recommendations for maximising the environmental value of the bus

7.2.1 The following paragraphs list the key actions needed to maximise the environmental value of bus services.

7.2.2 For bus operators:

- develop and promote best practice in eco-driving (including further tests on switching off engines whenever buses are stationary);
- continue investment in LCEBs when prices (and subsidies) make it financially attractive;
- market bus services to car users (especially car drivers) where existing bus services can compete with car and have spare capacity, so as to increase average loads and reduce car emissions;
- monitor the success of the bus industry in providing services for younger adults who have chosen not to acquire driving licences – the quality of bus provision may be important in retaining this "captive" market and postponing the age at which they decide to start driving (or dissuading them altogether);
- where spare capacity is not available, use customer relationship management systems to nudge customers towards more lightly loaded services (eg by smoothing out peaks in demand);
- collaborate in well-planned Quality Bus/Better Bus Area initiatives (see below).

7.2.3 For local authorities:

- continue implementation of Quality Bus/Better Bus Area initiatives which improve bus speeds, reliability and patronage (including addressing market failure for technologies that may not be commercially viable but which will contribute to social and environmental goals such as smart ticketing, real-time and other passenger information, etc);

- develop bus priority measures in particular to reduce the need for buses to stop (or nearly stop) in traffic and at junctions. This needs to include both protecting and enhancing the operation of bus services which are already good enough to compete with car travel, and to improve those where traffic delays are one of the barriers which prevent potentially competitive services from achieving their full potential;
- maintain and enforce bus priority measures to ensure that their benefits continue to be delivered;
- seek replacement of poorly loaded inefficient bus services with more efficient routes and modes of operation to deliver a better balance between social, environmental and economic aims, and work with operators to develop viable bus strategies as part of wider transport packages based on achieving growth in bus patronage;
- seek to ensure that land-use planning policies are tailored to allow and encourage efficient service by public transport.

7.2.4 For national governments:

- ensure that advice to consumers (or which may be used by consumers) makes it clear that individuals can reduce their contribution to carbon emissions by choosing to travel by bus rather than by car (technically, this means focussing on marginal rather than average emissions);
- consider whether the figures on passenger transport emissions used in carbon accounting should be revised to show businesses the merits of encouraging or requiring their staff to use public transport where reasonably available (again considering marginal rather than average emissions);
- continue the Green Bus Fund, preferably with a clearly expressed view as to what needs to be achieved to create a UK market in LCEBs which is commercially viable for both manufacturers and operators, and possibly extended to support for investment in off-bus equipment where new fuels or comparable changes are involved;
- consider the feasibility of offering green bus funding for retro-fit, if LCEG or comparable standard can be achieved in that way;
- provide continuing financial support for the Better Bus Areas initiative;
- commission further research on how carbon-efficient buses could be with a combination of eco-driving and better priority measures to reduce the amount of deceleration and acceleration required in traffic.

7.2.5 For the European Commission and bus manufacturers:

- continue to review the consequences of the Euro standards, particularly in terms of the balance between further improvement in local air quality and the need to reduce weight and fuel consumption in order to reduce GHG emissions, bearing in mind that recent changes to standards have tended to concentrate on local effects at the expense of the global impacts.

7.2.6 These actions and combinations of these actions –many of which are already written into existing policy statements – will allow the bus system to reduce its own GHG emissions, to make a useful contribution to reducing GHG emissions from cars, and at the same time support and enhance the social and economic role of the bus.

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[36] undated, but includes references up to at least 2005

[37] http://www.ciltuk.org.uk/pages/newsarticle?23019529-1056-4C22-A500-BA659A607EFC

[38] http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_132.pdf

[39] http://www.theitc.org.uk/docs/6.pdf

[40] http://cser.lboro.ac.uk/papers/S01-11.pdf

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[41] http://www.cleanaccessibletransport.com/Revised/Reports%20for%20publication/CleanBusGuide.pdf

APPENDIX A DATA AND EMISSIONS CALCULATIONS

A.1 Introduction

A.1.1 This Appendix sets out various figures used elsewhere in the report, with the sources from which they have been taken or estimated. These are notes rather than text, except for section A.6 which briefly explains how we have calculated the marginal emissions resulting from forcing a bus to make one additional stop.

A.2 Bus travel, operation and occupancy

A.2.1 Transport Statistics Great Britain (TSGB) provides a total bus and coach travel figure of 45,000,000,000 bus passenger Km. per year in 2010 [Table TSBG0101].

A.2.2 Elsewhere, TSGB [table TRA0101] gives a total bus and coach operations figure of 3.1 billion bus miles = 4.96billion bus Km.

A.2.3 Average bus/coach occupancy is therefore approximately 9 passengers per bus or coach The average for bus travel would be slightly lower when long-distance bus/coach travel is taken out (see below).

A.2.4 This is similar to the figures in AEA (2009), Carbon Independent[42] and CfIT[43].

A.2.5 This figure is of course the average over a wide range of load factors, with very large differences between different types of route, between different times of day and days of the week, and along each route in each direction. Other figures quoted to us during the study include an average of 5 on general tendered services in one of the PTE areas, but 25 on school services in the same area.

A.2.6 Long distance bus travel is thought to have higher occupancy rates. Although no data is regularly published, the European Environment Agency reported load factors in the range 16 to 19 for non-local bus and coach services in the UK between 2004 and 2008[44]. Average coach occupancy on the Bournemouth to London route was found to be 15 and 39 passengers per vehicle, for two different operators (White and Robbins, 2012).

[42] http://www.carbonindependent.org/sources_bus.htm

[43] CfIT (undated) p45/98 quotes 11 pax/bus [para 2.83]

[44] http://www.eea.europa.eu/data-and-maps/figures/long-distance-bus-occupancy-rates

A.3 Bus (and coach) trip length

A.3.1 NTS give 67 bus trips/person/year (NTS0409) totalling 301 miles (NTS0410) giving a national average distance 4.5 miles or 7.2Km. These figures are for local bus only.

A.3.2 Dargay (2010) estimated long-distance travel by coach over the period 2002-6 at about 1 trip per person per year, covering somewhere in or around the range of 118 to 132 miles (ie around 200Km). Long-distance is defined as over 50 miles (80Km) in one direction. This includes all travel by coach, for example on coach trips and holidays, not just on scheduled services.

A.4 Bus:car equivalence in network congestion

A.4.1 The standard unit for measuring traffic (and hence forecasting congestion) given a mix of vehicles using a road is the passenger car unit or pcu. A bus is typically counted as 2.5 or 3 pcus, so if one bus-Km replaces more than 3 car-Km the effect on congestion is likely to be beneficial; this in turn implies that there would probably be some additional carbon savings from decongestion of the remaining car usage.

A.5 Carbon emissions per unit of vehicle operation

A.5.1 Fleet weighted emissions for buses are reported by AEA (2009) as

- Urban 942 g CO_2 per km
- Rural 616 g CO_2 per km
- Motorway 669 g CO_2 per km
- with an overall figure of 822 g CO_2 per km.

A.5.2 The average GHG emissions of an average UK car of unspecified fuel are reported (DEFRA p19/50) as 205g CO_2 equivalent per Km. This is almost exactly one-quarter of the overall bus emissions figure above, so if one bus-Km replaces at least 4 car-Km, the carbon effect is neutral or an improvement. Conversely if removing one bus-Km produces more than 4 car-Km, the carbon effect is likely to be a worsening.

A.6 Green Bus Fund approvals

A.6.1 The numbers of buses financed by the English GBF are as follows:

- 349 in Round 1, June 2009 (http://assets.dft.gov.uk/publications/green-bus-fund/winningbidders.pdf);
- 169 in Round 2, July 2010 (http://assets.dft.gov.uk/publications/green-bus-fund/2010winningbidders.pdf); and

- 434 in Round 3, March 2012 (http://assets.dft.gov.uk/publications/green-bus-fund-round3/green-bus-fund-round-3-winners.pdf).

A.7 Effect of traffic conditions on bus emissions

A.7.1 We have made our own estimates of the additional emissions produced as a result of a typical bus having to stop and restart rather than covering the same distance at a "cruising" speed. The estimate was based on an example speed and acceleration profile extracted from TfL iBus data by Zhang et al (2012) and shown as the blue line in Figure 2 below. The speed and acceleration figures taken from this example profile were used in our own application of the instantaneous emissions model published in Int Panis et al (2006). The latter is based on some 36,000 measurements from instrumented vehicles of Euro I and Euro II types. The resulting rate of CO_2 emission is shown as the red line in Figure 2.

A.7.2 Emissions per Km calculated from these second-by-second calculations come out similar to the urban CO_2 per km figure quoted in A.5.1 above.

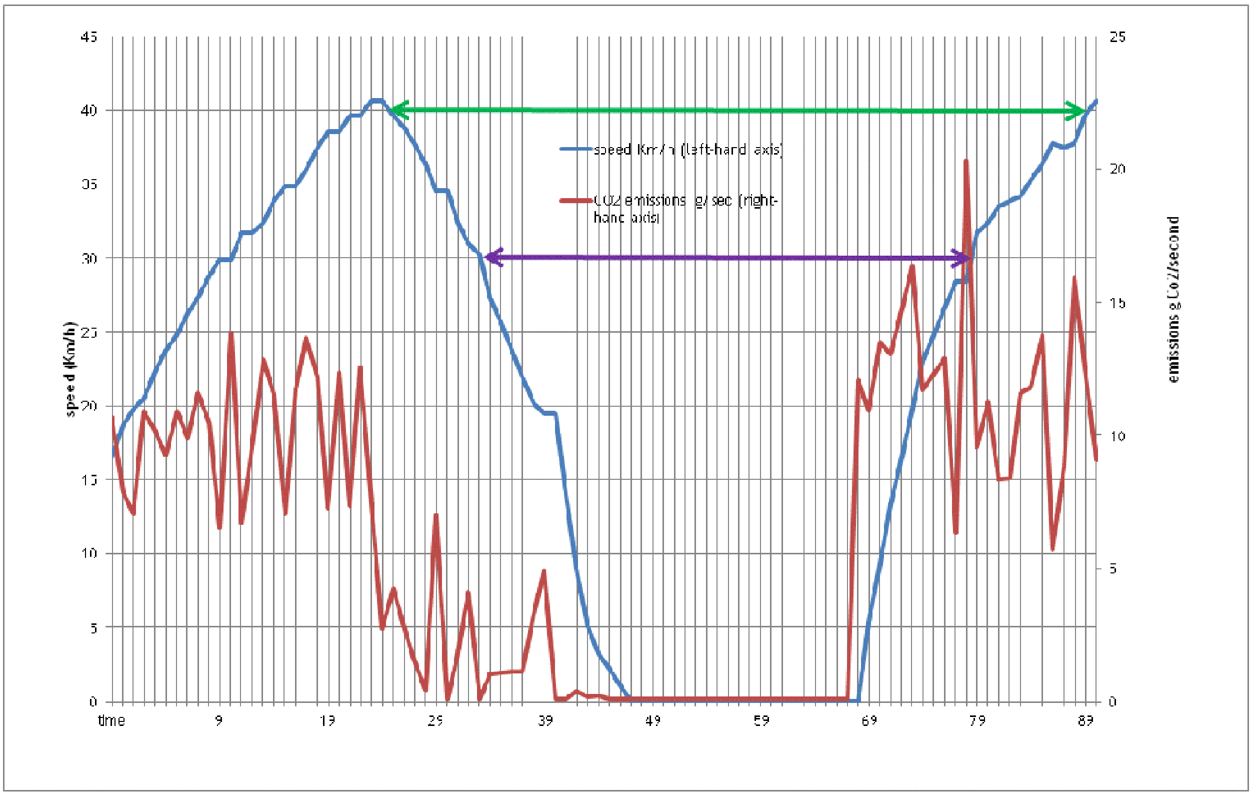

Figure 2 Example speed cycle and resulting emissions

Source: own calculations as described in text

A.7.3 From this, we estimated the emissions required for a bus travelling at 40Km/h to come to a complete stop, restart and accelerate back to 40 Km/h again. This was obtained simply by summing the emissions per second over the stop-start cycle corresponding to the green arrow in Figure 2. We also calculated, from the speed in each second, that the bus would cover about 325m in performing that cycle from 40Km/h to stop and back again; and we calculated the CO_2 which would be emitted by a bus travelling 325m at a steady 40Km/h. The extra CO_2 emitted for the stop-go cycle over 325m, compared with covering that distance at a steady speed of 40Km/h, will be about 84g. This figure excludes the emissions while the bus is stationary, so it is independent of how long the bus is stationary.

A.7.4 In dense urban conditions it is unlikely that a bus will only have to halt once in 325m. A more typical situation is probably to consider a bus moving at 30Km/h which has to come to a complete stop and restart – the cycle indicated by the purple arrow in Figure 2. This bus will cover about 125m by the time it has accelerated to 30Km/h again, and in the process will emit about 58g more CO_2 than if it had covered the same distance at a steady speed. Again, this excludes the CO_2 emitted while the bus is stationary.

A.7.5 The emissions from stopping and starting a bus that would otherwise be travelling at the urban speed limit of 48Km/h would of course be greater again.

A.7.6 The long average distance between stops on intercity bus travel is thought to be one of the main reasons, alongside higher occupancy rates (16-19 people per bus compared to around 9), that the carbon emissions for long-distance bus travel are reported to be approximately one fifth that of other bus travel at 31gCO_2e compared to 149 gCO_2e for an average local bus[45].

A.8 Smart-card readers installed in buses

A.8.1 Results from the DfT DfT Public Service Vehicle Survey show that at March 2011 one-third of buses in Britain outside London were fitted with a live ITSO-compliant smart-card reader[46]. (Within London, all buses on local services are fitted with Oyster card readers, which are non ITSO-compliant.) The proportions by country/region ranged from 77% in Scotland down to just 18% in non-metropolitan England. DfT say that the figures are based on survey returns only, and do not include imputation for operators who were not surveyed or did not respond; they conclude that they may therefore be slightly understated.

A.8.2 From 1 April 2010 operators receive an 8% increase in their BSOG rate if they have operational ITSO smartcard systems. They receive a 2% increase in their BSOG rate if they have fitted their buses with Automatic Vehicle Location (AVL) equipment. These incentives cannot be claimed for routes secured by Transport for London as part of the London Bus Network. For details of these incentives see:

[45] http://www.nationalexpressgroup.com/ourway/climatechange.aspx

http://www.cpt-uk.org/_uploads/attachment/378.pdf

http://www.defra.gov.uk/publications/files/pb13625-emission-factor-methodology-paper-110905.pdf

[46] http://www.dft.gov.uk/statistics/tables/bus0607/

www.dft.gov.uk/pgr/regional/buses/busgrants/bsog/avl-incentives.pdf. (Source: http://www.cpt-uk.org/_uploads/attachment/1094.pdf)

APPENDIX B CORRIDOR ANALYSIS

B.1 Introduction

B.1.1 The corridor analysis sought to address the questions of where investment in bus would be most valuable in terms of its contribution to meeting the carbon reduction target.

B.1.2 The corridors are not "case studies" of specific bus routes but generalised descriptions of a range of urban corridors with what are intended to be typical characteristics.

B.2 Corridors considered

B.2.1 We have considered six example corridors:

- an urban corridor within a large town or small city (large enough to have its own urban services rather than being served wholly by stops on inter-urban routes)
- two contrasting corridors in a medium-sized city:
  - one of them major corridor (serving a major off-centre destination eg a hospital as well as the city centre),
  - the other a secondary corridor, essentially linking residential areas to city centre;
- three corridors within a major conurbation
  - a major radial corridor with rail competition
  - a major radial corridor without rail competition
  - an orbital corridor linking two towns within the conurbation, neither of them the central city.

B.3 Variables considered

B.3.1 The variables considered in describing the bus routines included

- route length
- frequency
- number of stops

- base journey time in the absence of passengers or road traffic delays
- number of passengers, and hence boarding/alighting time as part of journey time
- frequency of stops for junctions, traffic congestion, road works etc (drawing on the TTR 2010 study) and the resulting increase in journey time
- walking time to stops
- waiting time at stops (from frequency and a level of (un)reliability assumed to result from delays, but assuming that all buses operate)
- fare (for fare-paying passengers).

B.3.2 The variables were combined into a generalised cost using a typical value of time.

B.3.3 The competing car journeys were considered simply in terms of

- average speed,
- operating cost and
- parking cost,

combined into a generalised cost using the same value of time as for bus passengers (since our interest is in the group of passengers who might use either).

B.3.4 The average speed for car was assumed to allow for traffic delays (and getting stuck behind buses), with no additional weighting for the delay or unreliability – on the basis that car users generally experience delay in their cars, which is much more comfortable than delay at a bus stop.

B.4 Results

B.4.1 The key results from this analysis were the ratio of the generalised cost of travel by bus to the equivalent generalised cost by car. Where the ratio is close to one, ie where the measured characteristics of the two modes are very similar, they are likely to be in close competition, and any improvement in bus is likely to have a greater effect in terms of winning car users than in a situation where bus is markedly inferior – though equally, where the two generalised costs are similar, any deterioration in buses and bus services may result in a greater loss to car than in a situation where bus is a poor alternative, used by few people unless they have no alternative.

B.4.2 The results that we obtained from our input assumptions about the different corridors ranged from near equality of generalised costs in the major conurbation corridors to a ratio of more than 2.5:1 (ie bus much inferior to car) for the smaller city corridor. The key figures are shown in the table below.

	Bus						Car	Bus:car
Corridor	**Buses per hour**	**Average journey (Km)**	**On-bus time with delays (min)**	**Waiting time with unreliability effect (min)**	**Bus fare (£)**	**gen cost (min)**	**car gen cost (min)**	**bus gc/ car gc**
Small city/ large town	4	3	15.3	7.5	1.60	57.5	22.20	**2.59**
Major corridor in medium city	6	5	23.5	7.5	1.90	69.3	44.00	**1.58**
Secondary corridor in medium city	3	4	18.5	7.5	1.60	60.7	37.60	**1.61**
Conurbation: major corridor, rail competition	8	5	22.0	5.6	1.65	61.1	61.00	**1.00**
Conurbation: major corridor, no rail	8	6	27.0	5.6	1.90	69.1	68.40	**1.01**
Conurbation: orbital corridor	3	4	19.7	7.5	1.40	59.5	45.60	**1.31**

B.4.3 One of the characteristics apparent in the table is that most of the difference in the attractiveness of bus compared to car, as measured by the ratios of the generalised costs, actually comes from the differences in the car generalised costs. This tends to confirm the view that bus is only likely to compete with car where it is particularly difficult or expensive to make use of cars, whether due to congestion (if this affects cars more than buses), parking problems/charging or (in London, and in theory elsewhere) road pricing.

B.4.4 Our original intention was to use the spreadsheet calculations behind the above table to examine the environmental consequences of different changes to bus provision. However, we had some difficulty in getting beyond the conclusion that the ratio of generalised costs measures how effectively the bus competes with car, other things being equal. (It should be noted that the ability of bus to compete with car in the with-rail corridor will be limited by the competition of rail for car, so bus improvements are likely to attract fewer car users in that case.) For example, we were unable to find information to quantify how much reductions in boarding times would reduce delays to other road vehicles, which is one of the potentially interesting and valuable consequences of smart ticketing systems.

B.4.5 The analysis has therefore served to confirm that bus improvements are most likely to attract car users to bus in major urban areas, and particularly in corridors into major centres where traffic and parking issues make driving less attractive.

APPENDIX C REVIEW OF CASE STUDIES

C.1 Introduction

C.1.1 This report summarises the results of empirical studies to consider the effects of investment in buses on passenger demand particularly modal shift from car travel.

C.1.2 Longitudinal studies of the effects of investment in the bus system are not undertaken on a routine basis so this review concentrates on a few published case study reviews which draw together the empirical research in this field.

C.1.3 The review for Greener Journeys reflects the initiative of the UK bus and coach industry to reduce CO_2 emissions from transport by delivering modal shift from the car. The aim of the initiative is to remove one billion car journeys from UK roads from investment in the bus system. This is intended to deliver both environmental benefits from lower transport emissions and economic growth from more efficient travel.

C.1.4 Investment in the bus system results in additional bus journeys from three main changes:

- new journeys as a result of the more attractive services;
- journeys transferred from other modes with lower emissions than bus - such as walking and cycling;
- journeys transferred from other modes with higher emissions than bus – principally car travel.

C.1.5 The first two of these require trade-offs between the disbenefits of higher bus emissions and the social and economic benefits of increased travel.

C.1.6 This appendix concentrates on the third element. When making estimates of modal shift it must also be recognised that many people previously making journeys by car would also have made longer journeys. Therefore the environmental benefits of modal shift to bus from car derive from:

- The use of a lower emission mode. Buses with the latest Euro V engines are very much cleaner than buses with older technology which still dominates the bus fleet. Therefore the effects of modal shift on emissions, varies on a route by route basis.
- The choice of a shorter journey. This principally applies for destinations such as shopping where a local destination by bus is selected if the bus

system is improved when otherwise a longer trip to a location with easy parking like an out of town centre might have been selected.

C.1.7 Even where short term effects can be quantified through a case study, it should be noted that the long term effects can be very much greater as people build lifestyles and trip choices around transport networks. Over time people move house, job and make life choices based around predictable elements of the transport system. The research does not yet permit simple conclusions about these effects from bus investment but activity based modelling using parameters derived from research on differing short and long term effects may help to identify factors which could be used in meantime. There was survey evidence from some passengers when the Stagecoach taxibus service was withdrawn from Fife that some passengers had moved house from Edinburgh to Fife since the new service made commuting practical.

C.1.8 Some bus development plans specifically seek modal shift and these need to be differentiated from general bus investment. Well executed plans designed specifically to deliver modal shift from car will deliver greater modal shift than untargeted bus investment.

C.2 Empirical Case Studies

Partnership Case Studies

C.2.1 The Sustainable Travel Towns experiments[47] in 2005 reviewed the impacts of a comprehensive package of measures, combining service quality enhancements with better information and marketing. This found that impacts are greater with a combined approach to infrastructure and marketing than if the focus is solely on infrastructure or solely on marketing. Examples of successful town-wide bus improvements from the sustainable travel town demonstrations include:

- Peterborough, where patronage increased by 40% over 4 years, following the introduction of real time passenger information, simplification and re-branding of the bus network, increased service frequencies, bus stop improvements and a comprehensive marketing programme.
- Worcester, where patronage increased by 27% over 4 years, following marketing, fares initiatives, and route improvements including a new orbital service.
- Brighton, where patronage increased by 45% over 9 years as a result of service and infrastructure improvements, high quality information, and fares initiatives.

[47] http://www.dft.gov.uk/publications/smarter-choices-changing-the-way-we-travel-main-document/

- Nottingham, where a package of re-branding, marketing, city centre bus stop enhancements and real time information reversed the decline in bus use and generated an estimated 2 million trips in one year.

C.2.2 In none of these cases were passengers interviewed so it was not possible to make an assessment of the modal shift from car. However, these increases are consistent with the partnership approaches to planning bus improvements which show that typical growth which can be achieved is between 10 and 50% when infrastructure and marketing approaches are combined (e.g. Davison and Knowles 2006).

C.2.3 The need for partnerships recognises that investment in bus infrastructure (bus lanes, bus shelters, information at bus stops, etc.) cannot be undertaken directly by bus companies and requires a partnership with the public authority. Similarly public authority programmes investment is only effective if the improvements to the infrastructure are matched with investment in the services (e.g. vehicles, driver training, marketing, fares etc).

C.2.4 The table below[48] summarises patronage changes from a number of large partnership investment programmes.

Existing evidence supporting patronage growth as a result of Quality Partnerships

Area	Scheme	Growth (%)	Period	Source
West Midlands	Line 33	40	18 months	TAS
	Superline	18	Initial	TAS
Edinburgh	Greenway (A8)	7	–	TAS
Nottingham	Calverton Connection	48	2 years	TAS
	Cotgrave Connection	15	2 years	TAS
Hertfordshire	Elstree and Borehamwood	20	–	TAS
	Lea Valley Green Route	20	–	TAS
Brighton and Hove	Network wide	5 per annum	1994–2001	TAS
Leeds	Scott Hall Road[a]	75 (25)[a]	5 years, 18 months	First
Ipswich	Superoute 66[a]	63 (33)[a]	5 years, 2000	First
Rotherham	Rotherham to Maltby	17	1998–2002	First
Oxford	City wide	52	1991–2001	Industry source
Portsmouth	Portsmouth to Leigh Park	25	15 months	Stagecoach
Cambridge	City network	25	4 months	Stagecoach
Working	Route 91	22, 1.5	2 years, following year	Arriva
Sheffield	X33 Sheffield to Bradford	50	2 years	Arriva
Telford	Redline	46	2 years	Arriva
	Blueline	12	1 year	Arriva

Targeted Marketing

C.2.5 Table 2.1 below summarises patronage changes from a number of large partnership investment programmes.

C.2.6 Stagecoach has reported some of the data from their telemarketing campaigns[49]. These have been undertaken in locations where services use high quality vehicles and good infrastructure such as Barrow, Ayrshire and Macclesfield, and show that between 10 and 30% growth can be obtained through low-cost targeted

[48] from TAS (2000), quoted in Davison and Knowles (2006)

[49] http://www.stsg.org/str/str38.pdf

marketing[50]. Based on customer surveys Stagecoach suggest that about 85% of the new customers attracted by bus travel incentives previously travelled by car. However these figures have not been independently verified and Stagecoach has only deployed this approach in selected locations where they identified was greatest potential for modal shift.

<u>Glasgow</u>

C.2.7 The effects of the Glasgow Streamline project were researched by MVA Consultancy (2008). This was a £60m investment programme in the bus system in Glasgow. Bus patronage figures were not available from this analysis but when surveyed, up to 10% of the users of one corridor responded that they had shifted mode to bus from car. The average proportion of new passengers mode-shifting across the city was estimated as 5%.

<u>Manchester</u>

C.2.8 Davison and Knowles (2006) undertook a detailed study of two improved bus corridors in Manchester and found that 11.5% of passengers had transferred from car on a radial corridor and 5.5% on a transverse route[51].

C.2.9 However more than 30% of bus travellers also had a car available so maintaining the quality of bus services relative to car is clearly important to maintain the bus market share.

<u>Surrey</u>

C.2.10 Looking at the relationship between bus investment and modal split the other way round, in an impact assessment of a possible decline in bus travel in Surrey 2010, TAS Partnership estimated that about 17% of bus passengers would switch to other modes. They divided up the 17% on each bus corridor based on trip length. The average bus trip distance is 8.2km and trips in excess of 2km were assumed to largely switch to car or taxi if a rail service was not available.

<u>Portsmouth</u>

C.2.11 A different kind of marketing, directed directly towards environmental goals, is represented by the various campaigns that have been promoting awareness of the environmental impact of transport and of greener alternatives to car use, including the various "car-free day" initiatives. One example that was monitored in some detail was the Portsmouth "Big Green Commuter Challenge" which was estimated to bring about a 48% reduction in CO_2 and 20% reduction in NO_x emissions from the journeys made by the thousand or so participants in the challenge (Wall et al, 2011). Whilst that is a small proportion of the commuter population of the city,

[50] Comparable results for Grimsby and Perth, again from Stagecoach marketing initiatives, are quoted in Balcombe et al (2004), section 8.8.3.

[51] TAS Consultants, 2000. Quality Bus Partnerships Case Study: Volume 4: Greater Manchester.

and a self-selected volunteer group of participants, it indicates the scale of improvement that can be achieved.

C.3 Conclusions

C.3.1 Modal shift to bus as a result of bus investment depends on the approach to investment and the target market. Overall, significant investment in the bus system can deliver modal shift. In the absence of other factors about 5% of the growth in bus patronage resulting from investment will be a modal shift from car travel. This will have less than 1% of an impact on car travel in the affected corridor.

C.3.2 However targeted approaches often combined with restraint on car travel can make much greater impacts. Co-ordinated investment and marketing programmes typically deliver 10 to 50% increases in bus patronage but the impacts of this on modal shift on bus patronage is less well researched. This is partly because modal shift is a complex concept: closely linked with trip length change, where short and long term effects are different, and which is usually looked at from the perspective of deterrence on car use than specific impacts on bus use.

C.3.3 Where there are restraints on car travel such as parking in city centres, then peak mode switching of around 10% was observed in Glasgow and 11.5% in Manchester. Elsewhere the mode switching is only around half this level at 5% of the growth in bus travel in the investment corridors.

C.3.4 When car drivers are targeted through an effective marketing campaign, in conjunction with bus services providing fast, high quality, reliable competitively priced services, then up to 85% of the trips generated can be mode shift from car.

C.3.5 The likely proportions of new bus users attracted from car by “ordinary” bus investments without a targeted marketing campaign are lower than the proportions of “lost” bus users who will switch from bus to car as a result of a reduction or worsening in bus service. For example, recent work for the Competition Commission[52] found that when asked about a hypothetical fare increase, 22% of the respondents who said they would stop using the bus said that they would transfer to car (as drivers or as passengers)[53].

C.3.6 We would expect that in the short term (when people are asked questions of "what would you do instead..." or "what did you do before...") one would see higher proportions of passengers transferring bus to car than from car to bus - because in

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[52] http://www.competition-commission.org.uk/assets/competitioncommission/docs/pdf/inquiry/ref2010/localbus/pdf/survey_final_report_221210_for_publication

[53] This asymmetry is further illustrated in Balcombe et al (2004), where Table 9.9 (p105) suggests that 33% of additional bus travellers will transfer from car, but 48% of lost bus travellers will transfer to car. These figures (based on at most three studies) seem very high, and may be based on studies carried out in corridors with bus services were particularly attractive relative to car use.

the short-term (or for the specific journey being discussed) people have commitments (to jobs, educational courses, medical treatment) which they have to meet as best they can, and many bus users if deprived of the bus will resort to making the journey by car (as drivers or passengers) instead.

C.3.7 In the longer term, a proportion of those displaced from the bus would find other modes (eg bicycle) or other destinations (ie other jobs, different doctors etc). The asymmetry is explicable in terms of more or less perfect information – it is hardly possible to use a bus without being aware of car as an alternative mode, but many car users have very little information about whether bus services are available as alternatives to their car journeys.

C.4 Annex - National Travel Survey Modal Share

C.4.1 There are 6 car driver trips for every bus trip so a large change in bus travel is still only a small change in car travel (and therefore emissions from cars). There are also three times as many trips as passengers in cars as by bus. Car occupancies are lowest for commuting when bus can also make the largest contribution to congestion reduction.

Bus Travel Modal Share (%)

Main Mode	2010
Walk	*22*
Bicycle	*2*
Car/van driver	*42*
Car/van passenger	*22*
Local and non-local buses	*7*
Rail	*3*
Other	*2*
All modes	*100*