ReVISIONS
WP14: Transport Supply - Phase 1

Transport technology options review
+
Method for defining the supply side of the options in the transport model

(DRAFT)
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1. Introduction

The EPSRC-funded ReVISIONS project is investigating how to plan new developments to be more sustainable through coordinated planning of spatial development and infrastructure for transport, water, waste and energy.

A new modelling framework (based around a Land Use Infrastructure Interaction LUII model) for testing of long term strategic policies is being developed in order to facilitate this. This model will capture the inter-relationships between land use and infrastructure for energy, buildings, transport, water and waste.

The SOLUTIONS project (precursor to ReVISIONS) found that changes in land uses applied to new developments and changes in transport infrastructure can be only relatively marginal compared to the amount of existing development. As a result, it found that focussing only on new developments and infrastructure initiatives can make only a small contribution to sustainable development. It concluded it was likely that new technologies, which can be applied to new developments as well as far more of the existing infrastructure, would be needed to provide more substantial benefits.

The ReVISIONS project is therefore aiming to assess the impact of new technologies (applied to transport, water, waste and energy) tested in combination with a number of different spatial options.

The work detailed in this report forms the output from Phase 1 of the transport supply aspects of WP14 (full details of the Phase 1 sub-contract between Newcastle University and Aberdeen University is contained in Annex A).

In short, there are three facets to the work:

1. identification of suitable approach to model changes in the transport supply including the ability to represent the new transport sector technologies
2. identification and review of new transport sector technologies which are likely to have an impact on sustainable development.
3. development of a set of methodologies for incorporating new technology measures in the transport supply model which will allow testing of the new technologies within the overall ReVISIONS modelling framework

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1 Work on transport demand is led by Cambridge University.
2. **Approach to model changes in the transport supply**

The modelling framework being developed by the ReVISIONS team is illustrated in Figure 2.1 and comprises of a new ReVISIONS land-use and choice model (based on MENTOR) linked to sector specific supply models in water, energy, waste and transport. The aim is to produce a robust strategic modelling tool that can be applied at the regional scale for testing integrated regional strategies by public sector organisations. Additionally, it will have ‘freeware’ open source software that is transparent, easy to understand and apply. It will allow regional organisations to gain a better understanding of the strategy alternatives and identify those that warrant further investigation with more detailed models.

The land use + choice model (which also includes a car ownership model) will produce information on population segmented by person type, household type and size, and daily travel production/attraction matrices segmented by person type which are converted to OD matrices by trip purpose and mode choice.

The future year outputs from this land-use + choice model will vary by land use policy and by policies / technologies / pricing measures applied in each sector. The spatial scale of these outputs will be based on ward level zoning. This forms the basis of the inputs to the individual sector supply models in water, energy, waste and transport.

![Figure 2.1: ReVISIONS modelling framework](image)

The policies / technologies / pricing measures to test will generally be applicable in the same manner in selected regions across the country. It may be that they only affect specific groups of the population (or affect some groups more than others), or specific area types (but in a consistent manner for areas of that type across the country).
Transport is a key part of the ReVISIONS modelling framework as it determines people’s travel choices and “costs” of travel, and hence influences the location of households and firms as well as energy demands.

Most transport supply models have been developed to provide the ability to assess the impacts of local transport schemes prior to introduction. They tend to contain a detailed representation of the road and public transport networks and split the study area into a large number of relatively small zones which generate trip demands. These models are extremely data intensive and if they are to cover a large area (e.g. a whole region) they take a very long time to run. For instance applying this level of detail at the national scale takes 74 hours to distribute the demand between zones and it then takes the newly developed GB assignment model a further 54 hours to assign the demand to the transport network. Using this approach to model the Regions separately would reduce these times but they would still require well over a day per region for each policy / technology / pricing measure to be tested.

The aim in ReVISIONS is not to be able to model specific local schemes, nor is it to provide accurate forecasts of the impacts of actual Regional or National policies. The aim is to be able to test the long term (2030 and up to 2050) impacts at the regional scale of a number of hypothetical measures or policies across the sectors which may become likely as a result of the enhancement and proliferation of existing new technologies.

Furthermore, given the multi-sectoral nature of the ReVISIONS model, policies in one sector can impact on other sectors (e.g. proliferation of electric vehicles impacts on the demand for energy and may have implications for the supply of energy). These relationships need to be identified and included in the modelling framework. This will inevitably require more feedback loops and hence more iterations to reach equilibrium. Therefore a key requirement for the supply side models is that they do not have very lengthy run times.

Due to the spatial scale of problem, the nature of the policies / technologies / pricing measures to be tested and the requirement for a relatively quick solution, a detailed representation of the transport networks is not considered to be absolutely necessary as long as the approach adopted is appropriate for purpose, robust, and can be run to test numerous combinations of policies / technologies / pricing measures.

After consideration of other alternatives it was felt that a simplified approach to simulating capacity constrained assignment was necessary and that the FORGE model approach adopted by the DfT in its use of the National Transport Model (NTM) for policy testing was generally suitable for use in ReVISIONS.

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2 Table 13.1 in WSP document "Equilibrium Modelling - Phase 2B Implementation report for NTM v3, December 2006"
http://www.dft.gov.uk/pgr/economics/ntm/ntmmodel2b.pdf

3 National Transport Model - High Level Overview, September 2009, Department for Transport.
http://www.dft.gov.uk/pgr/economics/ntm/highleveloverview.pdf
2.1 What is the National Transport Model and FORGE?

The NTM is a highly disaggregated multi-modal model of land-based transport in Great Britain. It comprises six modes - car driver, car passenger, rail, bus, walk and cycle.

The NTM has two main objectives:
- to produce forecasts in a future year of the main road transport indicators - traffic, congestion, carbon dioxide and pollutants - the NTM is designed to forecast long-term trends (currently 2015, 2025 and 2035) rather than individual years;
- to provide a policy and scenario testing tool by estimating the impact of a transport policy scenario or a change in forecasting assumption.

Therefore the NTM provides a systematic means of comparing the national consequences of alternative national transport policies or widely-applied local transport policies, against a range of background scenarios which take into account the major factors affecting future patterns of travel.
- Population and Employment
- Income / GDP
- Fuel Costs
- Fuel efficiency + Vehicle Standards  (variations in this can be tested)
- Alternative fuels uptake (biofuels)
- Policy measures, e.g. new National roads programme

Peer review and external validation have consistently shown that the National Transport Model (NTM) follows best practice, provides robust results and is fit for purpose. All the main forecasting assumptions, such as GDP, oil prices and population estimates are updated annually.

The basic NTM modelling framework is shown in Figure 2.2.

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**Figure 2.2: NTM modelling framework**
It is not proposed to use all the NTM sub-models shown in Figure 2.2 within the ReVISIONS modelling work.

Within the NTM the Car Ownership Model\(^4\), National Trip End Model\(^5\) and the demographic and planning input assumptions are collectively known as TEMPRO\(^6\). TEMPRO provides estimates of the number of trips made in each future year as a function of demographic and land use inputs and various economic forecasting assumptions. Trip productions are primarily generated by the location and structure of households and trip attractions by the location and structure of employment, schools, shops and leisure facilities.

In the centre of the system is the main Demand Model\(^7\) that first determines the geographic distribution of the trips and then the mode by which they are made. The Demand Model is not geographically detailed but it is highly segmented by trip length, trip purpose, and person type.

Within the ReVISIONS framework all the above tasks will be performed by the new ReVISIONS land-use and choice model (based on MENTOR).

ReVISIONS does however plan to follow the NTM’s simplified approach to simulating capacity constrained assignment utilising the FORGE sub-model. FORGE\(^8\) is a specialist highway model which takes outputs from a Demand Model (in our case the ReVISIONS land-use and choice model) to provide a more detailed estimate of highway traffic flows, congestion and pollution and models the traffic response to charges and changes in speed on particular road types.

The approach for integration between the ReVISIONS land-use/choice model and the FORGE model is described below and illustrated in Figure 2.3:

1. The ReVISIONS land-use model outputs daily production/attraction (PA) matrices segmented by person type at the ward level. Matrix adjustment is applied to convert PA matrices to OD matrices by trip type, car ownership and time of day. Input to ReVISIONS mode choice model.

2. The ReVISIONS mode choice model applies a discrete choice logit model and outputs OD matrix by trip type, mode of travel and time of day at the ward level.

3. A matrix conversion interface module converts OD matrix outputs from ward level to FORGE zonal representation by distance band. This is achieved using binary weight files available from the NTM (To be clarified at meeting with DfT on 16th July).

4. The NTM TRAFGEN tool uses the NTM base year (2003) Pass3 module output (estimates of traffic by road type, area type and sub-region known as mileage profiles\(^9\)) and links these to the OD matrix demand by distance band to generate traffic growth data (by road type, area type and sub-region) resulting from the future scenarios being tested.

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\(^6\) [http://www.dft.gov.uk/tempro/](http://www.dft.gov.uk/tempro/)


\(^8\) [http://www.dft.gov.uk/pgr/economics/ntm/etheroadcapacityandcosts3031.pdf](http://www.dft.gov.uk/pgr/economics/ntm/etheroadcapacityandcosts3031.pdf)

\(^9\) Mileage profiles provide the proportion of trip kms on each of the road types within each of the subregions for a given combination of distance group and area type.
5. Future year demands for freight are added. These are taken from NTM runs of Great Britain Freight Model (GBFM).

6. The program applies the traffic growth to the base year (2003) traffic database, to get a future year "demand" traffic volume in each cell. Speed-flow relationships are used to calculate the revised speed in each time period. From the speed, the fuel cost is calculated, added to any toll charges, and converted to minutes using the appropriate future year value of time (separate for each vehicle type).

7. This future year generalised travel time is compared with the base year value for each cell, and a set of rule-based responses applied. These shift traffic between cells, using elasticity values to determine the proportion of traffic which shifts, and the relative change in generalised time in the possible destination cells to determine where it shifts to. The allowed responses are:
   - Reassignment to another, less costly (in time), road of the same type in the same area type and sub-region.
   - Reassignment to another road of a lower road type in the same area type and sub-region (so motorway traffic can trickle down onto A-roads, and A-road traffic onto minor roads, but not vice versa)
   - Retiming of traffic from the weekday peak hours to the adjacent time periods
   - Reallocation of traffic across time periods, to reflect the extent to which responses modelled elsewhere have differential impact across different times of day.

8. Having shifted traffic, the program recalculates speeds and generalised times, and repeats the process until it converges to an equilibrium.

9. The outputs, which are all disaggregated by road type, area type and time of day include:
   - traffic (further disaggregated by vehicle type or car purpose)
   - total delay relative to free-flow speed (used for calculating congestion)
   - Traffic times, costs and any toll charges,
   - total tail-pipe emissions of the three major pollutants - CO2, NOx, PM10 - using emission equations as a function of speed at the detailed level

10. Car link speeds and any tolls are multiplied back by the mileage profiles to give a change in car driver journey speeds and money costs for each distance band and O-D area types. These revised generalised costs of car travel are fed back into the demand model (in our case the ReVISIONS land-use and choice model) for the next iteration.
Note that the assignment process is not intended to give accurate traffic levels on individual roads. The main purpose of the assignment model is to set up correspondence between trips (by distance band and origin/destination area types) and traffic (by road type, region, area type) for use in policy runs of the model.

Due to FORGE’s alternative representation of the supply model, the model can be run in much less time than a conventional network based assignment model.

A difficulty of using the FORGE approach is that it operates at a different level of spatial representation to the ReVISIONS land-use and choice model. Therefore within the ReVISIONS framework quite complex interfaces are therefore required to transfer data from one module to another.

The modelling of modes other than car has not been done explicitly (outside of mode choice modelling) by the NTM except for rail. Other modes will be represented within the ReVISIONS modelling in the mode choice model through cost and disutility functions but have no network assignment. It may be that this will also be the approach used to model rail based technology measures within RevISIONS (TBC).

Figure 2.4 illustrates how the NTM outputs and FORGE modelling fits within the overall ReVISIONS modelling framework.
Figure 2.4: Incorporating FORGE within the ReVISIONS modelling framework

Transport mode choice module
Derived from elasticities extracted from National Transport Model
Daily P/A matrices segmented by person type (ward level)
OD matrices by trip purpose (ward level)
Future year demands for freight added; taken from NTM runs of GBFM
OD matrices by mode + trip purpose (ward purpose) am peak; interpeak; pm peak

Other modes are represented in the mode choice model through cost and disutility functions but have no network assignment

Transport supply model using FORGE road capacity and costs model of NTM for highway
+ possibly using National Rail Model for rail

Daily P/A matrices segmented by person type (ward level)
OD matrices by trip purpose (ward level)
3. Identification and review of new transport sector technologies

A ‘rapid review’ of the trends and future technologies in the transport sector was conducted drawing on findings from relevant sources including key literature such as the Eddington and King reports and the Foresight Intelligent Infrastructure Study. Amongst other key projects and programmes reviewed were:

- the EU Future of Transport 2050 programme,
- “Transvisions: Report on Transport Scenarios with a 20 and 40 Year Horizon” (March 2009),
- UKERC Energy 2050 reports, including “What policies are effective at reducing carbon emissions from surface passenger transport? A review of interventions to encourage behavioural and technological change”, April 2009
- ‘energy efficient cities’ project on new technologies

In conducting the review into identifying suitable new technologies a number of criteria were applied to limit the number of technologies selected to those that were most relevant to the ReVISIONS study. The criteria applied were as follows:

a) Over the next 25 years is the technology inevitable, very likely or a far off vision?
   - Only consider those that are likely to be implemented or have significant take-up by users.

b) Is the technology likely to have significant impacts in travel behaviour or network conditions when aggregated to the regional level?

c) Is the technology likely to have significant impacts on sustainability? (this includes environmental as well as economic sustainability).

d) Can the technology be represented within a regional transport model and how will this be achieved?
   - It is essential to be able to adequately capture the characteristics of the technology in the model (through changes to model parameters).

e) Is the technology likely to have significant impacts on other sectors (e.g. demands for energy or health impacts etc.)
   - Those with synergies / conflicts with other sectors are the most interesting to the project but not all the transport measures need to impact on other sectors.

In total nine transport sector technologies were selected to be taken forward to the modelling phase of the work. These are listed below and were distributed across four areas of application as follows:
Highway measures - technologies to increase road capacity through advanced traffic management and signalling systems
   - 1. Adaptive Traffic Signal Control
   - 2. Motorway hard shoulder running
   - 3. In-vehicle dynamic route guidance systems

Bus based measures - technologies to reduce bus wait times or to increase bus speed
   - 4. Bus priority systems
   - 5. Real-time bus information on mobile devices
   - 6. Smart card payment

Rail based measures - measures to increase rail capacity
   - 7. Improvements to rail signalling systems (ERTMS)

Vehicle and engine technologies
   - 8. Electric Vehicles (EV), Plug-in Hybrid Electric Vehicles (PHEV) and Internal Combustion Engine (ICE)

In addition to the above measures the study also identified telecommuting as potentially impacting on the demand for travel although not explicitly being a transport sector technology.
   - 9. Telecommuting

It should also be recognised that all the above technology based measures may be tested in conjunction with a number of pricing measures, e.g. road-user charging, fuel price variations, public transport fare subsidies. These pricing measures should be considered in the testing phase of the ReVISIONS Transport modelling work.

Each of the nine technologies identified above have been reviewed in more detail identifying the following characteristics which form a set of inputs to the modelling phase of the work:
   o scale of introduction over time
   o the cost of introduction (per unit or per km as appropriate)
   o cost to user (per unit (e.g. purchase cost) or per km (e.g. operating cost) as appropriate)
   o any impacts in terms of changes to travel times, congestion levels, speeds, carbon emissions etc.
   o changes in capacity on the network.
   o spatial area classification in which the technology is applicable

Sections 3.1 to 3.9 presents a description and background information on each of the new technologies.

Section 4 goes on to describe how the technologies can be implemented in the ReVISIONS modelling framework and presents a summary containing the modelling inputs appropriate for use in the testing phase of the transport modelling work.
3.1 Adaptive Traffic Signal Control

Background

Improved traffic management which can maximise the efficiency and capacity of the existing road network is becoming increasingly necessary due to the continued increase in traffic volume and the limited construction of new highway facilities, especially in urban areas. The advent of ITS in the past 15 years has led to a number of applications that begin to provide an overall solution to the problem of traffic management including adaptive traffic signal control.

SCOOT (Split Cycle Offset Optimisation Technique) and MOVA are now very well established as the strategies of choice for adaptive traffic control in networked and stand alone applications. Adjustment is made to the traffic signal splits, offsets, phase lengths, and phase sequences in real time based on current traffic conditions, demand and road capacity. Adaptive signal control systems are able to optimize traffic signals to minimize delays and the number of stops rather than simply implementing settings according to a preconfigured plan calculated on historical data.

Both SCOOT and MOVA systems use sub-surface inductive loops to detect traffic conditions upstream of the junction and the resulting data is transmitted to a central computer where the optimisation process calculates the most appropriate signal settings. Data is transferred via dedicated telephone lines from the street. Figure 3.1.1 shows central computer screen shots illustrating SCOOT program outputs.

![Figure 3.1.1: Illustration of SCOOT system displays on central computer](image)

Both SCOOT and MOVA strategies rely on a high level of accurate traffic data and traditionally this data is gathered by detector loops buried in the road surface. However, being in the road surface, detector loops are vulnerable to damage. The differential stress caused by the weight of passing vehicles, thermal expansion and contraction, pavement shifting due to sandy soil conditions, pavement failure, or minor roadway construction can all cause the wires embedded in the pavement to break. Once damaged there is little chance of being able to repair a loop so it has to be replaced, which given its location in the road surface inevitably results in significant costs and disruption to traffic. Because of the likely traffic disruption it is often difficult in practice to effect loop repairs in a timely manner and in some cities it has been suggested that up to 25% of SCOOT loops may be out of action at any given time.
Therefore, although the materials involved with a loop are relatively inexpensive, the associated installation and repair costs, including disruption to traffic, have limited the installation of adaptive traffic signal control systems. The obvious solution is to move the detection out of the road surface altogether and use above ground detection, but until relatively recently the performance of such detectors has not really been shown to be good enough for SCOOT and MOVA applications.

However, new technologies such as wireless magnetometer vehicle-detection systems can overcome many of these cost and reliability issues. These systems employ ruggedised pavement-mounted, battery-powered magneto-resistive sensors to detect vehicle presence and movement. The sensors are wireless and transmit their real-time detection data via radio to a nearby access point, which then sends the data to a local traffic controller or to a central traffic management system (via IP communications) or to both at once (Figure 3.1.2).

Like inductive loops, the wireless sensors are pavement-mounted and placed exactly where vehicle detection is required. Because each sensor in its hardened plastic case occupies only a small spot typically in the center of a traffic lane, the sensors are not subject to the same stresses as an inductive loop and are not as readily damaged.

As a result of innovations in low-power circuitry and communications protocols, the average battery life of a sensor is 10 years. At the same time, installation of each sensor in the roadway can be conducted in less than 10 minutes, allowing shorter lane-closure durations and installation times than the installation of loops. The combined savings due to the system’s long life and simple installation make its overall life-cycle costs much less than that of loops.

Coupled with the cost savings and flexibility, this wireless vehicle-detection system provides a reliable, accurate and cost-effective alternative to inductive loop detectors and other detection technologies, and permits accurate vehicle detection to be deployed at a much higher density than has previously been possible.

![Figure 3.1.2: Wireless magnetometer vehicle detection system](image)
The costs of implementation

It is estimated that of the 12,500 signal controlled junctions in the UK around 25% currently operate under SCOOT and a further 8% are MOVA controlled\textsuperscript{10}.

A typical UTC system, brand new, costs anywhere between £40k and £60k for the instation system (hardware, software and a few desktop User Terminals). SCOOT adds up to £10k to this, the licence fee depending on the number of Junctions operating SCOOT. Support and maintenance for the instation typically runs at around £10k to £20k p.a.

Each Junction under UTC control (whether SCOOT or not) will require an Outstation device (or OTU). This adds about £2k to the cost of the junction installation, and there are likely to be additional detectors required. The cost of a “Junction” installation varies from around £10k for a simple PUFFIN crossing up to £50k or more for complex junctions such as roundabouts or gyratories. Maintenance costs for a junction vary significantly not just because of the variation in design but also the maintenance policy of the Local Authority and “unknowns” – mainly road traffic accidents, but also vandalism.

Interest in new communications technologies (fibre, ADSL and wireless mainly) indicates that savings offered by these are significant. There is also the issue that traditional analogue telephone communications are becoming more difficult to install and maintain.

Using radar/microwave and magnetometer detection instead of loops is also becoming more popular. As they are relatively new there is little data yet to indicate what the savings in maintenance costs might be. However the main advantage in this respect is that they can be maintained without having to close the road to traffic. The biggest savings appear to be achieved where detectors can communicate using a local wireless comms link to the junction controller – in this case there can be savings up to £10k on junction installation costs achieved by not having to install long cable runs between detector and controller.

\textsuperscript{10} Personal communication with Andrew Walker, Business Development Manager, PEEK Traffic Controls Ltd, 07/04/10.
3.2 Motorway hard shoulder running

Background

Large sections of the motorway network are becoming increasingly congested during peak periods, and these peaks are lasting for longer periods of time. This situation is forecast to significantly worsen over the next 20 years as car ownership levels and average driving distances continue to increase.

Building new roads is no longer an option in most situations. Widening of existing motorways from 3 to 4 lanes or from 2 to 3 lanes is being considered for over 200km of the motorway network in the UK. However the costs associated with this are considerable. For example the costs of conventional widening on the M42 from 3 lanes to 4 in each direction have been estimated at between £18m and £25m per km of motorway (at 2007 price levels). Motorway widening also requires considerable additional land-take, so the landscape impacts on heritage, biodiversity, water resources, geology and soils are significant.

An alternative to widening is to extend advanced signalling and traffic management systems more widely across the motorway network and then open up the hard shoulder for use as a running lane during congested times as part of a dynamic traffic management system. Hard shoulder running, when in operation, provides a similar capacity enhancement as widening. For a three lane motorway, a one-lane widening adds about a third to capacity.

Only a handful of countries currently operate schemes where the hard shoulder is used as a running lane. There is one scheme in the UK (the M42 pilot first introduced in Sept 2006), 17 schemes in the Netherlands, 6 schemes in Germany and one in the USA. In all instances the use of hard shoulder running has increased overall capacity, generated travel time savings and significantly improved journey time reliability while not negatively impacting on road safety.

The use of lower speed limits on the motorway, and the provision of additional capacity, can result in the smoother flow of traffic resulting in fewer incidences of stop-start traffic conditions and consequently vehicles on the road will move at more consistent and hence more fuel efficient speeds. In general, regardless of hard shoulder running, emissions per mile fall as average speed increases to 40-50mph where the fuel efficiency of the engine is greatest and then rises as the average speed increases towards 70mph and fuel efficiency falls. The gap between the two lines on the chart in Figure 3.2.1 illustrates the change in emissions associated with the M42 pilot. The chart shows that for the M42 the benefit was greater at lower speeds, where ordinarily, before the pilot, the traffic would have been subject to stop-start conditions.
Based on the experience from the M42 Pilot scheme in the UK the infrastructure required to allow hard shoulder to be used as running lanes includes the following: (See Figure 3.2.2 for an illustration of this infrastructure on the motorway)\textsuperscript{11}

- lightweight gantries with Variable Message Signs around every 500m;
- appropriate road markings, fixed signing and continuous safety fencing;
- Pan Tilt and Zoom (PTZ) cameras and HADECs cameras;
- fixed CCTV cameras typically up to 250m intervals;
- MIDAS;
- semi-automatic control system (SCS);
- lighting throughout the length of the scheme; and
- the necessary optical fibre cabling and communications links.

\textsuperscript{11} Advanced motorway signalling and traffic management feasibility study, DfT March 2008
The costs (at 2007 price levels) associated with delivering the M42 pilot were:

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>£m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure construction</td>
<td>53.6</td>
</tr>
<tr>
<td>Equipment</td>
<td>19.3</td>
</tr>
<tr>
<td>Control system</td>
<td>3.3</td>
</tr>
<tr>
<td>Consultancy fees</td>
<td>20.2</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>96.4</strong></td>
</tr>
</tbody>
</table>

If a larger scale scheme were to be implemented many of the above per km costs would be reduced or more widely shared (control system, consultancy fees). Therefore a cost of £4m per km can be assumed for large scale implementation.

This equates to a cost per km of motorway (both carriageways included) of **£5.6m** (outturn costs - covering the total cost of all of the design, development, delivery, construction, infrastructure and support costs from inception to maintenance handover).
3.3 In-vehicle dynamic route guidance systems

Background

In-vehicle dynamic route guidance is a form of Advanced Traveller Information System (ATIS) designed to provide users with information about the state of the road transportation network. ATIS include a technological infrastructure that collects data, processes them to generate traveller information and guidance, and disseminates the information to users. A wide array of sensor technologies that monitor traffic conditions, such as inductive loops or video cameras are used for data collection. These data are transmitted to a central management centre where they are automatically processed and analysed to extract the information of interest which may include not only route guidance and travel times but also details of incidents, weather and road conditions, speed recommendations, and lane-use restrictions. The information is then disseminated to users using various media, such as specialised website, variable message sign (VMS), or wireless communication directly to in-vehicle navigation systems (see Figure 3.3.1).

ATIS has the ability to benefit travellers and fleet operations (including public transport operations) in several different ways. The most direct would be the travel time savings that result from better routing. Improved routing can also translate into reductions in vehicle emissions, fuel consumption, traffic delays, and vehicle maintenance costs.

For commercial vehicles (e.g. public transport, taxi, DRT, goods) the accumulated time savings may be used to increase the allocation of deliveries per vehicle and so improve the efficiency of the fleet utilisation and generate additional revenue. ATIS may not only reduce travel times but also reduce the variability of these travel times by routing vehicles around incidents and other unexpected delays. This in turn led to higher traveller satisfaction with the transportation system and to shorter and more reliable delivery service for commercial vehicles. Notwithstanding the potential benefits of ATIS, there is also an argument that the more time saved by travellers can lead to more vehicle miles travelled.

Figure 3.3.1: Advanced Traveller Information Systems Configuration in a car (US FHA, 1998) and ATIS application on the website in British Columbia region, Canada
ATIS can be classified into various types of information which is utilised to generate routing and the timing of the dissemination of the guidance to drivers. More recently with the emergence of pervasive technologies, ways to collect data to improve road network reliability are evident (Schmocker and Lo, 2009). Toledo and Beinhaker (2006) evaluate the potential travel time savings of the various classes of ATIS using real-world traffic data that was collected from a freeway in Los Angeles, California, US. Table 3.3.1 shows the different information level, travel times and routing used in the Toledo and Beinhaker study. Travel times for the am peak trips, pm peak trips and all trips for the various levels of information are shown in Table 3.3.2 below.

Table 3.3.1 Information levels, travel times and routing (Toledo and Beinhaker, 2006)

<table>
<thead>
<tr>
<th>Information level</th>
<th>Travel time information</th>
<th>Routing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>Calculated as the length of a link divided by the speed limit</td>
<td>Static shortest path from origin to destination based on the provided travel times</td>
</tr>
<tr>
<td>Historical</td>
<td>Time-dependent travel times from the previous day</td>
<td>Dynamic shortest path from origin to destination based on the provided time-dependent travel times</td>
</tr>
<tr>
<td>Instantaneous / Pre-trip</td>
<td>Travel times from the current time interval</td>
<td>Static shortest path from origin to destination based on the current travel times at the departure time</td>
</tr>
<tr>
<td>Instantaneous / En-route</td>
<td>Travel times from the current time interval. Provided at every decision point (node) on the route</td>
<td>Static shortest path from current location to destination based on the current travel times. This path is re-evaluated at every decision point (node)</td>
</tr>
<tr>
<td>Predictive</td>
<td>Tune-dependent 'true' travel times</td>
<td>Dynamic shortest path from origin to destination based on the provided 'true' time-dependent travel times</td>
</tr>
</tbody>
</table>

Table 3.3.2 Average travel times for different information levels

<table>
<thead>
<tr>
<th>Information level</th>
<th>Am peak (min)</th>
<th>Savings (%)</th>
<th>Pm peak (min)</th>
<th>Savings (%)</th>
<th>All trips (min)</th>
<th>Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>75.6</td>
<td>-</td>
<td>88.4</td>
<td>-</td>
<td>82.0</td>
<td>-</td>
</tr>
<tr>
<td>Historical</td>
<td>74.9</td>
<td>0.8</td>
<td>87.0</td>
<td>1.6</td>
<td>80.9</td>
<td>1.3</td>
</tr>
<tr>
<td>Instantaneous / Pre-trip</td>
<td>71.3</td>
<td>5.6</td>
<td>83.6</td>
<td>5.5</td>
<td>77.4</td>
<td>5.5</td>
</tr>
<tr>
<td>Instantaneous / En-route</td>
<td>70.0</td>
<td>7.3</td>
<td>79.0</td>
<td>10.7</td>
<td>74.5</td>
<td>9.1</td>
</tr>
<tr>
<td>Predictive</td>
<td>68.4</td>
<td>9.5</td>
<td>76.2</td>
<td>13.8</td>
<td>72.3</td>
<td>11.8</td>
</tr>
</tbody>
</table>

An important assumption underlying the Toledo and Beinhaker (2006) study is that response to information does not affect traffic conditions, thus the market penetration of ATIS is assumed to be small. Therefore the number of drivers that change their routes in response to the information is negligible. As the market penetration of information provision services increases the assumption is not realistic any longer. The information drivers receive would affect the route choices of a more significant number of drivers. As a result, traffic flows and travel times on the network would be affected. Emmerink, Axhausen, Nijkamp and Rietveld (1995a, 1995b) observed that at the level of the individual informed driver, the travel time savings generally decrease when the ATIS market penetration increases. Figure 3.3.2, 3.3.3 and 3.3.4 (source: Emmerink, Axhausen, Nijkamp and Rietveld, 1995b) demonstrate the simulation experiments of the relationship between travel time saving and number of drivers using such information. The difference between the with and without information
curve has an interesting interpretation. It reflects the benefits to the population of drivers equipped with a dynamic route guidance (DRG) system. And can therefore, in combination with the cost of the system, be seen as an indicator of the market potential of these new technologies.

Figure 3.3.2 Travel time benefits of DRG in very congested network

Figure 3.3.3 Travel time benefits of DRG in congested network
A recent study on route choice behaviour (Elia and Shiftan, 2010) demonstrates that informed travellers (drivers) had faster learning rates and tended to base their decisions on memory relating to previous outcomes whereas non-informed travellers were slower in learning, required more exploration and tended to rely mostly on recent outcomes. Moreover, informed travellers were more prone to risk-seeking and had greater sensitivity to travel time variability. In comparison, non-informed travellers appeared to be more risk-averse and less sensitive to variability.

Fuel economy benefit of route guidance systems (such as ATIS) could save up to 10% of miles driven and proportional fuel consumption (ITSA, 2002). The timeliness and delivery of information will also influence the degree to which travellers use it and subsequent energy / CO2 emission impacts; and for the case of in-vehicle route guidance, benefits will likely be greater the less familiar a driver is with an area (Shaheen and Lipman, 2007).

References


[http://www.th.gov.bc.ca/atis/lgcws/index.html](http://www.th.gov.bc.ca/atis/lgcws/index.html)


### 3.4 Bus priority systems

**Background**

There are a number of new technologies which can increase the attractiveness of bus travel. One of these considered in more detail below includes bus priority systems.

These are often incorporated within a bus management system which allow operators to track and monitor their buses against the timetable or scheduled headway and also to record and analyse demand profiles via smartcard payment systems. Such sophisticated systems provide opportunities for better services to the travelling public. Figure 3.4.1 illustrates the technologies commonly applied in a bus management system.

![Figure 3.4.1 Technologies commonly applied in a bus management system](Source: Bus Priority – The way ahead, Department for Transport)

Bus priority systems have several benefits; reducing passengers’ travel times, operational savings for the operator due to quicker bus journeys, or increased service frequencies with the same number of vehicles.

Although methods of providing priority to buses at traffic signals have been available at isolated junctions since the late 1970’s these often required pre signals and bus advance
areas enable the bus to get to the front of other traffic at junctions requiring physical use of road space. ‘Virtual’ bus priority measures use various methods of communication to detect the presence of buses and activate traffic lights to give priority to buses at junctions. Selective Vehicle Detection (SVD), MOVA, Bus SCOOT and Automatic Vehicle Location (AVL).

These various technologies range from those which detect when a bus arrives at the traffic lights and then seeks to turn the lights green for the bus as soon as possible (limited benefits) through to technologies which can detect the location of a bus as it passes along its route and seek to set the lights ahead to provide priority to the bus – the level of this priority can be variable depending on whether the bus is running late or not. This has more recently been implemented for coordinated traffic signal control in SCOOT, a control strategy for traffic signals in urban areas.

Bus priority in SCOOT has provided reductions in delay as high as 50% when the degree of saturation is low. At high degrees of saturation, the reduction in delay is of the order of 5 - 10%. In extensive trials in London reduction of delay of around 4 seconds per bus per junction are typical. In terms of journey time savings this also varies widely according to traffic conditions (savings of up to 60% have been experienced) but an average value of between 10 – 20% can be expected to be achieved. (For more details on bus priority in SCOOT see http://www.scoot-utc.com/BusPriority.php?menu=Technical)

The cost of introducing bus priority to SCOOT is minimal if the SCOOT system is already in place and the buses are equipped with automatic vehicle location devices (see below for costs).

Reference:
3.5 Real time passenger information

Background

Bus management systems allow operators to track and monitor their buses against the timetable or scheduled headway. Information from the systems can be provided to the public in the form of real time passenger information, through various means: bus stop displays; SMS messages to individual subscribers; and web sites etc.

Most recent real time passenger information systems consist of Automatic Vehicle Locationing (AVL) equipment usually a GPS receiver fitted to each bus together with a radio transmitter, a central server and at stop signs. The bus communicates its position either on a regular (every 30 seconds) basis, or by exception, (when it reaches a certain point or does not reach a certain point within a time limited period). The central server then interprets the information from the bus and communicates the information using another radio transmitter, to the bus stop signs or to websites and to mobile devices on request.

Although the provision of real time passenger information to bus stop displays has been shown to reduce perceived wait time by between 20% - 30% (see Caulfield and O’Mahony, 2009) this does not result in an actual reduction in wait time.

If passengers were to be informed of real time bus information (via their mobile device) before they arrive at the bus stop then actual savings in wait time could be experienced as passengers have the opportunity of optimizing (i.e., delaying) their bus stop arrival time and thus reduce time spent waiting at a stop (Figure 3.5.1). Since the value of time for passengers waiting for a bus has been well documented to be approximately twice the value of time for passengers after they have boarded the vehicle the benefits of this are reinforced.

![Image of real time passenger information](image.png)

Figure 3.5.1: Example of real time passenger information sent to website or mobile device
(Source Ferris et al, 2010)
Evidence from the US Department of Transportation (2006) revealed that while 95% of Transit Tracker users (real time bus arrival information system via either phone or the internet) agreed the system reduces their wait time, although there are at present, no solid measures of what the average reduction in wait time actually is. Further evidence from the OneBusAway system implemented in Seattle, USA found that 91% of users reported spending less time waiting while 8% reported no change (Ferris et al, 2010).

The actual wait time savings will vary according to the frequency of the bus services in place. For instance passengers using a frequent service with 10 minute headway would not benefit from real time passenger information as much as those using a service with 30 minute headway. Therefore the provision of real time passenger information to mobile devices is assumed to provide a 33% reduction in wait time to bus users in urban areas while in rural areas the average wait time should be reduced by 66%.

The main costs of providing the information are related to on board automatic vehicle locationing equipment. On board GPS receiver, on board processor, radio card and antenna costs in the order of £1,600 - £3,500 at 2008 prices (Source - AECOM 2008) dependant on technology and radio network employed. These costs will decrease over time and will become lower as the scale of deployment of the technology increases.

Britain has approximately 40,000 conventional buses in service. To equip all of these at £2000 per bus would cost £80m. Replacement is needed every 5 years.

The costs to the user of receiving information currently range from 1 or 2 p per text up to 15p per text. However, as mobile communication becomes ubiquitous this cost will become submerged into communication contracts and so the marginal cost will be insignificant.

References:


3.6 Smartcard payment systems

Background

The main components of a smart ticketing system in public transport are:

1. A smart card, which could be personalised or be anonymous. The card is typically in plastic bank-card format which contains a tamper-resistant chip for security purposes. The card may contain a photograph, and may contain other applications (on the plastic and/or on the chip) – financial or related to local services. The card may be issued by a Local Authority or a Transport Operator. In the future, transport smart cards might be replaced by a bank card or mobile phone. Work is underway by the payment schemes to revise their international Chip and PIN specifications to meet the need of transport across the globe.

2. Card Reading Devices. On buses, an Electronic Ticket Machine (ETM), or validator reads from and writes to the chip on the card (Figure 3.6.1). In rail stations, gates and platform validators will perform the same functions. When a smart card is brought into proximity (a few centimetres) with an ETM, communication takes place between them. ETMs would typically be sited next to a bus driver, on railway station platforms, in station gates, on board trams, or carried by inspectors to check card validity.

Figure 3.6.1: Example of contactless smart card and reader from ‘Mastercard’

In addition to the above there will also be a network of depot computers for collecting the transaction data from the readers. This is then periodically forwarded to a centralised database management system run by a Local Authority or a large operator. This acts as the storage facility for the collected data and contains specialist software for analysis of the transaction data.

Smart ticketing has been shown to have many benefits including reducing congestion, fraud reductions, increased ridership and efficiencies in ticket sales. However the greatest benefit to bus users and operators is that of reducing bus dwell times. As well as reducing boarding times at transport nodes for passengers this also benefits operators through improved running times and fuel efficiency.
Although there are several smart ticketing schemes currently operating in the UK, there is considerable variation between the schemes in their stage of development, size, coverage and the technology used. Many of them are proprietary schemes that are not interoperable. Implementation of nationwide interoperable smart ticketing schemes could deliver enhanced benefits.

A comprehensive study by the DfT and Detica (2009) provides a high level review of the costs, as well as the tangible and intangible benefits seen by existing smart ticketing schemes in use on all modes of public transport. It uses this evidence, the detail at this point largely provided by bus schemes, to provide an early indication of the economic case for a national coverage of smart ticketing schemes.

The cost modelling shows that there are considerable start-up costs to rolling out national smart ticketing schemes across England (~£1bn). The on-going costs are lower but also significant. The study shows that the estimated capital costs could be justified within one year of full roll-out and subsequent full take-up.

The benefits to passengers suggested from the study show that with full interoperability 75% of passenger boarding time could be saved amounting to 15 seconds per stop. This equates to a total average journey time saving of 2 ½ minutes. A second study (YorCard) suggests a boarding time saving of 3 seconds per passenger through smart card ticketing.

The cost to users is relatively low (as Oyster Card evidence demonstrates) while the emergence of other technologies such as Near Field Communications (NFC) equipped phones is likely to change the face of smart ticketing within a few years. Mobile Network Operators estimate that upgrading a mobile handset to be NFC capable only adds about 1% to the cost of the handset and Sony-Ericsson recently announced that all their handsets will be NFC-capable by 2010. Therefore the cost to the user will become negligible.

The capital cost for operators for full roll-out is estimated to be £1.1billion with annual operating costs of £260million (DfT and Detica, 2009).
3.7 Improvements to rail signalling systems (ERTMS)

Background

The past decade has seen sustained growth in rail travel. An on-going challenge for the railway is to find cost-effective ways of providing more capacity. This can be achieved through a number of measures including commuter rail station platform lengthening, reconfiguration of the carriage layout to increase standing space (for commuter journeys of less than 1 hour) and improvements to rail signalling systems (Bartar, 2010).

There is also a desire to increase rail speed through a combination of the expansion of rail electrification and introduction of super express trains on key commuter corridors and high speed intercity rail services for longer distance travel to offer an alternative to air travel.

This creates a trade-off that will need to be considered between higher speed trains reducing journey times but at the same time requiring increased headway and hence reducing capacity.

The Institution of Railway Signal Engineers (IRSE) have examined this on plain line and identified that the maximum capacity occurs at about 70 km-h; however, capacity only starts to be reduced to any noticeable extent at speeds above 100 km-h, which are less relevant for suburban railways – the main focus of ReVISIONS.

Therefore ReVISIONS will focus attention on the network wide enhancement of rail signalling, specifically the introduction of the European Rail Traffic Management System (ERTMS).

ERTMS contains three basic elements (Railway Engineers Forum, 2007):

1. ETCS (European Train Control System) – the ‘signalling’ element of the system and includes the control of movement authorities, automatic train protection and the interface to the interlockings.

2. GSM-R (Global System for Mobiles – Railways) – the ‘communication’ element containing both a voice communication network between control rooms and trains, and a bearer path for the ETCS data.

3. ETML (European Traffic Management Layer) – the operations management level intended to optimise train movements by the intelligent interpretation of timetable and train running data.

ERTMS also comes in 3 application ‘levels’.

- Level 1 – little more than a harmonised ATP (Automatic Train Protection) system overlaid on existing conventional signalling systems but built to EU standards. Requires only a limited part of the ETCS element. It also permits non ETCS fitted trains to continue to run.
- Level 2 – a full train control and communication system using both ETCS and GSM-R. Retains existing train detection systems for positional information and can, where necessary, be overlaid on existing colour light signals. Uses radio for the delivery of movement instructions. Unless overlaid on conventional signalling, non ETCS trains cannot run.
- Level 3 – a fully radio dependent version of Level 2 where most trackside signalling infrastructure can be removed and the functionality moved to either Radio Block Centres (RBCs) or the on board train equipment. Can also facilitate moving block signalling. Non fitted ETCS trains cannot run.

Levels 1 and 2 are commercially available and a variant of Level 3 is under development for regional use. Much work remains to be done before Level 3 is a reality for mixed traffic, densely used, main lines.

The proposed introduction of an ERTMS signalling system can enhance capacity by allowing reduced headways and junction margins through reduction and optimisation of block lengths and by continuous ‘sighting’ of signal aspects (Network Rail, 2008).

Modelling work from TRL (2010) has investigated the theoretical capacity improvements of ERTMS over 4 aspect signalling.

- ERTMS Level 2 using existing infrastructure
  - Plain Line: 32% for an Electrostar: 35% for a Thameslink Train
  - Station stop: 13% for an Electrostar: 24% for a Thameslink Train

- ERTMS Level 2 with half size blocks
  - Plain Line: 41% for an Electrostar: 44% for a Thameslink Train
  - Station stop: 16% for an Electrostar: 29% for a Thameslink Train

- ERTMS Level 3 moving block
  - Plain Line: 47% for an Electrostar: 51% for a Thameslink Train
  - Station stop: 16% for an Electrostar: 29% for a Thameslink Train

According to the DfT’s ERTMS National Implementation Plan (DfT, 2007), when aligned with signalling renewals, implementation of ERTMS on the infrastructure in the UK will be complete in 2038. This Plan covers 72% of the infrastructure in the UK national network. The Plan has been developed in consultation with industry stakeholders and represents the best view of the UK rail industry, based upon information available.

The following figures show a graphical representations of ERTMS infrastructure and rolling stock implementation for 2024, 2034 and 2044. On each map, the incremental increases on each of the indicators are highlighted by the red blocks i.e. volume of ERTMS fitment which has occurred within the timeframe of the previous graphic and that in the current graphic. ERTMS fitment volumes completed in previous periods is indicated by the blue blocks. The grey blocks represent the SEUs, passenger vehicles, freight vehicles and on-track plant volumes across the entire UK network.

By 2044 it can be seen that the blue blocks which highlight the volume of fitment in the Plan, do not extend to the highest level of the scales. This is because the Plan does not cover the UK National network in its entirety. These graphics only reflect the elements of the network which are included in the Plan (TEN routes and Sub National). The Plan covers 72% of the UK national network infrastructure.
Cost of Introduction

Fitting rolling stock with new equipment is always expensive. An international study in 2006 showed the cost of fitting ERTMS equipment to trains in Europe to be (Railway Engineers Forum (2007):

- Train Equipment cost per cab £50k
- Fitting cost per cab for new train £35k
- Retro fitting existing train per cab up to £200k

The DfT (2007) estimate that more than 50% of the trains in the UK will require retro-installation of equipment. Retro-installation of an existing train requires it to be out of service for 10 days.

The railway engineers forum advocates the policy that all new build trains be fitted with ETCS and GSM-R in the factory and that the provision for ETCS and GSM-R in existing trains to be done during rolling stock major overhauls, preferably with equipment being fitted as well.

The cost benefit analysis conducted by the National ERTMS Project team in 2006 concluded that the cost of fitting lineside equipment for ERTMS was significantly cheaper than conventional signalling and that therefore ERTMS would be the system of choice for the future. Additional benefits, such as improved capacity, would be a bonus.

The commonly held perception is that ERTMS (principally the ETCS and GSM-R elements) has a high first cost with an expensive on board installation element, but that in the longer term, the ‘whole life’ costs will be cheaper when compared to a current proprietary signalling system.

Rolling stock and infrastructure equipment has a 35 year asset life.

References

http://www.rssb.co.uk/research/RSSB%20T915%20Capacity%20Report.pdf


3.8 Electric Vehicles (EV), Plug-in Hybrid Vehicles (PHEV) and Internal Combustion Engine (ICE)

Background

Electricity as a transport fuel results in zero emissions at the point of use. If it is produced from low CO2 sources, such as renewable, nuclear or, potentially, fossil energy with carbon capture and storage, it can have low or even effectively zero CO2 over its life cycle. It can also be produced from the full range of energy sources (Wikipedia, accessed 25/02/2010). Currently the main drawbacks with electric cars are their relatively low speed, short range and lengthy recharging times (King, 2007) and the cost of the technology. However, the development of hybrid vehicles using a combination of internal combustion engine using conventional fuel and electricity or a combination of a fuel cell powered by hydrogen and electricity or a mixture of both are gradually getting more popular. EUCAR (2009) illustrated the path way from ICE with 0% ‘emission free’ towards pure Battery electric vehicle of 100% ‘emission free’; the hybrid vehicles range from stop/start, mild, full, plug-in (parallel), plug-in (serial/range extension) and fuel cell (Figure 3.8.1).

![Figure 3.8.1 Electrification of the powertrain (EUCAR, 2009)](image)

It is anticipated that the switch to electricity will yield the benefits of higher efficiency energy converters in the form of pure electric motors as battery-motor systems are typically three times as efficient as hybrid combustion energy systems. Although full battery electric vehicles (BEVs) represent the ultimate target, hybrid electric vehicles (HEV) which can plug into the grid (PHEV) may serve as a transition technology primarily through the lowering of battery costs in the medium term. So far, a solely BEV market has been a failure in the US car market (Cao and Mokhtarian, 2004), although the range of cars on offer has been very limited and restricted largely to either very small ‘town cars’ or, so far, relatively expensive family sized cars. But hybrid cars using a mixture of internal combustion engine and electricity (e.g. Toyota Prius) has established a 3% car market in the US by 2007 (Transport and Environment, 2009) with Toyota Prius recording 1.43 million sales by August 2009 (Wikipedia).

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The major difference between HEV and PHEV is that HEVs have a very limited electric only capability and do not at any time plug into the grid.
Generally, electricity is distributed via a grid, so the basic charging infrastructure for electric vehicles is essentially in place. However, the large-scale uptake of pure electric cars requires wide availability of charging points, though given that electricity is already supplied diffusely, this should be straightforward to implement (King, 2007), although, depending on the rate and scale of introduction, attention must also be paid to the capacity of the low-voltage grid at the neighbourhood level. BERR and DfT (2008) reported that the UK has ‘sufficient generating capacity of low carbon electricity to cope with the uptake by 2030, assuming that charging is managed and targeted at off-peak periods, where there is currently surplus capacity. Although this raises key questions about when people will actually plug-in, which is likely to be influenced by myriad factors including personal convenience, daily schedules, and household behaviour. The need for additional capacity over the longer term depends on a host of unknown factors particularly the future grid mix and interactions with other sectors (this is also known as vehicle to grid scheme). For example, under a carbon constrained scenario with high amounts of wind energy, more installed capacity would be needed to meet electricity demand in order to cope with intermittent supply (Ekins and Skea 2009). From a number of international scenarios on the development of electric vehicles analysed (including UK), in the short term, hybrids will penetrate global markets sooner and more easily than fully fledged electric vehicles (Transport and Environment, 2009). The main reason is that new vehicle technology is likely to penetrate slowly and in turn usually takes 10 to 20 years to achieve 5% of new sales. However, it should be borne in mind that there are still many uncertainties over how and who would invest billions of pounds in the energy sector in the short term and the critical shift in energy planning necessary for the interactions between transport, housing and power sectors, all of which need a clear policy framework (IEA, 2008).

Although many uncertainties exist surrounding the scale and timing of market penetration, various global studies have developed optimistic scenarios ranging from between 40% to 90% market shares of various EV technologies between 2030 and 2050 (WBCSD, 2004; WEC, 2007; IEA, 2008; Berr and Dft 2008; McKinsey, 2009). However, the effectiveness of large-scale vehicle electrification to meet carbon emission targets is dependent upon decarbonization of the power sector while ensuring sufficient capacity for increasing electricity demand.

In 2007, the total number of vehicle registered in the UK was 33.9 million (Figure 3.8.2) of which 83.2% (28.2 million) are cars, 9.4% LGVs, 1.6% HGVs, 0.5% buses and coaches, 3.5% motorcycles, and 1.8% other (DfT Vehicle Licensing Statistics, 2007). Furthermore, 1000 cars are registered as Electric Vehicle (EV) and 16,000 are registered as non-plug-in EV (HEV). The total distance travelled by UK vehicles in 2006 was 506.4 billion km of which 79% was by cars, 13% LGVs, 6% HGVs, 1% each for buses and motorcycles. The average car journey was 13.6 km and 93% of all car journeys were less than 40km. The urban journeys had taken 38% share for all types of vehicle journeys with rural (42%) and motorways (20%). According to the Society of Motor Manufacturers and Traders Limited (SMMT) industry analysis, in 2006 there were 1.65m cars and commercial vehicles (CVs) produced in the UK. In the same year there were 2.73m vehicles newly registered. In 2005 there were 34.59m cars and CVs in use. It is estimated that over 2m vehicles are currently scrapped each year. The CV market was just under 390,000 units in 2006. The LCV market accounts for almost 85% of all CV registrations. Figure 3.8.3 shows total car sales by different fuel type.
UK DfT with BERR (2008) develop four scenarios for the introduction of electric cars until 2030 (Table 3.8.1). It has been underlined in the report that the scenarios do not represent forecasts or estimates of the future, rather they have been built to understand the potential magnitude of electrical energy required over time, the potential CO2 savings, impacts upon air quality and the potential storage available for Vehicle to Grid schemes. Business as Usual (BAU) and Mid-Range (MR) scenarios envisage the growth of EVs (Electric Vehicles) to be largely confined to large inner city areas, and therefore it can be argued that they are more easily incentivised in these areas. Outside of these environments both HEVs and PHEVs will be the alternative vehicle choice to conventional powertrains. The high (HR) and extreme range (ER) scenarios rely on the UK government wanting to position the country as a world leader in low carbon car use, manufacture and development, and that a mix of technologies will be developed to achieve this. Other scenarios for comparison can be seen in the highlighted box (Figure 3.8.4) that refers to the McKinsey report (2009).
Table 3.8.1 Uptake of electric vehicles (EV and PHEV) (Source: DfT and BERR, 2008)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2010 EV</th>
<th>2010 PHEV</th>
<th>2020 EV</th>
<th>2020 PHEV</th>
<th>2030 EV</th>
<th>2030 PHEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as Usual</td>
<td>3,000</td>
<td>1,000</td>
<td>70,000</td>
<td>200,000</td>
<td>500,000</td>
<td>2,500,000</td>
</tr>
<tr>
<td>Mid-Range</td>
<td>4,000</td>
<td>1,000</td>
<td>600,000</td>
<td>200,000</td>
<td>1,600,000</td>
<td>2,500,000</td>
</tr>
<tr>
<td>High-Range</td>
<td>4,000</td>
<td>1,000</td>
<td>1,200,000</td>
<td>350,000</td>
<td>3,300,000</td>
<td>7,900,000</td>
</tr>
<tr>
<td>Extreme Range</td>
<td>4,000</td>
<td>1,000</td>
<td>2,600,000</td>
<td>500,000</td>
<td>5,800,000</td>
<td>14,800,000</td>
</tr>
</tbody>
</table>

The variable costs which influence the market penetration of EVs will be: fuel price, battery cost, electricity costs and market interventions (BERR and DfT, 2008). The uptake of variable tariffs is suggested (ibid). Electricity whole market sales currently exhibit variations in price from £40 to £120 per MWh (ibid). Batteries can account for up to 75% of the extra cost of HEV and PHEV. Li-ion batteries can cost from £685 per kWh to £1780 per kWh (Transport and Environment, 2009). Electric cars usually use between 0.11 and 0.2 kWh/km while most cars have a range of 160km, this means a battery for electric car needs between 17 and 32 kWh (ibid).

BERR and DfT (2008) noted that the current high cost of batteries is a significant barrier to the uptake of EVs and PHEVs. Although whole life running costs of EVs and PHEVs may over time become lower than conventional ICVs (Internal Combustion Vehicles), the capital cost of EVs and PHEVs will always be higher in the study timeframe due to the significant additional cost of the batteries. With current battery costs, an EV equivalent of a current production vehicle could be more than double the forecourt price. According to the European Commission’s research body, the JRC (2008, cited in Transport and Environment, 2009), hybrid vehicles on the market cost on average £2,670-4,450 more than comparable conventional models. The additional cost of hybridisation is £3,115 per medium-sized vehicle. Comparison estimates can be seen in the highlighted box below sourced from the McKinsey report (2009).

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33 All the euro estimates based on currency conversion using [http://www.pounds2euro.com/](http://www.pounds2euro.com/)

The report looks at reducing CO2 emissions from the car sector at the global transport system. It considers 3 scenarios up until 2030:

1. Improving internal combustion engines,
2. A mixture of hybrid, electric and internal combustion technologies, and
3. A hybrid and electric technologies scenario.

Figure 3.8.4 shows the different scenarios and sales of electric cars predicted in the McKinsey report (2009).

The hybrid and electric scenario assumes a rapid transition towards a world of electricity-based powertrains. In the most aggressive electrification scenario, greenhouse gas emissions from the transport sector might be reduced by 81% relative to the no-action baseline. The report does not detail the timing of the transition but lists certain factors that will dictate it: costs, a technical breakthrough that significantly reduces battery system costs, and development of an infrastructure that supports vehicle charging on a mass scale.

Figure 3.8.4 Different scenarios and sales of electric cars (McKinsey 2009:7)
The McKinsey report emphasizes that focusing solely on ICE would likely be more cost effective but it would do little to prepare the automotive sector for a transition to a new propulsion systems capable of achieving greater emission reductions in the longer term. The report estimates that optimising the fuel efficiency of ICE (together with other measures such as changing driving behaviour, regulating traffic flow etc. – integrated approach) could result in a 42% emissions saving relative to the no-action baseline, equivalent to a global fleet average emission of 170 g CO2/km by 2030.

Figure 3.8.5 shows the potential saving of CO2 emissions from different scenarios.

**Figure 3.8.5 Potential saving of GHG emissions across different scenarios (McKinsey 2009: 6)**

Cost to user (McKinsey 2009: 12-13):

1. Internal Combustion Engines: optimised technologies today can improve fuel efficiency up to 39% (relative to today’s conventional ICE vehicles) at additional cost of around £2,667 per vehicle.
2. Hybrid Electric Vehicle (HEV): current HEV technology can improve fuel efficiency by about 44% at additional cost of almost £3,556 per vehicle.
3. Plug-in Hybrid Electric Vehicle (PHEV): combined with other optimised feature can improve fuel efficiency of 65-80% at additional cost of £14,338 for a vehicle with an electric driving range of 60km.
4. Electric Vehicle (EV): by 2030, EVs could provide well-to-wheel emissions reduction of 70-85% with cost reductions for batteries 5-8% per year, at additional cost of £32,009 today to £5,157, over the next two decades for a vehicle with driving range of 60km.
Regarding the Internal Combustion Engine (ICE), the King review (2007) stated that there are limits to decarbonisation through development of conventional petrol and diesel engine. In the medium term, further efficiency gains are likely to come increasingly from the use of electric hybrid propulsion system. Table 3.8.2 below summarises the cost saving of ICE improvement.

<table>
<thead>
<tr>
<th>Cost saving</th>
<th>£300 - £500 lower fuel bill a year (on 10,000 miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 reductions (see below of breakdown ICE technologies)</td>
<td>Up to 30% (through fuel efficiency)</td>
</tr>
<tr>
<td>Direct injection and lean burn*</td>
<td>10 – 13% (£200-400)</td>
</tr>
<tr>
<td>Variable valve actuation*</td>
<td>5 – 7% (£175-250)</td>
</tr>
<tr>
<td>Downsizing engine capacity with turbocharging or supercharging*</td>
<td>10 – 15% (£150-300)</td>
</tr>
<tr>
<td>Dual clutch transmission*</td>
<td>4 – 5% (£400-600)</td>
</tr>
<tr>
<td>Stop – start*</td>
<td>3 – 4% (£100-200)</td>
</tr>
<tr>
<td>Stop start with regenerative braking*</td>
<td>7% (£350-450)</td>
</tr>
<tr>
<td>Electric motor assist*</td>
<td>7% (£1,000)</td>
</tr>
<tr>
<td>Reduced mechanical friction components*</td>
<td>3 – 5% (negligible)</td>
</tr>
<tr>
<td>Total introduction cost</td>
<td>Extra £1,000 - £1,500 per vehicle</td>
</tr>
</tbody>
</table>

* Number in brackets is extra cost per vehicle

References


3.9 Telecommuting

Background

Telecommuting, also known as teleworking, is generally defined as work at a remote location or home office rather than working at a fixed employer-provided site or office. The essential feature of telecommuting is ‘the use of information and communications technologies to enable remote working from the office (DTI, 2003). With the development of communication technologies, such as mobile phones, personal computers and the internet, it is becoming increasingly feasible for people to work from home or in other locations that are remote from centralised office, distribution or production facilities. This type of working arrangement potentially widens opportunities for people to participate and remain in employment as well as to change working patterns and to impact on the health, safety and welfare of the workers involved (Ruiz and Walling, 2005).

On its own transport substitution through the use of ICT will deliver only modest reductions in overall traffic levels for 3 basic reasons:

- Commuting trips are only around half of all trips by car (DfT, 2007a)
- Recent UK figures provided from the National Travel Survey between year 2002 and 2005 show 83% of full-time employees currently consider it would not be possible for them to work at home (DfT, 2005). Even accounting for changing working practices in the future, probably only about 30-40% of work can effectively be done on a flexible location basis.
- It is likely that other trips will be generated (see for example evidence on travel time budget theory as described below).

UK evidence has shown an apparent higher incidence of part-day homeworking compared to whole-day homeworking amongst full-time paid employees - the implication is that this could in future contribute to spreading of peak period traffic (Haddad, Lyons and Chatterjee, 2009). Glaister (2008) observed that the potential benefit offered by innovations such as homeworking and so-called Soft Travel Demand Management (STDM) might deliver, at best, a 15% reduction in car traffic (DfT, 2007b). That is, optimistically, 15 years’ worth of traffic growth at the forecast rate (Glaister, 2008). Under this scenario congestion would be kept at current levels in the medium term, requiring an enormously expensive national public information campaign to sustain. Unless there is an unprecedented revolution in the attraction and effectiveness of homeworking the contribution it can make is small in relation to the domestic transport problem facing the nation. Furthermore, A US study using travel time budget theory shows that people’s travelling time is relatively steady over time at the aggregate level though when measured at disaggregate level, the results vary with strong relationship to individual and household characteristics (Mokhtarian and Chen, 2004). Thus, relating to homeworking travel reduction potential, this evidence demonstrates that people still do travel despite the home working environment.

Nevertheless most recent UK and European studies have concluded that homeworking reduces travel and therefore associated carbon emissions (Banister et al., 2007). UK DfT concluded that teleworking could reduce UK car commuting trips by 3 – 12% (Cairns et al., 2005).

Lake (2008) observed that without homeworking, the consequence would include an extra six billion commute miles on UK roads each year and over 35 million additional m² of
employment floorspace would be needed to accommodate the displaced homeworkers.

Table 3.9.1 shows potential benefit of telecommuting.

**Table 3.9.1 Average saving from avoiding commuting (source: Lake et al., 2008)**

<table>
<thead>
<tr>
<th></th>
<th>Average employed worker</th>
<th>Full-time homeworker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance saved per year</td>
<td>1175 miles</td>
<td>3915 miles</td>
</tr>
<tr>
<td>CO₂ saved per year</td>
<td>364.5kg</td>
<td>1187 kg</td>
</tr>
<tr>
<td>Time saved per year</td>
<td>61 hours</td>
<td>202.5 hours</td>
</tr>
</tbody>
</table>

*Note: Calculated on basis of 45 working weeks per year*

According to the Labour Force Survey (cited in Ruiz and Walling, 2005), in spring 2005, around 3.1 million people in the UK worked mainly in their own home, or in different places using home as a base. Of these homeworkers, 2.4 million used both a telephone and computer to carry out their work at home (teleworkers). Of these, 2.1 million could not work at home (or use home as a base) without using both a telephone and a computer (TC teleworkers). Most teleworkers (1.8 million) worked in different places using their home as a base. Relatively few people (0.6 million) worked mainly in their own home. In 1997 teleworkers represented 40% of homeworkers. By spring 2005 this had risen to 77%.

Although teleworkers represent a small proportion of the total workforce, this proportion increased from 4% in spring 1997 to 8% in spring 2005 (Figure 3.9.1). The numbers working from home is growing by some 3.5% a year (Banister et al., 2007).

**Figure 3.9.1 UK Trend Telecommuters (source: Ruiz and Walling, 2005)**

The Labour Force Survey 2005 (as cited in Ruiz and Walling, 2005) showed that around 90% of teleworkers work in managerial, professional, associate professional and technical, and
skilled trade occupations. In other less skilled occupations, the potential is substantially less. The proportion of workers who telework in their own home is highest in the banking finance and insurance industry. Table 3.9.2 shows the breakdown of type of occupation by homeworkers in the UK.

**Table 3.9.2 Characteristics of UK homeworkers and telecommuters**, spring 2005

<table>
<thead>
<tr>
<th></th>
<th>All in employment</th>
<th>Homeworkers</th>
<th>of which: teleworkers</th>
<th>of which: TC teleworkers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Works mainly in own home</td>
<td>Works in different places using home as a base</td>
<td>Works mainly in own home</td>
<td>Works in different places using home as a base</td>
</tr>
<tr>
<td>Man</td>
<td>53</td>
<td>36</td>
<td>68</td>
<td>41</td>
</tr>
<tr>
<td>Women</td>
<td>47</td>
<td>64</td>
<td>21</td>
<td>59</td>
</tr>
<tr>
<td>Employment status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employee</td>
<td>87</td>
<td>32</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>Self-employed</td>
<td>13</td>
<td>62</td>
<td>64</td>
<td>62</td>
</tr>
<tr>
<td>Unpaid family worker</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Full-time</td>
<td>72</td>
<td>49</td>
<td>79</td>
<td>53</td>
</tr>
<tr>
<td>Part-time</td>
<td>28</td>
<td>51</td>
<td>21</td>
<td>47</td>
</tr>
<tr>
<td>Occupation (SOC 2000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Managers and Senior Officials</td>
<td>16</td>
<td>19</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>2 Professional occupations</td>
<td>13</td>
<td>14</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>3 Associate Professional and Technical</td>
<td>17</td>
<td>23</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td>4 Administrative and Secretarial</td>
<td>7</td>
<td>22</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>5 Skilled Trades Occupations</td>
<td>27</td>
<td>5</td>
<td>34</td>
<td>3</td>
</tr>
<tr>
<td>6 Personal Service Occupations</td>
<td>7</td>
<td>12</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>7 Sales and Customer Service Occupations</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>8 Process Plant and Machine Operatives</td>
<td>6</td>
<td>2</td>
<td>8</td>
<td>1*</td>
</tr>
<tr>
<td>9 Elementary Occupations</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

| Total (thousands) = 100%             | 28,049            | 768          | 2,324                 | 3,092                    | 603                       | 1,774                     | 2,377                    | 524                       | 1,538                     | 2,062                     |

Source: Labour Force Survey

*a* Excludes people on government employment and training schemes who, although classified as in employment, are not asked the LFS homeworking or teleworking questions.

*b* Homeworkers work mainly in their own home, or in different places using home as a base, in their main job.

*c* Teleworkers are a subgroup of homeworkers who use both a telephone and a computer to work at home, or in different places using home as a base.

*d* TC teleworkers are a subgroup of teleworkers who could not work at home, or in different places using home as a base, without using both a telephone and a computer.

*e* Totals have been adjusted for non-response to the homeworking and teleworking questions. Percentages are based on those who gave a valid response.

* Estimates are based on a small sample and may be subject to a high degree of sampling variability.

Banister et al. (2007) evaluated the comparative impacts of teleworking versus office carbon impacts. This proposes a typical carbon cost of using a room for home-based telework as being 173kg CO2 per year if one day per week, and 865kg per year if five days per week (costs of heating and lighting a room plus equipment energy use). Moreover, the number of homeworkers who are classed as working mainly in their own homes is likely to reach 850,000 by 2010, most of whom will use TC.

James (2008) on homeworking impact on carbon emission observed that it is clear that
homeworking will increase energy consumption but the extent of the increase is uncertain due to various variables including: level of insulation, thermal storage, age, size and homes location etc. Table 3.9.3 presents some data on energy consumption.

**Table 3.9.3 Energy Consumption of UK Homes and Offices (James, 2008)**

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Energy Consumption (kwh/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office – naturally ventilated, cellular (2003 average)</td>
<td>205</td>
</tr>
<tr>
<td>Office – naturally ventilated, open plan (2003 average)</td>
<td>236</td>
</tr>
<tr>
<td>Office – air conditioned, standard (2005 average)</td>
<td>404</td>
</tr>
<tr>
<td>Office – air conditioned, prestige (2005 average)</td>
<td>568</td>
</tr>
<tr>
<td>Dwelling (UK 2005 average, all stock)</td>
<td>261-368</td>
</tr>
<tr>
<td>Dwelling (built to 1998 Building Regs)</td>
<td>128-216</td>
</tr>
<tr>
<td>Dwelling (built to 2005 Building Regs)</td>
<td>75-124</td>
</tr>
</tbody>
</table>

Source: Carbon Trust, Employee Awareness Posters (2003) and Letcher, M with Chambers, C Towards Low-Carbon Housing Developments (2005)

A study by Sun Microsystems’ Open Work flexible working programme (as cited in James, 2008) measured that equipment energy consumption at office was 130 watts per hour per worker - that is twice the approximately 64 watts per hour of home office equipment energy consumption. The reason for this is because the office employees tend to use workstations and monitors while more home employees use laptops that require less power than traditional pc/monitor combinations. Moreover, James (2008) concluded that electricity consumption connected with telecommunications use is relatively negligible.

**References**


Mokhtarian P. and Chen, C. (2004) TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets. Transportation Research Part A 38(9-10): 643-675


4. Methodologies for incorporating new technology measures in the transport supply model

This section suggests a set of methodologies for incorporating the new technology measures (described in Section 3) in the transport supply model which will allow testing of the new technologies within the overall ReVISIONS modelling framework.

For each technology a description is provided on how the technologies can be implemented in the ReVISIONS modelling framework and a summary containing the modelling inputs appropriate for use in the testing phase of the transport modelling work is presented.

4.1 Adaptive Traffic Signal Control

Implementation in the ReVISIONS modelling framework

SCOOT is in use worldwide and has been shown to give significant benefits over the best fixed time operation. The measured benefits of SCOOT depend on the efficiency of the previous method of control and on site factors, such as the distance between junctions and the flows of vehicles.

The effectiveness of the SCOOT strategy has been assessed by major trials in numerous locations. The results from the trials are detailed at the following address: http://www.scoot utc.com/documents/survey_results.pdf. A selection of these for the UK are summarised in Table 4.1.1 below.

**Table 4.1.1 Outcome of SCOOT trials**

<table>
<thead>
<tr>
<th>Location</th>
<th>Previous Control</th>
<th>% Reduction in Journey</th>
<th>% Reduction in Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glasgow</td>
<td>Fixed-time</td>
<td>12% AM Peak</td>
<td>20% PM Peak</td>
</tr>
<tr>
<td>Coventry (1981)</td>
<td>Fixed-time</td>
<td>14% AM Peak</td>
<td>22% PM Peak</td>
</tr>
<tr>
<td>Worcester (1996)</td>
<td>Fixed-time</td>
<td>16% AM Peak</td>
<td>23% PM Peak</td>
</tr>
<tr>
<td>Southampton (1984;5)</td>
<td>Isolated V-VA^*</td>
<td>18% AM Peak</td>
<td>26% PM Peak</td>
</tr>
<tr>
<td>London (1985)</td>
<td>Fixed-time Average 8% cars, 6% Average 19% buses</td>
<td>20% AM Peak</td>
<td>39% PM Peak</td>
</tr>
</tbody>
</table>

On average, it is estimated that SCOOT would reduce delays by approximately 12% against up-to-date signal settings and 20% over a typical fixed-time system. In practice, fixed time plans go out of date as traffic patterns change, by about 3% a year on average, so the benefits of SCOOT over an older fixed time plan would be even greater.

From the evidence, it is not unreasonable to assume an average reduction in journey times for cars of 8% across urban areas where SCOOT control is in place. As about 33% of the existing urban junctions are already either SCOOT or MOVA controlled expanding the urban...
areas served by SCOOT or MOVA from 33% to 100% would result in average journey time savings of 5.5% for all drivers across the urban area.

The approach for applying this to the ReVISIONS modelling would be to run the FORGE model using adjusted speed-flow curves for road types in urban areas. The adjustment will reflect a 5.5% reduction in travel time represented by a higher speed for the same levels of flow. This effectively means the speed flow curve is moved to the right on horizontal axes as shown by the illustrative example in Figure 4.1.1 (the red line representing the adjusted speed flow curve).

Figure 4.1.1: Example of adjustment to urban central link speed flow curve

Summary for modelling inputs

- **Level of Uptake** - 100% of urban junctions which are currently signal controlled is technologically possible. Currently around 25% are SCOOT controlled and a further 8% are MOVA controlled.
- **Adoption over time** - Actual implementation over time will depend on finance available.
- **Costs** - Costs for traditional inductive loop installations range from £18,000 to £25,000 per typical 4 arm junction. For wireless magnetometer vehicle detection system these are much lower – possibly as low as £5000 per junction. To upgrade the 8000 existing non adaptive signal controlled junctions to SCOOT control, assuming installation costs of £10,000 per junction would require and extra £80m.
- **Benefits** – the main benefits are time savings to drivers - Evidence from numerous sites suggest an average 8% saving in journey times in areas with SCOOT or MOVA control compared to fixed time control. Expanding the urban areas served by SCOOT or MOVA from 33% to 100% would result in average journey time savings of 5.5% for all drivers across the urban area. For our work, travel time savings will be calculated by the FORGE model based on adapted speed flow curves for urban road types (as illustrated in Figure 4.1.1).
- **Impacts on other sectors** - Little or no additional energy demand as only applied at junctions which are already signal controlled.
4.2 Motorway hard shoulder running

Implementation in the ReVISIONS modelling framework

In strategic transport models, congestion effects are estimated using curves that map the speed of traffic with flow levels, these being different for different types of roads. Increased capacity reduces congestion for a given flow and this is modelled by changing the speed-flow relationship recognising that the fall off in speed as traffic increases will occur at a higher flow level.

The results of the M42 hard shoulder running pilot have been used to develop a speed flow curve and to determine the flow at which hard shoulder running is 'switched on'. The motorway speed flow curves used to model hard shoulder running are shown in Figure 4.2.1 below. As flows on a link increase the speed declines as shown by the light blue line which is for a dual 3 lane motorway. When the flow reaches a figure of 4200 vehicles, and the speed is approximately 60 mph, the model allows use of the hard shoulder and increases the capacity of the link. In normal circumstances such an increase in capacity would result in speeds increasing to those shown by the pink line (for D4M) however, with hard shoulder running the speed is maintained at approximately 60 mph and then declines gradually as flows increase until it meets the existing dual 4 lane motorway curve at a flow of approximately 5800 vehicles per hour. This is shown by the dark blue line. For flows in excess of this figure the vehicle speeds decline as if the link were a normal 4 lane motorway.

Applying the above described speed flow curve to links of type ‘Motorway’ within the FORGE model allows simulation of the opening and closing of lanes on motorway links. In doing so the model assumes that the hard shoulder is able to provide the same capacity as a normal motorway lane.

Figure 4.2.1: Motorway hard shoulder running (HSR) speed flow curve
Summary for modelling inputs

- **Level of Uptake** - 100% of motorway network is technologically possible.
- **Adoption over time** - Actual implementation over time will depend on finance available.
- **Costs** – £4m per km motorway. Total Motorway Network in England = 2846km. Total cost of introducing across the motorway network is £11,384m
- **Benefits** – the main benefits are time savings to drivers - As calculated by generalized cost outputs from FORGE. For our work, travel time savings will be calculated by the FORGE model based on adapted speed flow curves for motorway road types (as illustrated in Figure 4.2.1).
- **Impacts on other sectors** - Energy demands: Annually, electricity to run the system 71,850 KWh per km. Total energy demand across the motorway network is 204 MWh. Total energy cost = £5748 per KM = £16.35m per annum (assuming 8p per KWh)

### 4.3 In-vehicle dynamic route guidance systems

Implementation in the ReVISIONS modelling framework

In vehicle route guidance systems have the potential to reduce travel times ranging from 1% to 40% for informed drivers. However, different information levels and different times of travelling (am/pm) can lead to different time savings. For ReVISIONS, it is envisaged that the level of information available to users, considering available current technology in the market, are at the Instantaneous / En-route and predictive level, so it is expected that in-vehicle route guidance can save between 7.3 – 9.5% travel time at am peak and 10.7 – 13.8% at pm peak as documented in Toledo and Beinhaker (2006). Emmerink, Axhausen, Nijkamp and Rietveld (1995b) observed that depending upon the level of congestion, in-vehicle route guidance with en-route information provision can benefit up to 15% travel time saving to equipped driver under low levels of market penetration (below 20%). At the high level market penetration, the average network travel time savings are between 3 and 5% compared to the situation without information.

Summary for ReVISIONS modelling inputs

- **Level of Uptake** – 100% of drivers equipped with in-vehicle guidance is possible but the optimum user benefit is achieved when up to 20% of the drivers are equipped. The relative benefit per equipped user diminishes when uptake exceeds this level although the total network benefit continues to increase at higher levels of uptake.
- **Adoption over time** – It is likely that 20% of urban drivers will be equipped with in-vehicle route guidance by 2030. A total market uptake of 50% of drivers could be expected by 2050. The diminishing returns above this level suggest this is the limit of adoption.
- **Costs** – the cost of technology increases with the level of information provided. New vehicles now have the option to be equipped with the technology at an extra cost. But seeing the evidence of limited optimum market benefit, the price decrease of the technology is expected to be modest.
- **Benefits** – the main benefits are travel time savings and reductions in travel time variability that increase with the sophistication of the methods used to estimate the travel time information. The average travel time savings for all network users when 20% of drivers are equipped with in vehicle route guidance is approx 3.5% for all drivers in
congested conditions and 2.5% in very congested conditions. When 50% of drivers are equipped the average travel time savings for all network users is 3% in congested conditions and 5.5% in very congested conditions.

- **Impacts on other sectors** – Little or no additional energy demand is required for in-vehicle navigation systems.

### 4.4 Bus priority systems

**Implementation in the ReVISIONS modelling framework**

The bus priority measure will be implemented in the ReVISIONS modelling framework by making suitable adjustments to the average bus speed parameters. This will result in a variation to the generalized cost of travel by bus which will effect a change in the mode choice modelling. From this, there will be a change to the model estimates of overall vehicle-km driven and hence a resultant change in congestion and CO2 emissions.

**Summary for modelling inputs**

- **Level of Uptake** - Provided at all junctions in urban areas where SCOOT system is in place. 100% of urban junctions which are currently signal controlled is technologically possible.
- **Adoption over time** - Actual implementation over time will depend on finance available.
- **Costs** – Minimal if extensive SCOOT system is introduced as a separate measure.
- **Benefits** – Average value of bus journey time savings of between 10 – 20% can be expected. Apply increase in average speed of buses of 15% in urban areas. [note: for our work average bus speeds are input to the choice model and buses are not modelled on a network]. ReVISIONS choice model applies suitable VOT to time savings.
- **Impacts on other sectors** - Energy demands do not change significantly compared to operating standard traffic signal control.

### 4.5 Real time passenger information

**Implementation in the ReVISIONS modelling framework**

Real time passenger information to mobile devices will be implemented in the ReVISIONS modelling framework by making suitable adjustments to the average bus wait time parameters.

This will result in a variation to the generalized cost of travel by bus which will effect a change in the mode choice modelling. From this there will be a change to the model estimates of overall vehicle-km driven and hence a resultant change in congestion and CO2 emissions.
Summary for modelling inputs

- **Level of Uptake** - Depends on proliferation of mobile devices. Current levels of ownership suggest close to 100% use possible.
- **Adoption over time** - Actual implementation over time will depend on finance available.
- **Costs** – £80m to equip all buses. Replacement required every 5 years. Assumes bus management system infrastructure in place.
- **Benefits** – Average wait time to be reduced by 33% in urban areas and 66% in rural areas. ReVISIONS choice model applies suitable VOT to time savings. Note that VOT for passengers waiting for a bus is greater than VOT for passengers after they have boarded.
- **Impacts on other sectors** - Not significant

4.6 **Smartcard payment systems**

Implementation in the ReVISIONS modelling framework

Smartcard payment systems for buses will be implemented in the ReVISIONS modelling framework by making suitable adjustments to the average bus board time parameters.

This will result in a variation to the generalized cost of travel by bus which will effect a change in the mode choice modelling. From this there will be a change to the model estimates of overall vehicle-km driven and hence a resultant change in congestion and CO2 emissions.

Summary for modelling inputs

- **Level of Uptake** - Potentially 100%
- **Adoption over time** - Actual implementation over time will depend on finance available.
- **Costs** – Capital cost for full roll-out of £1100m plus £260m annual operating costs.
- **Benefits** – Average journey time saving of 2½ minutes per bus trip. ReVISIONS choice model applies suitable VOT to time savings.
- **Impacts on other sectors** - Not significant

4.7 **Improvements to rail signalling systems (ERTMS)**

Implementation in the ReVISIONS modelling framework

It is the station stop capacity improvements which are of most relevance to ReVISIONS.

It has been established that on average the theoretical capacity enhancements provided by ERTMS Level 2 signalling are likely to result in approximately one additional path per hour becoming available in each direction on each route corridor, once a desired performance benefit has been taken into account.

So where there were previously 6 trains per hour (under 4 aspect block signalling), ERTMS level 2 would enable 7 trains per hour or a capacity improvement of 16% (i.e. in line with the
TRL modelled ERTMS level 2 with half size blocks station stop capacity increases for Electrostar services. So the level of capacity increase depends on the current frequency of services in a route corridor.

Summary for modelling inputs

- **Level of Uptake** - 72% of the UK national network infrastructure is planned. This includes almost all of the suburban rail services in the South East.
- **Adoption over time** – Full adoption of ERTMS over 72% of the national network is planned by 2038. Half of the full adoption (or approx 35% of the national rail network) plan will be complete by 2024.
- **Costs** – Train equipment costs are approx £50k per train. Fitting cost per cab for new train £35k; Retro fitting existing train per cab up to £200k. 50% of train rolling stock will require retro fitting. It is assumed that ‘whole life’ costs of installing and maintaining lineside equipment will be equivalent to current proprietary signalling systems.
- **Benefits** – the main benefits are increase in capacity on the rail network. The capacity increases depend on the current frequency of services in route corridors. On average an extra train per hour can be accommodated as a result of ERTMS signalling.
- **Impacts on other sectors** - Energy demands: Electricity to run the system is likely to be lower than existing proprietary signalling systems although this will not be significantly lower.

4.8 Electric Vehicles (EV), Plug-in Hybrid Vehicles (PHEV) and Internal Combustion Engine (ICE)

Implementation in the ReVISIONS modelling framework

The uptake of the different types of technology within the car fleet is the most relevant to ReVISIONS. This is especially true to anticipate the likely change in total greenhouse gas emissions. The total UK car fleet today (2010) is 33.9m; assuming an extra 2.05m cars per year (based on less optimistic growth of car sales, refer to SMMT) and cars scrapped of 2m per year; the car fleet by 2020 will turn to 34.15m and by 2050 to 34.4m. This number is consistent with DfT and BERR (2008) forecasts.

The current proportion of fuel type in the new car sales is 44% diesel, 55% petrol and 1% alternative fuel (includes EV and PHEV). By 2030, it is expected that the proportion of petrol and diesel ICE would be equal (50:50) whilst the alternative fuel vehicle gradually increases. By 2050, it is expected that the proportion of petrol and diesel ICE would be (40:60) whilst the alternatively fuelled vehicles would occupy the major share of the car fleet. For ReVISIONS data input, different types of car fleet forecast based from DfT and BERR report (2008) could be adopted to suit different land-use scenarios. See Table 3.8.1 for the estimated uptake suggested by DfT and BERR report (ibid).

It should be noted that the improvement in EV technology will lead to improvement in energy consumption. Table 4.8.1 below illustrates the likely improvement in energy demand by EV based on the DfT and BERR report (2008). Table 4.8.2 demonstrates the improvement of vehicle technology projections on impacts to the CO₂ emissions based on the DfT and BERR report (2008).
### Table 4.8.1 Electric Vehicle energy demand

<table>
<thead>
<tr>
<th>Electric Vehicle type</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>EV</td>
<td>0.16 kWh/km</td>
<td>0.13 kWh/km</td>
<td>0.11 kWh/km</td>
</tr>
<tr>
<td>PHEV (50% electric + 50% fuel)</td>
<td>0.16 kWh/km + fuel</td>
<td>0.13 kWh/km + fuel</td>
<td>0.11 kWh/km + fuel</td>
</tr>
</tbody>
</table>

### Table 4.8.2 Comparison of EV and an ICE over the vehicle lifetime (180k km)

<table>
<thead>
<tr>
<th>Vehicle Manufactured in</th>
<th>EV</th>
<th>ICE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Defra long term marginal factor</td>
<td>Petrol</td>
</tr>
<tr>
<td>Emission factor well to wheel gCO2e/km</td>
<td>69</td>
<td>172</td>
</tr>
<tr>
<td>Lifetime vehicle carbon use kg CO2 -equiv</td>
<td>12,384</td>
<td>30,916</td>
</tr>
<tr>
<td>Vehicle Manufactured in 2020</td>
<td>Emission factor well to wheel gCO2e/km</td>
<td>56</td>
</tr>
<tr>
<td>Lifetime vehicle carbon use kg CO2 -equiv</td>
<td>10,062</td>
<td>25,864</td>
</tr>
<tr>
<td>Vehicle Manufactured in 2030</td>
<td>Emission factor well to wheel gCO2e/km</td>
<td>47</td>
</tr>
<tr>
<td>Lifetime vehicle carbon use kg CO2 -equiv</td>
<td>8,514</td>
<td>21,639</td>
</tr>
</tbody>
</table>

**Note:** The Defra long term marginal factor “assumes that, over a long time period (a decade or more) avoided electricity use will displace generation at a new Combined Cycle Gas Turbine (CCGT) plant” (Defra; Guidelines to Defra’s GHG Conversion Factors; 2008 cited in BERR and DfT, 2008)

### Summary for modelling inputs

- **Level of Uptake** – 2.05m new cars (with assumption that 2m cars are also scrapped each year) each year of which EV and PHEV gradually take share in the market as suggested by DfT and BERR report (2008); ICE cars are expected to comprise an equal share between petrol and diesel, but the overall number of ICE cars is expected to reduce with the increase in EV and PHEV share over time.
- **Adoption over time** – depends on the scenario tested. For business as usual (BAU) scenario, by 2030 only 8% of the car fleet is EV or PHEV, but for extreme scenario, by 2030 the EV and PHEV share can reach 59% share of the total UK car fleet.
- **Costs** – For individuals, the cost would relatively be modest for conventional ICE with a little improvement towards greener engines but gradually increases as the technology getting towards pure EV.
- **Benefits** – reduction in CO₂ emissions.
- **Impacts on other sectors** – Energy demands: Electricity to charge the EV and PHEV. UK has ‘sufficient generating capacity of low carbon electricity to cope with the uptake by 2030, assuming that charging is managed and targeted at off-peak periods, where there is currently surplus capacity. However investment for the longer term has been suggested to start as soon as now to cope with the future electricity demand if the target of CO₂ reduction is to be met and to anticipate the numerous factors of personal and household convenience.
4.9 Telecommuting

Implementation in the ReVISIONS modelling framework

The telecommuting contribution to trip reduction can be assessed through the design forecast of the distribution proportion of workers and its employment business sectors. Workers type can be categorised by socio-economic group (SEG) of the head of the household for employed households as reported in the MENTOR land-use model that was used in the SOLUTIONS project. This category can be matched to fit the category used by the Labour Force Survey to contextualise the projection percentage uptake of teleworkers/homeworkers relative to the employment types. Referring to Table 3.9.2 from Labour Force Survey (2005), occupation category 1, 2 and 3 can be part of SEG1; occupation category 5 and 6 can be part of SEG2; occupation category 8 can be part of SEG3 and the rest are SEG4 (includes: category 4, 7 and 9). Table 4.9.1 below shows the matching category of the worker type for the MENTOR and Labour Force Survey.

The proportion of homeworkers who mainly work from home is 0.8m / 3.1m equal to about 26% of the total homeworkers of which 73% belongs to SEG1 (56%) and SEG2 (17%) workers type. So, by 2030, homeworkers who mainly work from home can reach 1.9m workers of which 1.4m belongs to SEG1 and SEG2 type workers. By 2050, it can reach 3.8m of which 2.8m belongs to SEG1 and SEG2.

Table 4.9.1 MENTOR worker type and Labour Force Survey employment type

<table>
<thead>
<tr>
<th>MENTOR workers type</th>
<th>Labour Force Survey category</th>
<th>2005 (million)</th>
<th>2030 (million)</th>
<th>2050 (million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>In 2005: Total Labour Force: 28.1m of which 3.1m is homeworkers (HW) (of which 2.4m are teleworkers (TW))</td>
<td>~ 3.5% increase / year (source: Banister et al., 2007)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HW</td>
<td>TW</td>
<td>HW</td>
<td>TW</td>
<td>HW</td>
</tr>
<tr>
<td>Total workers</td>
<td>3.1</td>
<td>2.4</td>
<td>7.3</td>
<td>5.6</td>
</tr>
<tr>
<td>SEG1 – professional and managerial</td>
<td>1 (Managers and Senior Officials)</td>
<td>1.4 (45%)</td>
<td>1.55 (64%)</td>
<td>3.3</td>
</tr>
<tr>
<td>SEG2 – other non manual</td>
<td>5 (Skilled Trades Occupation)</td>
<td>1.1 (35%)</td>
<td>0.5 (21%)</td>
<td>2.6</td>
</tr>
<tr>
<td>SEG3 – skilled manual</td>
<td>8 (Process Plant and Machine Operatives)</td>
<td>0.2 (6%)</td>
<td>0.05 (2%)</td>
<td>0.4</td>
</tr>
<tr>
<td>SEG4 – semi skilled and unskilled manual</td>
<td>4 (Administrative and Secretarial)</td>
<td>0.4 (13%)</td>
<td>0.3 (13%)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

The impact of homeworkers to commuting can also be reconsidered by adjusting the distribution proportion of employment floorspace. MEPLAN categorises employment floorspace into six different economic sectors as can be seen in the Table 4.9.2 below.
Table 4.9.2 Firms for employment are categorised into economic sectors

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Business-financial and business services</td>
</tr>
<tr>
<td>2</td>
<td>Retail – retail, catering, repairs</td>
</tr>
<tr>
<td>3</td>
<td>Education – primary and secondary</td>
</tr>
<tr>
<td>4</td>
<td>Service – other services and primary industry</td>
</tr>
<tr>
<td>5</td>
<td>Primary – transport and construction</td>
</tr>
<tr>
<td>6</td>
<td>Industry – manufacturing industry and distribution</td>
</tr>
</tbody>
</table>

The BT flexible working scheme (as reported in Dwelly and Lake, 2008) with 16% of UK-based employees full-time home-based has achieved a £500m reduction in BT’s property portfolio. Regarding Table 4.9.2 above, sector 1 (business-financial and business services) and sector 4 (service – other services and primary industry) would have the most impact from the increase of homeworkers.

Summary for modelling inputs

- **Level of Uptake** – 3.5% increase of home-based worker each year through population with different employment category distribution
- **Adoption over time** – SEG1 and SEG2 consist of about 75% of the homeworkers, so, the distribution of these socio-economic group (SEG) of the population would potentially show bigger role for telecommuting
- **Costs** – For individuals, the cost would relatively be modest as the procurement of Telephone and Personal Computer (PC) and broadband internet facilities are very competitive at the current market.
- **Benefits** – the BT study (as reported in Dwelly and Lake, 2008) demonstrates that main benefits of homeworking are: increases productivity, reduce travel time, ensures key people are always in reach and in touch, reduces cost overheads, increases the power to attract and retain premium skills, reduces absenteeism and work-related stress, encourages a happier, more motivated workforce and reduces negative impacts on the environment.
- **Impacts on other sectors** – Energy demands: Electricity to run the ICT system at home and the heating system. James (2008) observed that home office energy consumption is about half the regular business office energy demand.

4.10 Summary of scenario testing for each technology

Table 4.10.1 summarises the scenarios to be tested for each technology detailing specific values for key features of the technology scenario which should be applied to the model inputs.

The overall modelling framework is illustrated in Figure 4.10.1 with each technology listed alongside the changes required to key input parameters such as speeds, travel times, capacities and costs. This diagram indicates the modules within the ReVISIONS modelling framework to which the changes in input parameters need to be made.
### Table 4.10.1 Summary of scenarios to be tested for each technology

<table>
<thead>
<tr>
<th><strong>Adaptive Traffic Signal Control</strong></th>
<th><strong>Level of Uptake</strong></th>
<th><strong>Adoption over time</strong></th>
<th><strong>Costs</strong></th>
<th><strong>Benefits</strong></th>
<th><strong>Impacts on other sectors</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Upgrade 8000 existing non adaptive signal controlled urban junctions to SCOOT or MOVA</td>
<td>Actual implementation over time will depend on finance available</td>
<td>Assuming installation costs of £10,000 per junction would require and extra £80m</td>
<td>Average journey time savings of 5.5% for all drivers in urban areas</td>
<td>Little or no additional energy demand as only applied at junctions which are already signal controlled</td>
<td></td>
</tr>
</tbody>
</table>

| **Motorway hard shoulder running** | 100% of motorway network is technologically possible | Actual implementation over time will depend on finance available. | £4m per km motorway. Total cost for all motorway network is £11,384m | Time savings to drivers based on adapted speed flow curves for motorway road types. | Energy demands: electricity to run system across the motorway network = 204 MWh p.a. Cost = £16.35m p.a. (at 8p/KWh) |

| **In-vehicle dynamic route guidance systems** | 100% of drivers equipped with in-vehicle guidance is possible but benefit per user diminishes when uptake exceeds 20% | 20% of urban drivers by 2030; 50% of drivers by 2050 | Av. travel time savings for all network users: 3.5% in congested and 2.5% in v. congested conditions (20% uptake); 3% in congested and 5.5 % in v. congested conditions (50% uptake) | Little or no additional energy demand is required for in-vehicle navigation systems |

| **Bus priority systems** | Provided at all junctions in urban areas where SCOOT system is in place. | Actual implementation over time will depend on finance available. | Minimal if extensive SCOOT system is introduced as a separate measure. | Average value of bus journey time savings of between 10 – 20% can be expected. Apply increase in average speed of buses of 15% in urban areas. | Energy demands do not change significantly compared to operating standard traffic signal control. |

| **Real-time bus information on mobile devices** | Depends on proliferation of mobile devices. | Current levels of ownership suggest close to 100% use possible. | £80m to equip all buses. Replacement required every 5 years. | Average wait time to be reduced by 33% in urban areas and 66% in rural areas. | Not significant |

<p>| <strong>Smart card payment</strong> | Potentially 100% | Depends on finance available. | Capital cost for full roll-out of £1100m plus £260m annual operating costs. | Average journey time saving of 2½ minutes per bus trip | Not significant |</p>
<table>
<thead>
<tr>
<th>Improvements to rail signalling systems (ERTMS)</th>
<th>Level of Uptake</th>
<th>Adoption over time</th>
<th>Costs</th>
<th>Benefits</th>
<th>Impacts on other sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>72% of the UK national network infrastructure is planned.</td>
<td>Full adoption of ERTMS over 72% of the rail network by 2038. Half of this complete by 2024.</td>
<td>Train equipment costs are approx £50k per train. Fitting cost per cab for new train £35k; Retro fitting existing train per cab up to £200k (applies to 50% of train rolling stock).</td>
<td>Increase in capacity on the rail network. On average an extra train per hour can be accommodated as a result of ERTMS signalling.</td>
<td>Energy demands: Electricity to run the system is likely to be lower than existing proprietary signalling systems although this will not be significantly lower.</td>
<td></td>
</tr>
</tbody>
</table>

| Improvements to rail signalling systems (ERTMS) | Gradually increasing share of fleet will be EV and PHEV (see fig 3.8.1). Different forecast scenarios are put forward. | By 2030 under business as usual (BAU) scenario only 8% of the car fleet is EV or PHEV, but for extreme scenario the EV/PHEV share can reach 59%. | For individuals, the cost would relatively be modest for conventional ICE with a little improvement towards greener engines but gradually increases as the technology getting towards pure EV. | reduction in CO₂ emissions | Energy demands: UK has ‘sufficient generating capacity of low carbon electricity to cope with the uptake by 2030, assuming that charging is managed and targeted at off-peak periods. Spatial and temporal spikes in energy demand to be assessed by Cambridge / Surrey |

| Electric Vehicles (EV), Plug-in Hybrid Electric Vehicles (PHEV) and Internal Combustion Engine (ICE) | Even accounting for changing working practices in the future, probably only about 30-40% of work can effectively be done on a flexible location basis. | 3.5% increase of home-based worker each year through whole population with different employment categories showing greater increases than others (e.g. SEG1 and SEG2 consist of about 75% of homeworkers). | For individuals, the cost would be relatively modest. It is unlikely that there would need to be significant additional communications infrastructure investment to that which is already planned. | Homeworking reduces travel and therefore associated carbon emissions. Teleworking could reduce UK car commuting trips by 3 – 12%. The actual reductions will be an output of the Land-use/choice model. | Electricity to run the ICT system at home and the heating system. James (2008) observed that home office energy consumption is about half the regular business office energy demand. |
Figure 4.10.1  Illustration of new technology incorporation within the ReVISIONS modelling framework
Annex A  REVISIONS – Sub-contract details

Deliverables and delivery dates for scope of work to be completed by Aberdeen University:

1  Rapid review of trends in the transport sector - review the state-of-the-art and the future trends  (due 6 weeks from agreed start date)
   o Review of car-based advances in technology and their requirements for and likelihood of adoption over a 10 year, 20 year and 40 year time horizon.
   o Review of the Public Transport based advances in technology and their requirements for and likelihood of adoption over a 10 year, 20 year and 40 year time horizon.
   o Review of other technologies affecting travel choices, e.g. teleworking, information systems.

   A limited number of technologies will be selected and investigated further in the development of options

2  Development of options  (due 10 weeks from agreed start date)
   o Assessment of infrastructure measures and costs required to support new car-based technologies.
   o Assessment of infrastructure measures and costs required to support new Public Transport based technologies.

   This will include consideration of how settlement size, density and location influence the options.

3  Review of modeling practices  (due 3 months from agreed start date)
   o Investigation of NTM and other regional level transport models to identify techniques for representing (in the model) transport network alterations and inclusion of new technologies at the regional scale.

4  Research method for incorporation of the options in the supply side of the model  (due 4 months from agreed start date)
   o A set of methodologies will be proposed which will enable the options developed to be incorporated within the supply side of the regional model through adjustments to the capacities, costs or speeds of the transport supply networks.

5  At the end of the Phase 1 of work a short report will be produced on the initial review, options developed and method for defining the supply side of the options in the transport model  (due 4 months from agreed start date)
1. It’s not only marketplaces that govern the penetration of new technologies but of course public policies and regulations often play a huge role as well. For example, we’ve had the technologies to mount and deliver “smart paratransit” for decades (e.g., real-time, shared-ride, door-to-door services) – e.g., GPS, routing/scheduling optimization software. In the U.S. and elsewhere, regulations that limit market entry and the design of innovative services often inhibit such actions (with resistance to competition often coming from the protected monopolists – public bus companies and medallion-owning taxi operators). Thus “enabling policies” must be packaged with technologies to allow for significant market penetration, particularly in the urban transport field.

2. SOLUTIONS. Not sure if I totally agree that transport and land-use strategies will yield small sustainability benefits in coming years. The context and setting matter. When combined with congestion charges and parking management, the elasticities between transport services and land-use changes can be appreciable. Higher energy prices, such as through substantial carbon taxes, can be expected to strengthen these relationships over time. In the U.S., lifestyle preferences (driven by shifting demographics, including childless households and empty-nesters) are driving the demand for traditional urbanism oriented toward high-quality public transport. All of this said, I agree that “technology” will play a pivotal role in advancing sustainable transport in coming years.

3. Regarding the role of technology in improving traffic conditions. There is always the concern of any improvement that increases travel speeds (e.g., expanded road capacity or technologies) having secondary (and sometimes unanticipated) impacts, notably induced demand/growth and sometimes reduced (or suppressed) demand/growth. Time-budget theory and empirical evidence shows that the time devoted to travel has remained largely unchanged in modern, industrialized societies for the past 150+ years. In the US, it has remained fairly constant at 1.1 hours per day per person since 1840. As average speeds increase, locations of urban activities change and people make more trips, resulting in a fairly constant Vehicle Hours Traveled (VHT). Average travel distances (and VMT) have, of course, steadily risen. Thus the trillions of dollars in massive transport infrastructure investments have failed to change daily hours of travel or curb daily miles of travel. Thus can new technologies be expected to have any different impacts of VHT (hours of travel) or VMT (miles of travel)? Is this a fundamental truth that all speed-savings get eclipsed by structural changes in numbers and distances of motorized trips? Of course, if we can move people with low-carbon fuels in smaller, more fuel-efficient vehicles, there will no doubt be sustainability benefits (environmentally that is; with regard to the social dimension of sustainability, this is debatable). Several U.S. studies show that the carbon-
reducing benefits of technologies have been substantially muted by the growth in VMT over the past decade.

4. Land-use strategies and technologies can be reinforcing and synergistic. Compact, mixed-use development can promote electric vehicles with limited geographic ranges since trip destinations tend to be closeby. Solar panels that form canopies at major bus stops can pipe into a smart electric grid that guides mass-transit vehicles as well as charge vehicles that are dwelling at timed-transfer points. Such infrastructure is compatible with TOD (transit oriented development).

5. ATIS. Besides in-vehicle guidance, ATIS could help promote dynamic ridesharing as well. Public policies could facilitate this by designing for dynamic ridesharing intercept points. HOT lanes could be further inducements.

6. Scholars at UC Berkeley have done a fair amount of work on wireless vehicle-detection system – Mobile Millennium (http://traffic.berkeley.edu/). I agree this has a promising future.

7. Technologies and system designs that reduce conflicts between buses and other vehicles – e.g., dedicated lanes; signal prioritization; queue-jumper lanes – can allow for better scheduled adherence and on-time performance. Advanced payment smart cards reduce dwell and boarding times of buses, which further increases reliability and on-time arrivals. With the aging of the baby boomers, walking up bus steps and fumbling for coins to make fare payments will further increase dwell times. All this speaks for the need for more smart-card technologies – plus same-level board-alighting through low-floor and knelling buses – to expedite the boarding/alighting process.

8. Similar evidence has been uncovered in the U.S. on part-time homeworking. Some evidence suggests that in-neighborhood services (restaurants, pubs) can be an inducement to part-time homework.