

ACHIEVING CARBON EFFICIENT TRANSPORT: BACKCASTING FROM LONDON

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ABSTRACT

Transport is a major user of carbon-based fuels, and is increasingly being highlighted as the sector which contributes least to CO₂ emission reduction targets. This paper reports on the findings of the current VIBAT London study (www.vibat.org) which considers the role of the transport sector in reducing CO₂ emissions in London.

A backcasting study approach is used, testing the likely impacts of alternative images of the future for 2025. A transport and carbon simulation game (TC-SIM) is also developed for London. Within this, users are able to consider a series of potential policy packages – low emission vehicles, alternative fuels, pricing regimes, public transport, walking and cycling, strategic and local urban planning, information and communication technologies, smarter choices, ecological driving and slower speeds, long distance travel substitution, freight transport, and international air – and select variable levels of application to help achieve headline CO₂ emission reduction targets. The roles of two external “enabling measures” are also considered – carbon rationing and oil pricing.

The paper considers an optimised future policy package for 2025. A deep reduction in transport CO₂ emissions is theoretically possible, yet practically very difficult to achieve. The main perceived problem is in engendering an interest in the public to change consumer purchases and behaviours. The huge challenge now is to map and discuss a variety of policy pathways to carbon efficiency in the transport sector, and then to enable and achieve a level of consumer and behavioural change consistent with strategic aspiration.

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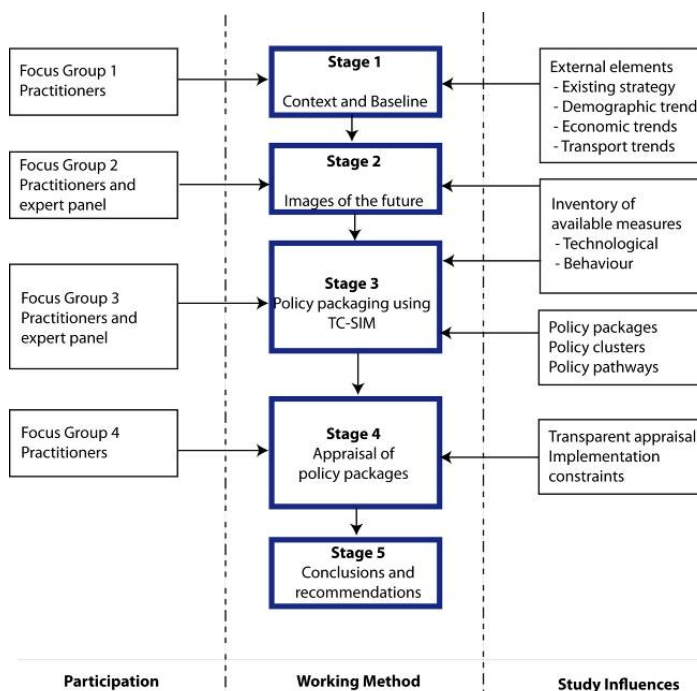
1. INTRODUCTION

Global warming and projected rises in greenhouse gas (GHG) emissions pose a major challenge for the world. Population growth, increased average incomes and material consumption mean that reducing emissions becomes very difficult. The transport sector contributes around 25% carbon dioxide (CO₂) emissions in the UK, yet remains the major under-performing sector in contributing to emissions reductions. Trend-breaking futures are required to help mitigate and adapt to the potential impacts of global warming.

This paper draws on findings from the VIBAT London study (Visioning and Backcasting for Transport in London, see www.vibat.org). It uses London as a case study, and a simulation model of the city, to develop and test potential future scenarios for different levels of application of different policy packages. London provides a very interesting case study as per capita transport emissions, particularly in inner London, are the lowest in the UK. There are already impressive efforts to fund and develop sustainable transport measures.

There are a series of stages to the project (Figure 1). The first is to establish the baseline for transport CO₂ emissions and appropriate targets for CO₂ reduction; this is followed by the development of alternative images of the future, policy packaging to achieve the adopted target and an assessment of synergies between policy packages. The analysis reflects a number of external elements, such as demographic, economic and transport trends. Each stage of work is tested with practitioners and/or an expert academic panel.

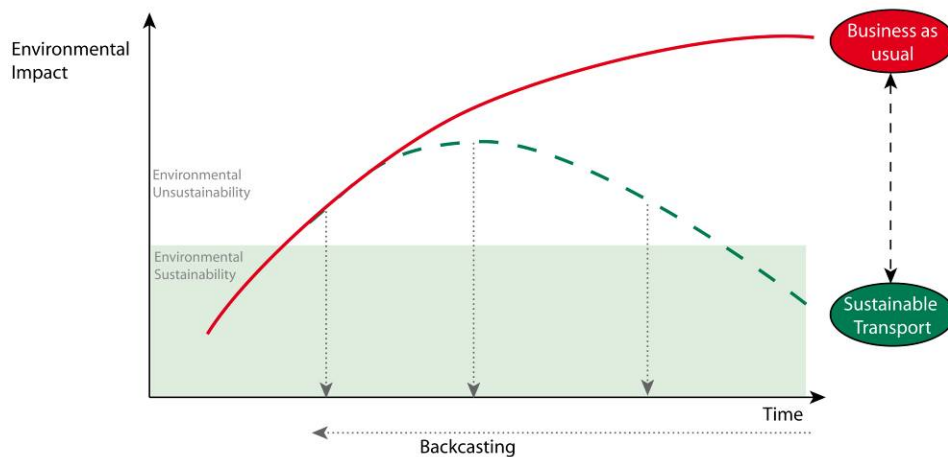
Figure 1: The Study Process



Futures studies have been increasingly used in the last few decades to illustrate what might happen to society in adapting to challenging future trends and targets. This study follows a backcasting study approach (Figure 2). Backcasting has been developed as a particular niche of futures analysis, as a complementary method to forecasting and scenario building. It is a methodology particularly suitable for analysing topics that require trend-breaks – e.g. sustainable transport. There was a particularly strong backcasting debate in Sweden in the 1980s over energy futures. Much of the initial working methodology was developed in this period (Johansson et al., 1983). The well-known OECD project on Environmentally Sustainable Transport (EST – OECD, 2000) and the EU-POSSUM project (POSSUM, 1997; and Banister et al, 2000) introduced the backcasting methodology to the transport planning field in Europe. It has since been used in the VIBAT-UK study (Hickman and Banister, 2006) and elsewhere.

The backcasting methodology seeks to develop a policy pathway to an agreed trend-break future. Instead of starting with the present situation and projecting prevailing trends (forecasting), the backcasting approach designs images of the future, representing desirable solutions to societal problems, and “casts back” to the present. A policy pathway is then developed to achieve this desirable future.

Figure 2: The Backcasting Study Approach



This paper describes backcasting as used in the London context. It develops the business as usual (BAU) transport CO₂ emission baseline and target, before outlining the range of policy measures available to reduce CO₂ emissions. These are assembled into policy packages to ensure consistency and effectiveness so that the potential benefits can be made complementary and synergetic. An optimal strategic package of policy measures is developed. Finally, some conclusions are made on the emerging lessons drawn from recent analysis in the carbon efficient transport field.

2. THE BASELINE

London is aiming to become a “model” sustainable city that can combine population growth with economic prosperity and a fair society, but at the same time reduce its carbon emissions. Current levels of emissions (2006) in London are around 44 MtCO₂ (million tonnes of carbon dioxide). Achieving large reductions in carbon emissions, whilst retaining economic and quality of life goals, is likely to be difficult, even with a static population and employment base. Add in large population and economic growth and the task to reduce aggregate emissions becomes considerable. London’s population is expected to grow by 23% to 9 million in 2050 from 2006 levels, and the economy will grow by between 100% and 150% over the same period (GLA, 2004).

To help tackle this great challenge, a large amount of strategic forward planning and analysis has been carried out by the public agencies in London. Transport for London has produced Transport 2025 (T2025) (TfL, 2006a) and the Mayor’s Transport Strategy (TfL, 2006b). The Greater London Assembly has produced the London Plan (GLA, 2004) and Climate Change Action Plan (CCAP) (GLA, 2007). The headline CO₂ reduction targets adopted for London are as follows:

- T2025: a 30% reduction in CO₂ emissions by 2025 in the transport sector on a 1990 base;
- CCAP: a 60% reduction in CO₂ emissions by 2025 across all sectors, against a BAU Scenario.

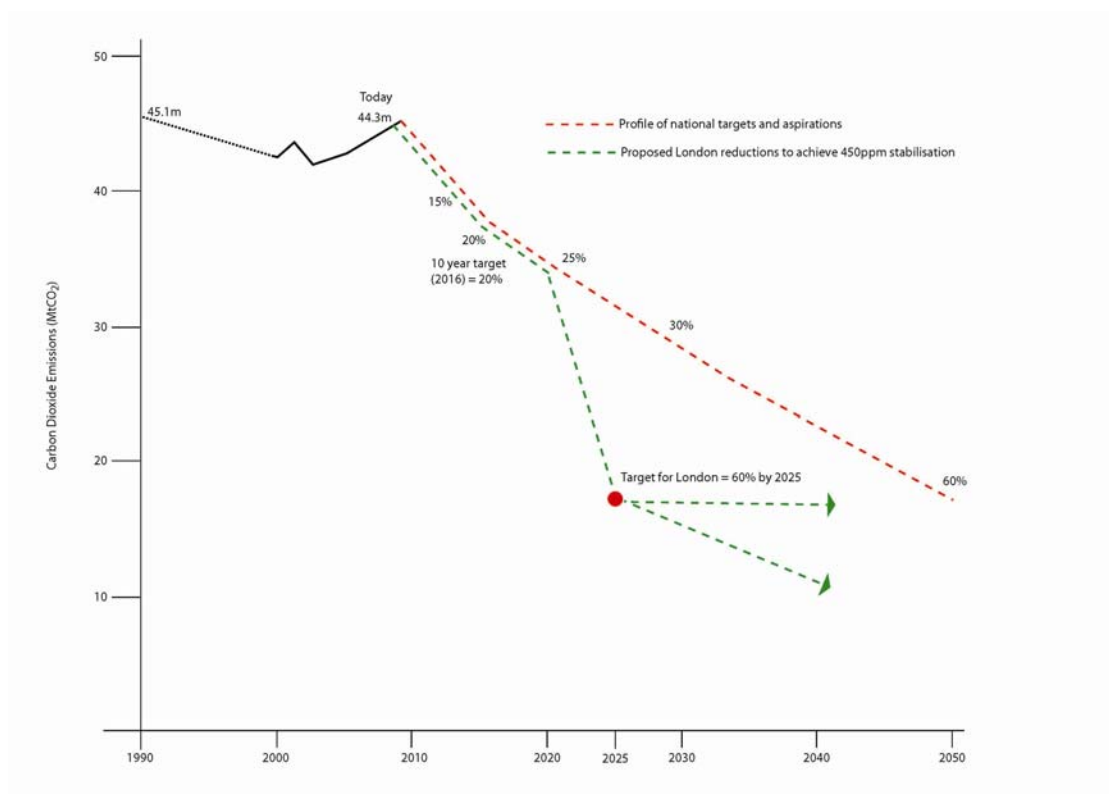
The strategic aspiration for a 60% reduction in CO₂ emissions by 2025 is thus very ambitious, albeit relative to a BAU scenario (Table 1 and Figure 1).

Table 1: CO₂ Projections and Targets for London, excluding Aviation (MtCO₂)

Scenario	1990	2006	2025	2050
BAU projection (cross sectoral)	45.1	44.3	51.0	
BAU projection (ground transport)	9.5	9.6	11.7	
CCAP target (cross sectoral) <i>60% reduction against a BAU projection</i>			30.6	
T2025 target (ground transport) <i>30% reduction by 2025 on a 1990 base</i>			6.7	
VIBAT London target (ground transport) <i>60% reduction by 2025 against a BAU projection</i> <i>80% reduction by 2050 against a BAU projection</i>			4.7	2.3

From Hickman, R. et al (2008)

Figure 3: CO2 Emission Baseline and Target for London



(based on GLA, 2007)

Within London, the transport sector accounts for 22% of ground-based transport CO₂ emissions (9.6 MtCO₂). This proportion rises dramatically if aviation is included. The allocation for London, as used in the Climate Change Action Plan (GLA, 2007), is that half of emissions from all flights landing at London airports are allocated to London residents' emissions. This results in the aggregate transport emissions rising to 48%. Within the ground-based transport sector, car-based CO₂ emissions (49%) and road freight (23%) dominate.

The policy response at the UK level is less well developed. Here, top-down target setting has gradually produced more stringent policy targets, but in all cases international aviation is excluded. In the UK, the Kyoto Protocol (1997) seeks to achieve a 12.5% reduction in six GHG below 1990 levels over the period 2008-2012. The Protocol expires in 2012 and negotiations are ongoing for a replacement agreement. The UK domestic target was for a 20% reduction of CO₂ emissions below 1990 levels by 2010 (DETR, 2000). Current projections are that this target will not be met without the purchase of permits through the EU Emissions Trading Scheme, and this target seems to have effectively been abandoned. A "pathway towards" a 60% reduction of CO₂ emissions by 2050 has now been endorsed by the UK Government (DTI, 2003). The new Climate Change Act will mean this latter target becomes legally binding (2008). The target would be for a 60% reduction in CO₂ emissions by 2050 (using a 1990 base), with clearly set intermediate targets.

The striking feature of all these targets is the huge gap between BAU projections and the emissions reduction targets. Achieving this scale of change is likely to be very difficult as much of it involves lifestyle change (Figure 3).

2. IMAGES OF THE FUTURE

The second stage of the VIBAT London project is to develop alternative images of the future, images that offer a trend-break relative to the BAU projection. Two images are developed, drawing on previous futures work, particularly the VIBAT-UK study (Hickman and Banister, 2006) and the DTI Foresight Intelligent Infrastructure Futures study (DTI Foresight, 2006).

A number of drivers of change are taken into account: such as changing demographic and household structures, including an ageing, yet more active population (greater demand for mobility - passengers and goods); increasing world trade and globalisation, emergence of networked organisations, clusters and supply chains, yet the rising importance of local provision (complex flows); rapid technological developments and the emergence of 'digital natives' (the new generation growing up accustomed to technology); taxation increasingly based on resource consumption rather than income; yet decline in the power of national governments and distrust in institutions (ability to influence change); increasing awareness of sustainability issues and demand for change; and the gradual emergence of radical solutions to climate change.

Image 1: Perpetual Motion

Under image 1 London is developed with a strong emphasis on technological change. The demand for transport remains strong and mobility, including air travel, continues to grow. There is a ready acceptance of new technology, both in the home and the workplace, but particularly in transport with a keen desire to overcome the consequences of CO₂ emission increases through clean technology. However, this concern is not backed up by major lifestyle changes; only marginal changes occur using ICT to reduce the need to travel for certain activities (e.g. some use of teleconferencing and home shopping). Mobility levels remain unaffected; particularly travel by private car in the suburbs.

The main aim of transport policy is to achieve the required CO₂ emissions target with a minimum of change in terms of behaviour. Car traffic still grows and dominates in terms of modal share, with trip lengths increasing and occupancy levels remaining about the same as in 2000. The main changes are in pushing hard on hybrid technologies and alternative fuels so that the overall average emissions profile of the total car stock reduces to 100 gCO₂/km or below in 2025.

There is also considerable investment in alternative fuels to reduce the carbon content of existing internal combustion engines (ICEs) and the non-electric parts of hybrids. Niche electric vehicles also have a limited role for low speed vehicles in central London, provided that their source of energy is renewable. The cost of fuels rises overall, but this increase falls increasingly on those car users that continue to consume fossil fuels. New materials are used to make vehicles lighter.

Although behavioural change is also acknowledged as being important, the general view is that little lifestyle change is required, apart from clear pricing signals to encourage less fuel consumption and a switch to cleaner technologies.

Image 2: Good Intentions/Urban Colonies

Under image 2 London develops with a strong emphasis on environmental and wider sustainability objectives. Economic and social considerations are still important, however are not pursued at the cost of environmental goals. Slowly, the importance of designing the urban environment for less travel and efficient use of resources achieves great importance. Over time, technology systems become essential to deliver carbon efficiency.

Within London, the central activity zone is an important centre for growth, but growth is also concentrated in the suburbs, with local, polycentric growth. Societal benefits accrue from a society integrated more at the local level. People in this scenario are environmentally aware and more careful in their use of resources.

This image is also market driven, but has a much stronger social and environmental emphasis, and is focused on improving quality of life. The transition to the technological society is moderated by greater social intervention. The economy is a knowledge-based economy, producing specialist products for hi-tech businesses. It is accepted that behavioural change is the essential basis needed to address the required CO₂ emissions targets, however technology is also important – there is realism though in terms of expected application.

In the transport sector, the expectation in this image is that there will be a slight reduction in the total amount of travel distance by each person in 2025 and again to 2050, but the effect of this will be offset as population will have increased in London. The main reduction has not taken place in the number of trips made, but in the length of trips. The distribution has changed, with some growth in long distance trips, but these are more than compensated for by the increase in shorter more local trips. The desire for less travel (and distance for freight distribution) links in with the greater social awareness and conscience of the population, and the importance of community and welfare objectives. The lock-in to car dependency (as found in image 1) is broken with social priorities pushing for greater use of public transport and other clean modes of transport.

There is less dependence on technological solutions, but cars become cleaner over the period (130 gCO₂/km or below for new cars by 2025) through new taxation and pricing incentives to use more efficient and cleaner technologies, with tax reductions for not owning a car or for participating in car sharing schemes. Real fuel prices increase over the period; increases in oil prices are an effective enabler to achieving carbon efficient transport.

3. PACKAGING THE POLICY LEVERS

A wide range of policy levers are available to help reduce transport CO₂ emissions and move towards the images of the future. These work best within packages, allowing complementary measures to work together. A transport and carbon simulator (TC-SIM) is developed in the VIBAT London study to help explore the packaging of policy options. TC-SIM is a participation tool which includes a scenario building and policy discussion platform, with a spatial base, around which decisions in relation to possible future scenarios and policy packages can be made. The 12 policy packages (PP) considered cover: PP1: Low emission vehicles; PP2: Alternative fuels; PP3: Pricing regimes; PP4: Public transport; PP5: Walking and

cycling; PP6: Strategic and local urban planning; PP7: Information and communication technologies (ICT); PP8: Soft measures “smarter choices”; PP9: Ecological driving and slower speeds; PP10: Long distance travel substitution; PP11: Freight transport; PP12: International air travel.

Each policy package can be selected at a variety of levels of intensity of application – typically a “low”, “medium” or “high” level of application. The assumption in terms of background traffic growth is that traffic grows year on year as an extrapolation of recent trends. Relative to the rest of the UK, London is different in that traffic growth has been limited in recent years, and it appears to have reached the top of the “S” curve of traffic growth.

The BAU application is assumed to be the Reference Case (Scenario 1) in T2025 (TfL, 2006a). This broadly represents the current fully funded investment strategy for TfL and is thus the best representation of current BAU. It does however represent a significant amount of funding – approximately £2-7 billion per annum to 2025 (TfL, 2006a).

The modelling behind TC-SIM has been developed to allow quantification of the potential impacts of a range of policy interventions in multiple combinations. It uses and combines a variety of data sources, including London Travel Survey (LTS) modelling runs, a spreadsheet of transport CO2 emissions developed by TfL, a vehicle fuel penetration spreadsheet developed for Defra and a number of other databases.

4. AN OPTIMAL STRATEGIC POLICY PACKAGE

An optimal policy package is developed in this paper, using a range of policy levers (technological and behavioural), and hence is broadly targeted at Image 2 Good Intentions/Urban Colonies.

Figure 4: TC-SIM “An Optimal Strategic Policy Package”



Table 2: An Optimal Strategic Policy Package

Policy Package	Comment	% of VIBAT London Target by 2025
PP1 Low Emission Vehicles	Medium: 120 g/km car fleet; 135 g/km light good vehicles	14%
PP2 Alternative Fuels	Low	4%
PP3 Pricing Regimes	BAU/medium – BAU congestion charging scheme; medium parking charging	1%
PP4 Public Transport	Medium – medium investment strategy; medium fare reduction	9%
PP5 Walking and Cycling	Medium	2%
PP6 Urban Planning	BAU	-
PP7 ICT	Medium	1%
PP8 Soft Measures	Medium	2%
PP9 Slower Speeds and Ecological Driving	Medium	6%
PP10 Long Distance Travel Substitution	Medium	3%
PP11 Freight Transport	Medium	-
Progress against VIBAT London Target (60% reduction against BAU 2025)		42%

Note. Target achievement is shown against a BAU projection. Within the BAU for London, the T2025 Reference Case (Scenario 1) is normally used.

A number of points are made against the levels of policy package application:

PP1 Low Emission Vehicles: this package is extremely important to the goal of reducing transport CO₂ emissions, since most emissions are related to car use. There are some difficulties with the current level of implementation (in terms of technological penetration); hence major efforts need to be made in developing a range of incentives for manufacturing and purchasing low emission vehicles for the mass market. A medium level of application is assumed in the TC-SIM modelling – a 120 g/km car fleet and 135 g/km light good vehicles by 2025. Clearly there is much more potential here and mandatory targets need to be developed to provide an incentive for the motor industry to apply a higher level of technological implementation.

PP2 Alternative Fuels: again there is some difficulty in implementing this policy package (including recent concerns concerning the use of biofuels and wider alternative fuels in terms of land take and knock on effects). A low level of application is assumed, and there is little impact in terms of CO₂ reduction at the mass market scale.

PP3 Pricing Regimes: Congestion charging or area-wide road pricing could potentially make a substantial difference to CO₂ emissions on a London-wide scale. The BAU application assumes the current congestion charge scheme (with the western extension) is operated. There is more potential here. Road pricing could be operated for the whole of London as part of a UK-wide scheme, and also on an environmental basis (i.e. the charging relates to the carbon emissions profile of the vehicle and the number of passengers). This would give clear signals to consumers to switch to more efficient cars or to other modes of transport. There are political difficulties with implementing this package, hence the modelling assumes only a BAU application of the congestion charge (the current scheme) and a medium application of parking charging (a tightening of the current parking supply and higher charging).

PP4 Public Transport: Public transport investment is critical in allowing consumers to choose carbon efficient means of travel. There is already an extensive public transport network in London, with massive investment plans in Transport 2025 (TfL, 2006a). The BAU application assumes that the Reference Case (Scenario 1) in T2025 is implemented. This is broadly all currently funded projects, not including Crossrail. It therefore includes capacity and frequency upgrades on the Underground, National Rail and Docklands Light Railway. More investment could be considered, as represented in Scenario 4 in T2025, or even beyond. This might include Crossrail and potentially wider schemes such as Crossrail 2 (a north-south pan-London link), additional tram routes and demand responsive public transport in the suburbs. The modelling assumes a medium intensity investment in public transport (T2025 Scenario 4, Full Programme) and a medium level of fare reduction.

PP5 Walking and Cycling: Similarly, investment in walking and cycling facilities and in the streetscape and public realm makes carbon efficient means of travel more attractive, particularly for short journeys. There is already a fairly extensive walking and cycling network in London, yet aggregate walking and cycling mode shares remain low relative to the best examples in Europe. The BAU application assumes that the Reference Case (Scenario 1) in T2025 is implemented, with the current funded walking and cycling projects being implemented. The modelling

assumes a medium intensity investment in walking and cycling (T2025 Scenario 4, Full Programme) – a higher level of investment than BAU.

PP6 Urban Planning: This package focuses on using urban structure to support sustainable transport, with efforts directed at both strategic and local scales. Strategically, urban structure is used to support public transport use through higher density development being clustered around an upgraded public transport system. More locally, urban areas are master-planned to vastly improve their urban design quality, attractiveness for living and working. There is complementary heavy investment in walking and cycling facilities and streetscape design. The BAU application assumes that the Reference Case (Scenario 1) in T2025 is implemented. This represents the urban strategy of the London Plan (GLA, 2004) – some polycentric thickening of densities, with most effort made in central London, and some investment in improved streetscapes, again mostly in central London. The modelling reflects this level of application.

PP7 ICT: the scope for CO₂ reduction from this package seems limited. A complex adaptation of social interaction is more likely than a simple substitution. The modelling assumes a medium intensity application of ICT however the impacts are not great in terms of transport CO₂ reduction. The benefit here is in developing flexible working lifestyles (homeworking) which breaks the tendency to commute 5 days a week, often by car.

PP8 “Smarter Choices” Soft Measures: This option includes investment in workplace and school travel plans, personalised travel planning programmes and future changes in car ownership (including leasing and car clubs), car sharing and travel awareness initiatives. These are important supporting measures to other packages, but they also have an important impact on reducing CO₂ emissions in their own right. The BAU application assumes that the Reference Case (Scenario 1) in T2025 is implemented. This broadly represents all funded projects. There is more potential if funds were made available for a greater intensity of application of this package. The modelling assumes a medium intensity application of soft measures to reduce travel CO₂ emissions. It should be noted, however, that impacts may be less than often forecast due to diminished returns when spread beyond the initial enthusiastic take up.

PP9 Slower Speeds and Ecological Driving: This option has the potential for substantial immediate and long term benefits if take up is high in terms of reduced speeds and changed driving styles. Slower speeds have the potential to provide extensive savings with some 15-20% reduction in CO₂ emissions if a maximum speed limit of 80 km/hr is introduced on motorways and trunk roads, with lower speeds on other roads such as residential roads. Effective compliance is a critical issue and is likely to impact on end CO₂ reduction impacts. Lower speeds need to be combined with awareness programmes and better driving techniques to reduce fuel use. The BAU application assumes that speed limits remain the same and there is little funding of driver skill initiatives. There is therefore more potential if funds were made available for a greater intensity of application of this package. The modelling assumes a medium intensity application of this package to reduce travel CO₂ emissions. However, the impacts are less than often expected due to enforcement difficulties.

PP10 Long Distance Travel Substitution: There is some limited potential for long distance travel substitution of rail to air (e.g. Eurostar) but the savings here are not likely to be substantial. Only travel within the London boundary is considered, hence the longer journey effects are not included. The BAU application assumes that only existing high speed train services operate. There would be more potential if a network of services was built. The modelling assumes a medium intensity application of this package; however the CO2 reduction impacts remain small.

PP11 Freight Transport: Freight transport is covered tangentially in several of the other policy packages, but this package concentrates on the freight sector as a whole with a series of measures targeted at reducing CO2 emissions. Different applications of the policy package draw from changed handling factors (the number of links in the supply chain), reduced length of haul, improved rail mode share, reduced empty running, improved fuel efficiency and choice of fuel/power source (McKinnon, 2007). The modelling assumes a medium intensity application of the package; however the CO2 reduction impacts remain small.

The result of the above implementation strategy is a reduction in CO2 emissions in the order of a 42%, relative to the 60% reduction target against a 2025 BAU. Good progress has been made against the target (70% achievement rate), but much stronger application of the policy packages is required. The difficulty is that a substantial investment in vehicle technologies, infrastructure and behavioural measures is already assumed, and this may be optimistic as these initiatives have been taken individually and not in a mutually reinforcing way.

Considerable further efforts are therefore required in terms of developing the incentives and mechanisms for a trend break in the delivery of carbon efficient transport. The most difficult future area is probably in engaging the public to deliver substantial behavioural change. High intensity application of all policy measures is required if we are to achieve the ambitious headline targets. The challenge of delivering such a trend break is currently being seriously underestimated.

An interesting and important dimension here is how policy packages should be best grouped together to form a mutually supporting, synergetic strategy. Urban planning, for example, might be used well to support a higher public transport, walking and cycle mode share. Some policy packages may not work well together. The mechanism should theoretically be able to deal with:

- Positive and negative interactions and synergies between policy packages/enabling mechanisms;
- Double counting of policy benefits;
- Positive and negative multiplier effects (greater or less than the sum of the parts);
- Positive or negative snowball effects over time

The framework as developed (see Annex) considers the first three of these potential relationships. This is the part of the analysis that is currently being developed within the VIBAT-London study. Conceptually, it is not difficult to identify where the

most promising positive benefits of policy packaging may take place, but the real difficulty is in obtaining empirical evidence that can be used in the TC-SIM model.

5. “KNOWN UNKNOWN”: INTERNATIONAL AIR TRAVEL AND ENABLING MECHANISMS

There are at least two difficult [and critical] policy areas that are currently far from being resolved. The first is international air travel, which has until recently been growing at a rate of 6% per annum (doubling every 12 years). There is little acceptance of the need for reducing the growth in demand, yet emissions from air travel are soon to become a major problem to the achievement of CO₂ reduction targets (Bows and Anderson, 2007). Two problems are evident. One relates to how international aviation should be accounted for in emission reduction targets. At present they are either excluded (as in most transport planning analysis concerning this topic) or they are considered as contributing a major part of city-based emissions. In London the calculations are that half the full international aviation CO₂ emissions are allocated to residents (CCAP; GLA, 2007). The problem is either one of omission or one of very large numbers. The potential for growth in this sector over the next 20-40 years is likely to exceed all other transport related emissions. The second, and more important, problem is that at present there are very few technological opportunities available to reduce emissions for the air sector. Many of the planes flying today will still be in use in 2025 and even 2050 (for example, the new A380). The only way to reduce emissions is therefore to reduce demand - through pricing, regulation and even rationing – and there is little political [or public] appetite for these policy levers.

This leads us onto the second difficult and unresolved policy area: enabling mechanisms. Further incentives or enabling mechanisms may be required to help achieve the headline CO₂ reduction targets as adopted – this paper has demonstrated the difficulties involved in achieving deep reductions in CO₂ emissions. One of the possibilities is carbon rationing. There are a number of possible ways of implementing a rationing scheme in the transport sector. The most likely are through car manufacturers, fuel suppliers or as personal carbon allocations (PCAs). Each would involve a cap and trade system with an overall level of emissions, probably reducing in volume over time. This enabling mechanism might help achieve high intensity application in the preceding packages. Again, however, there are very large implementation difficulties, particularly with PCAs (Defra, 2008; EAC, 2008). There is, however, some precedence here. The EU Emissions Trading Scheme (EU ETS) is already running, where some major polluting industries are allocated trade emission permits, and can use or trade them according to the levels of CO₂ produced. The transport sector is likely to be included in this scheme in 2010, with international air emissions also being included. The idea is to set a cap on the aggregate level of emissions and trade within this level. Trading is likely to be at the business and/or national level. Much uncertainty however remains as to how to implement a trading mechanism for carbon.

Very much related is the price of oil. Recent price rises have an important impact on travel demand (in early July 2008 Brent Crude oil prices were at \$140 per barrel, an increase of nearly 100% over the last 12 months). The typical elasticity used for vehicle travel with respect to fuel price is in the order of –0.15 in the short run and –0.3 over the long-run (Graham and Glaister, 2002). Recent price rises, we would

expect, should be feeding through to reduced demand for travel – hence may be acting as an effective enabler of reduced carbon dependency in travel. There is some limited evidence of this.

6. CONCLUSIONS: BACKCASTING FROM 2025

There are a range of policy pathways towards substantial improvements in carbon efficiency in the transport sector. All represent significant breaks against current trends and are likely to be very difficult to implement. A number of conclusions can be drawn:

1. The current trends mean that the transport sector continues to perform poorly in contributing to cross-sectoral CO₂ reduction targets. The clear message is to work more effectively across the broader range of policy packages available and at a higher intensity of application relative to current trends.
2. A balanced package of measures, described in this paper as an “optimal strategic policy package”, should take us near to the adopted 60% CO₂ reduction target. The large caveat here is that this assumes a successful level of application across a wide range of policy levers. Heavy investment is however required to move beyond a 40% reduction in emissions.
3. Low emission vehicles and alternative fuel penetration are likely to remain the most important policy levers as they tackle carbon efficiency in the dominant mode of travel (the private car). The main difficulty here is in achieving any level of success in penetration to the mass market. The motor industry and government need to develop mechanisms to achieve this, including mandatory targets for manufacturers. The 100 g/km car and 125 g/km light goods vehicle should be developed as a mandatory target for an agreed future year, say 2025.
4. There is also much potential in the behavioural measures, including pricing regimes, increased use of public transport, walking and cycling, ecological driving and slower speeds, and more efficient freight transport. Urban planning and soft measures, as well as acting in their own right, potentially perform very important roles as supporting measures to other policy packages, enabling higher levels of success in implementation.
5. There is little current understanding concerning synergies between policy levers and packages. Much further analysis is required on this issue, amongst others.

The likelihood of deep CO₂ reductions in the transport sector is looking slim, although some progress has been made in certain cities. The public needs to radically change their purchasing patterns and behaviour to be more carbon efficient. The means of knowledge dissemination, communication, participation in decision-making and marketing of policy options and futures all need to be considerably enhanced. Tools such as TC-SIM, applied to different contexts, could play an important role in testing different options with a range of different users. The backcasting approach offers a way forward to this future policy [and lifestyle] dilemma. The huge challenge now is to map out and discuss a variety of policy

pathways to carbon efficiency in the transport sector, and then – the difficult step – to enable and actually achieve a level of consumer and behavioural change consistent with strategic aspiration.

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ANNEX

Table A1: Policy Package and Enabling Mechanism Synergy Matrix

			Synergetic Policy Package (PP _j)												
	Policy Package ID	Policy Package Name	PP1	PP2	PP3	PP4	PP5	PP6	PP _j	PP7	PP8	PP9	PP10	PP11	PP12
			Low Emission Vehicles	Alternative Fuels	Pricing Regimes	Public Transport	Walking & Cycling	Urban Planning	Policy Package j	ICT	Soft Measures	Slower Speeds	Long Distance Travel Substitution	Freight Planning	International Air Travel
Main Policy Package (PP _i)	PP1	Low Emission Vehicles	1	F _{2,1}	F _{1,3}	F _{1,4}	F _{1,5}	F _{1,6}	F _{1,j}	F _{1,7}	F _{1,8}	F _{1,9}	F _{1,10}	F _{1,11}	F _{1,12}
	PP2	Alternative Fuels	F _{2,1}	1	F _{2,3}	F _{2,4}	F _{2,5}	F _{2,6}	F _{2,j}	F _{2,7}	F _{2,8}	F _{2,9}	F _{2,10}	F _{2,11}	F _{2,12}
	PP3	Pricing Regimes	F _{3,1}	F _{3,2}	1	F _{3,4}	F _{3,5}	F _{3,6}	F _{3,j}	F _{3,7}	F _{3,8}	F _{3,9}	F _{3,10}	F _{3,11}	F _{3,12}
	PP4	Public Transport	F _{4,1}	F _{4,2}	F _{4,3}	1	F _{4,5}	F _{4,6}	F _{4,j}	F _{4,7}	F _{4,8}	F _{4,9}	F _{4,10}	F _{4,11}	F _{4,12}
	PP5	Walking & Cycling	F _{5,1}	F _{5,2}	F _{5,3}	F _{5,4}	1	F _{5,6}	F _{5,j}	F _{5,7}	F _{5,8}	F _{5,9}	F _{5,10}	F _{5,11}	F _{5,12}
	PP6	Urban Planning	F _{6,1}	F _{6,2}	F _{6,3}	F _{6,4}	F _{6,5}	1	F _{6,j}	F _{6,7}	F _{6,8}	F _{6,9}	F _{6,10}	F _{6,11}	F _{6,12}
	PP _i	Policy Package i	F _{i,1}	F _{i,2}	F _{i,3}	F _{i,4}	F _{i,5}	F _{i,6}	F _{i,j}	F _{i,7}	F _{i,8}	F _{i,9}	F _{i,10}	F _{i,11}	F _{i,12}
	PP7	ICT	F _{7,1}	F _{7,2}	F _{7,3}	F _{7,4}	F _{7,5}	F _{7,6}	F _{7,j}	1	F _{7,8}	F _{7,9}	F _{7,10}	F _{7,11}	F _{7,12}
	PP8	Soft Measures	F _{8,1}	F _{8,2}	F _{8,3}	F _{8,4}	F _{8,5}	F _{8,6}	F _{8,j}	F _{8,7}	1	F _{8,9}	F _{8,10}	F _{8,11}	F _{8,12}
	PP9	Slower Speeds	F _{9,1}	F _{9,2}	F _{9,3}	F _{9,4}	F _{9,5}	F _{9,6}	F _{9,j}	F _{9,7}	F _{9,8}	1	F _{9,10}	F _{9,11}	F _{9,12}
	PP10	Long Distance Travel Substitution	F _{10,1}	F _{10,2}	F _{10,3}	F _{10,4}	F _{10,5}	F _{10,6}	F _{10,j}	F _{10,7}	F _{10,8}	F _{10,9}	1	F _{10,11}	F _{10,12}
	PP11	Freight Planning	F _{11,1}	F _{11,2}	F _{11,3}	F _{11,4}	F _{11,5}	F _{11,6}	F _{11,j}	F _{11,7}	F _{11,8}	F _{11,9}	F _{11,10}	1	F _{11,12}
	PP12	International Air Travel	F _{12,1}	F _{12,2}	F _{12,3}	F _{12,4}	F _{12,5}	F _{12,6}	F _{12,j}	F _{12,7}	F _{12,8}	F _{12,9}	F _{12,10}	F _{12,11}	1
Enabling Mechanism (EM _k)	EM1 BAU	Carbon Rationing BAU	0	0	0	0	0	0	0	0	0	0	0	0	0
	EM1 Medium	Carbon Rationing Medium	EM _{1,1}	EM _{1,2}	EM _{1,3}	EM _{1,4}	EM _{1,5}	EM _{1,6}	EM _{1,j}	EM _{1,7}	EM _{1,8}	EM _{1,9}	EM _{1,10}	EM _{1,11}	EM _{1,12}
	EM1 High	Carbon Rationing High	EM _{2,1}	EM _{2,2}	EM _{2,3}	EM _{2,4}	EM _{2,5}	EM _{2,6}	EM _{2,j}	EM _{2,7}	EM _{2,8}	EM _{2,9}	EM _{2,10}	EM _{2,11}	EM _{2,12}
	EM _k	EM _k	EM _{k,1}	EM _{k,2}	EM _{k,3}	EM _{k,4}	EM _{k,5}	EM _{k,6}	EM _{k,j}	EM _{k,7}	EM _{k,8}	EM _{k,9}	EM _{k,10}	EM _{k,11}	EM _{k,12}
	EM2 BAU	Oil Price Increase BAU	0	0	0	0	0	0	0	0	0	0	0	0	0
	EM2 Medium	Oil Price Increase Medium	EM _{3,1}	EM _{3,2}	EM _{3,3}	EM _{3,4}	EM _{3,5}	EM _{3,6}	EM _{3,j}	EM _{3,7}	EM _{3,8}	EM _{3,9}	EM _{3,10}	EM _{3,11}	EM _{3,12}
	EM2 High	Oil Price Increase High	EM _{4,1}	EM _{4,2}	EM _{4,3}	EM _{4,4}	EM _{4,5}	EM _{4,6}	EM _{4,j}	EM _{4,7}	EM _{4,8}	EM _{4,9}	EM _{4,10}	EM _{4,11}	EM _{4,12}

Formulae:

$$TCR = \sum_{i=1}^{12} \left(CR_{ppi} \times \left(F_{i,i} + \alpha_i \sum_{k=1}^2 EM_{k,i} \right) \right) + \sum_{\substack{j=1 \\ j \neq i}}^{12} \left(CR_{ppj} \times \left(F_{i,j} + \beta_j \sum_{k=1}^2 EM_{k,j} \right) \right) \quad (1)$$

$$TCR_{ppi} = \left(CR_{ppi} \times \left(F_{i,i} + \alpha_i \sum_{k=1}^2 EM_{k,i} \right) \right) + \sum_{\substack{j=1 \\ j \neq i}}^{12} \left(CR_{ppj} \times \left(F_{i,j} + \beta_j \sum_{k=1}^2 EM_{k,j} \right) \right) \quad (2)$$

Where;

$$TCR = \sum_{i=1}^{12} (TCR_{ppi}) \quad (3)$$

Notes:

- A.1. If PP1, PP3 and PP4 are selected in a specified order, then the selection of PP3, assuming PP1 has been previously selected, may result in a change in the carbon reduction associated with PP1 and equally PP3. Equally if PP1 and PP3 have been previously selected and PP4 is selected then change in the carbon reduction of PP1 and PP3, and for that matter PP4, may subsequently arise.
- A.2. The extent of this change is determined by the use of equations 1 and 2 together with the use of the corresponding synergetic factors reflected within the above synergy matrix. In addition a change in the overall carbon reduction of all selected policy packages and enabling mechanisms is likely to arise as defined by use of equation 1.

Definitions:

TCR	Total carbon reduction across all selected policy packages and enabling mechanisms including synergetic impacts.
TCR_{ppi}	Total carbon reduction associated with a single primary policy package (PP _i) encompassing synergetic impacts associated with other selected secondary policy packages (PP _j) and enabling mechanisms (EM _k).
CR_{ppi}	Carbon reduction for the selected primary policy package (PP _i) which does not include synergetic impacts associated with other selected secondary policy packages (PP _j) and enabling mechanisms (EM _k).
CR_{ppj}	Carbon reduction associated with other selected secondary policy packages (PP) which does not include synergetic impacts associated with other selected primary (PP _i) and secondary (PP _j) policy packages and enabling mechanisms (EM _k).
$F_{i,i}$	Factor denoting the nature of the synergy existing between two policy packages. In this case the two policy packages are identical and correspond to the diagonal or trace of the synergy matrix. The value of the factor for these cells is 1.0 in all instances. This represents a value which is then multiplied by carbon reduction associated with the selected primary policy package (CR_{ppi}).
$F_{i,j}$	Factor denoting the nature of the synergy existing between two different policy packages. In this case the two policy packages are not identical and correspond to the non-diagonal or non-trace elements of the synergy matrix. The value of the factor for these cells ($F_{i,j}$) will vary and is unlikely to be unity; for example may be -1 for synergetic policy packages which entail full double counting of policy benefits/impacts. This represents a value which is then multiplied by carbon reduction associated with the selected secondary policy package (CR_{ppj}).
$EM_{k,i}$	Factor denoting the nature of the synergy existing between the enabling mechanism k and a selected primary policy package i .
$EM_{k,j}$	Factor denoting the nature of the synergy existing between the enabling mechanism k and a selected secondary policy package j .
α_i	Primary policy package enabling mechanism direction factor, denoting the direction of change of the selected primary policy package i under consideration. If carbon reduction arises in comparison to the business as usual scenario then the factor is +1.0; otherwise in the case of an increase in carbon emissions the factor becomes -1.0. The factor only becomes negative for PP1 if the user selects a car or freight emission rate which is greater than the existing business as usual emission rate.
B_j	Secondary policy package enabling mechanism direction factor, denoting the direction of change of the selected secondary policy package j under consideration. If carbon reduction arises in comparison to the business as usual scenario then the factor is +1.0, otherwise, in the case of an increase in carbon emissions, the factor becomes -1.0. The

factor only becomes negative for PP1 if the user selects a car or freight emission rate which is greater than the existing business as usual emission rate.

It is possible to introduce an additional condition within the application of B_j that, for instances of full double counting of policy package benefits, ensures that if $F_{i,j} = -1$ then $B_j = 0$, i.e. the enabling mechanism synergies effectively do not apply in this instance.