Towards a 60% Reduction in UK Transport Carbon Dioxide Emissions: A Scenario Building and Backcasting Approach

Robin Hickman
Halcrow Group Ltd
Vineyard House
44 Brook Green
London
W6 7BY
Tel: +44 (0)20-8233-3555
Switchboard: +44 (0)20-7602-7282
Fax: +44 (0)20-7603-0095
Email: hickmanro@halcrow.com
www.halcrow.com

David Banister
Professor of Transport Planning
The Bartlett School of Planning
University College London
Wates House
22 Gordon Street
London
WC1H 0QB
Tel: +44 (0)20-7679-7456
Fax: +44 (0)20-7679-7502
Email: d.banister@ucl.ac.uk
www.ucl.ac.uk/~ucf696
www.bartlett.ucl.ac.uk/research

Keywords
Transport emissions, carbon dioxide, scenario building, backcasting.

Abstract
This paper examines the possibilities of reducing transport carbon dioxide emissions in the UK by 60% by 2030 using a scenario building and backcasting approach. It draws on the VIBAT project, which examines Visioning and Backcasting for UK Transport Policy, and examines a range of policy measures (technological and behavioural), assessing how they can be effectively combined to achieve the required level of emissions reduction. The intention is to evaluate whether such an ambitious target is feasible, identify the main problems (including the transition costs), and the main decision points over the 30-year time horizon.
Introduction: The Poverty of Traffic Growth

“If there is such a thing as growing human knowledge, then we cannot anticipate today what we shall know only tomorrow ... no scientific predictor - whether a human scientist or a calculating machine - can possibly predict, by scientific methods, its own future results.”

Popper, K.R. (1957)

The general rise in environmental consciousness is one of the major cultural and political transformations of recent years. Pre-Rio de Janeiro in 1992 and Kyoto in 1997 few people outside the research community had heard of the term 'sustainability'. However translating this improved awareness into effective action - in terms of tackling climate change and actually reducing greenhouse gases emissions - is perhaps the most important issue facing the global community today.

Authors such as Popper greatly emphasised the importance of new knowledge for the development of society. The challenge for this paper is to provide evidence to help plan for the future development of society and to react positively to what we perceive as current trends. The particular focus is to examine the possibilities of reducing transport carbon dioxide (CO2) emissions in the UK by 60% by 2030. The analysis uses a scenario building and backcasting approach and examines a range of policy measures (behavioural and technological), assessing how they can be effectively combined to achieve the required level of emissions reduction. The intention is to evaluate whether such an ambitious target is feasible, to identify the main problems (including the transition costs), and the main decision points over the 30-year time horizon.

The paper is structured as follows:

• An introduction to futures studies, including a review of forecasting, scenario building and backcasting approaches
• The conceptual framework to the Visioning and Backcasting for UK Transport Policy (VIBAT) study
• A summary of the climate change and global warming problem including an assessment of the UK transport sector’s contribution
• The setting of a baseline and targets for 2030, forecasting the business as usual situation for all forms of transport in the UK, and assessing the scale of change in terms of achieving the emissions reductions.

The Order of Things, Futures Studies and Backcasting

Over the years various perspectives on societal change have evolved. A number of ideas have gained much coverage in the literature. For example:

• Kuhn’s celebrated concept of paradigm shift (1962) attempts to depict ‘step-changes’ in the level of understanding. Seeking to explain scientific revolutions, Kuhn suggested that there was a ‘normal science’, which scientists and practitioners accepted for a time as a basis for everything they did. They accepted a particular ‘paradigm’ or in Kuhn’s own words: “some accepted examples of actual scientific practice - including law, theory, application and instrumentation - which together provide models from which spring particular coherent traditions of scientific research.” Kuhn argues that, at particular points in time, scientists become aware of anomalies in their worldview; they find things that the prevailing paradigm does not explain well. Science then

---

1 This paper reports on the work carried out during the early stages of a study by the Bartlett School of Planning, University College London and the Halcrow Group for the Department for Transport under the New Horizons Research Programme 2004/05. The study is titled ‘Visioning and Backcasting for UK Transport Policy’ (VIBAT). See www.ucl.ac.uk/~ucft696/vibat.html
enters a new phase, in which the old paradigm is scrapped and a new one developed in its place. Applied to science (and indeed other fields), Kuhn’s theory has become widely used.

- Kondratieff (1935) similarly developed the notion of waves of development. Arguing from a Marxist standpoint that the falling rate of profit operates with particular force every 50 years or so, a periodic major crisis is found in the capitalist system. This, Kondratieff says, is because the possibilities of a given generation of technologies have been exhausted. Only by the diversion of new capital into a new a new set of technologies, could this tendency be overcome.

- Schumpeter (1939) translates these principles into business cycles, giving dates to the rise of new industries.

Foucault (1970) more fundamentally asks “How is it that thought detaches itself from the squares it inhabited before - general grammar, natural history, wealth - and allows what less than twenty years before had been posited in the luminous space of understanding to topple down into error, into the realm of fantasy, into non-knowledge?” There is therefore a philosophical basis for our thoughts in the transport and climate change field: how do we develop a real step change in travel behaviour and emissions, and seek to change our methods of filtering the ‘experience of reality’, or what Foucault might label ‘the order of things’?

The use of futures studies is likely to help us. They have developed on the back of such high-level thinking and are often used to illustrate what might happen to society in order to permit the individual, or society itself, to adapt to perceived future trends. The position taken by Popper was that the level of future uncertainty was only partly determined by the present conditions and trends of society as we know them. Dreborg (1996) terms this problem as indeterminacy.

The most effective futures studies are used to define a broader conceptual framework for discussing the future and to contribute to policy formulation and the emergence of unforeseen new options. The Swedish currently lead the field in futures studies. Their tradition, for example, in backcasting allows different actors a better foundation for discussing goals and taking decisions, and either to act or seek further knowledge. France similarly follows a strong research tradition called La Prospective (translated as developing scenarios of future states); and Germany one of Leitbilder (inspiring visions or guiding images).

Futures studies are often not concerned with predicting the future, but instead with creating a choice of futures by outlining alternative possibilities which can form the basis for planning and policy development. Banister and Stead (2004) categorise futures studies as considering one or more of the ‘three Ps’:

- **Possible** futures: what might happen?
- **Probable** futures: what is most likely to happen?
- **Preferable** futures: what we would prefer to happen?

A variety of related techniques have been employed over the years. For example, trend and mega-trend analyses (both quantitative and qualitative), delphi studies, scenario building, wild card, visioning and futures workshops.

Steen and Åkerman (1994) have usefully carried out a survey of studies concerning transport and energy consumption in Sweden for the Swedish Committee on Climate Change. Their key conclusion is that few studies take sustainability seriously into account. Figure 1 characterises the range of possibilities. The horizontal axis represents different types of study approaches available; the vertical axis progress towards sustainability.
The classification of study approaches can be summarised as follows:

- **Directional** studies: these tend to concentrate on short or medium term horizons; typically investigating economic and other measures that promote behaviour more in accordance with the natural environment. Research often focuses on mitigation measures for environmental difficulties. Proposed measures work broadly in the direction of sustainability, but how close they bring society to the sustainable goal is not normally addressed. In the UK, examples from the transport sector would be many of the multi-modal studies carried out in recent years.

- **Short term** studies: take short term official (usually governmental) forecasts as a starting point and try to find a means of achieving them. These forecasts are often an initial (but critically unquantified) step to a broader goal such as sustainability. UK local transport plans provide an example here: they are focused on local objective and target achievement, yet their horizons are relatively short term and there is no attempt to understand the implications of investment on (or contributions towards) national environmental targets.

- **Forecasting** studies: often apply a longer term perspective using some form of forecasting methodology. Predicted developments often fall short of sustainability goals, either because study remit is restrictive or chosen methodology precludes major change. An example here might be some of the sub-regional, sustainable communities-related land use and transport growth studies.

- **Alternative solutions** and visions: a number of these studies use backcasting techniques, and start with the development of images of future scenarios. There have been few studies of this type in the UK.

The traditional forecasting approach is still frequently used in many research studies. There are however strong concerns as to the usefulness of forecasting in the study of highly complex, long term sustainability problems (see, for example, Dreborg, 1996). Based on ‘business as usual’ existing trends, forecasting is unlikely to generate sufficiently radical solutions if these are required.

Achieving sustainability, for example, critically requires more than marginal changes at many levels of society. Approaches that focus on the problem to be solved, rather than on present conditions and current trends, are better suited to achieving real solutions that will move us towards sustainability.

Scenario development studies have been used extremely frequently since the 1950s. One of the earliest and well-known scenario-based studies was originally developed for the U.S. federal government in the 1950s by the Rand Corporation to study how nuclear wars might start (Martino, 1983).
was popularised as a business tool by organisations such as Shell Oil in the 1970s. Shell’s management team, armed with forecasts of how consumers and countries might react to oil shortages, were better equipped than many of their competitors to deal with the shock of the oil crisis in 1973 and its aftermath. One of the first definitions of a ‘scenario’ dates back to Kahn and Wiener in the mid-1960s. Scenarios were defined as: “Hypothetical sequences of events for the purpose of focusing attention on causal processes and decision points” (Kahn and Wiener, 1967).

In the 1960s, many companies started using scenario-based studies, based on Kahn’s principles, because they faced increasing problems with ‘traditional’ prediction methods. The starting point for many of the scenarios was to identify ‘predetermined’ and ‘undetermined’ elements. The predetermined elements are the same in each scenario; the undetermined elements are elaborated in several ways, depending on possible future developments, and thus result in different future images (Van der Heijden, 1996). A further, well-used definition of the term scenario emanates from the Netherlands: “A description of society’s current situation (or a part of it) of possible and desirable future societal situations, and the series of events between current and future situations.” (Becker and Van Houten, 1982).

There is a distinction to be made between scenarios and visions or images of the future. Visions or images of the future are often static ‘snapshots’ in time, whereas scenarios are dynamic, logical sequences of events.

Banister and Stead (2004) make an important point: in transport analysis, travel is a product of changes in existing patterns of demand and the travel generated by new activities. Much of the growth in travel is caused by decisions taken outside the transport arena, yet it is often the transport system that has to accommodate these changes. Two kinds of scenarios can also be distinguished: projective and prospective. A projective scenario’s starting point is the current situation; extrapolation of current trends results in future images (and known as forecasting). Forecasting scenario studies are very common in transport studies. Problems are assessed due to current and future transport activity, based on the continuation of current socio-economic trends. A prospective scenario starts with a possible or desirable future situation, usually described by a set of goals or targets established by assumed events between the current and future societal situations. Backcasting is one form of prospective scenario building.

The term backcasting was first introduced by Robinson (1982) to analyse future energy options in terms of how desirable futures could be attained. The major distinguishing characteristic is: “a concern, not with what futures are likely to happen, but with how desirable futures can be attained. It is thus explicitly normative, involving working backwards from a particular desirable end-point to the present in order to determine the physical suitability of that future and what policy measures would be required to reach that point.” (Robinson, 1990).

The major differences between forecasting and backcasting studies are shown in Table 1.

**Table 1: Comparing Forecasting and Backcasting**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Forecasting</th>
<th>Backcasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philosophy</td>
<td>Justification as the context</td>
<td>Discovery as the context</td>
</tr>
<tr>
<td></td>
<td>Causality determinism</td>
<td>Causality and intentions</td>
</tr>
<tr>
<td>Perspective</td>
<td>Dominant trends</td>
<td>Societal problem in need of a solution</td>
</tr>
<tr>
<td></td>
<td>Likely futures</td>
<td>Desirable futures</td>
</tr>
<tr>
<td></td>
<td>Possible marginal adjustments</td>
<td>Scope of human choice</td>
</tr>
<tr>
<td></td>
<td>Focus on adapting to trends</td>
<td>Strategic decisions</td>
</tr>
<tr>
<td>Approach</td>
<td>Extrapolate trends into future</td>
<td>Define interesting futures</td>
</tr>
<tr>
<td></td>
<td>Sensitivity analysis</td>
<td>Analyse consequences and conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for these futures to materialise</td>
</tr>
<tr>
<td>Method and</td>
<td>Various econometric models</td>
<td>Partial and conditional extrapolations</td>
</tr>
<tr>
<td>technique</td>
<td>Mathematical algorithms</td>
<td>Normative models, system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dynamic models, Delphi methods,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>expert judgement</td>
</tr>
</tbody>
</table>

(Based on Geurs and Van Wee, 2000, 2004; and adapted from Dreborg, 1996)

---

2 Robinson credits the idea of backcasting to Lovins.
Figure 2 shows the main features of the process. Instead of starting with the present situation and prevailing trends, the backcasting approach designs images of the future representing desirable solutions to societal problems. Possible paths back to the present are then developed. The term ‘scenario’ covers both the images of the future and the trajectory leading back to the present date.

**Figure 2: The Backcasting Conceptual Framework**

(From OECD, 2000)

In Sweden backcasting techniques have been applied in a series of energy future studies, starting in the 1970s (see Lönnroth, M., Johansson, T.B. and Steen, P., 1978; and described in Steen, 1997). More recently futures studies have been carried out with similar approaches, in sustainable transport, recycling and waste management (Dreborg and Steen, 1994; Jungmar et al, 1995). The EU-POSSUM project (Banister et al, 2000) was the first to assess European transport policies as to their consistency and feasibility, using a qualitative scenario-based approach based on backcasting. The OECD project on Environmentally Sustainable Transport (EST) (OECD, 2000; 2001; 2002) is very well known and also used backcasting to consider what the transport system would look like in Europe if current transport emissions were reduced by 80-90% (see www.oecd.org).

Steen and Åkerman (1994) conclude that the backcasting approach is most appropriate when the subject to be studied is a major societal problem that needs to be addressed. The following characteristics favour backcasting approaches:

- When the problem to be studies is complex, affecting many sectors and levels of society
- When there is a need for major change, i.e. when marginal changes will not be sufficient
- When dominant trends are part of the problem, and when these ‘business as usual’ trends are often used as the basis for forecasting
- When the problem is one of externalities, which the market cannot treat satisfactorily
- When the timeframe is long enough to allow considerable scope for deliberate choice.

As we can see, all of these criteria are applicable to an analysis of climate change and reducing transport emissions in the UK. Importantly few backcasting studies are used as a blueprint of the desirable future or a cut and dried action plan. Instead Steen et al (1994) and Van den Belt (1988) pursue the idea of a continual revision of targets or constructive technology assessment (CTA). This paper seeks to build on this evolving work and develop thinking in the UK on futures studies with a particular focus on the transport emissions sector.
Conceptual Approach to the Study

The current study of UK transport policy and the potential for a 60% reduction in CO₂ emissions by 2030 consists of three main stages – baseline and target setting, images of the future, and policy packages and pathways - as shown in Figure 3.

Figure 3: The Study Process

The work stages, in summary, are shown below:

Stage 1: Baseline and Targets
- A review of background research and literature, including previous backcasting studies and the main external challenges likely to face transport policy makers over the next 30 years. For example, social and demographic trends, technological innovation, globalisation and reduction of economic barriers, and environmental degradation, and their inter-relationships with travel behaviour in terms of energy consumption, journey lengths, mode share and congestion.
- This stage establishes a baseline and targets within which the visions of the future can be constructed. This allows us to establish the nature and scale of change needed from the trend based future (the business as usual). Here we produce the main quantitative baseline for the project, namely the CO₂ emissions data for each mode of transport in 1985 and 2000 (the base years) and 2015 and 2030 (the forecast years) for the business as usual (based on National Road Traffic Forecasts 1997), together with the targets for the image of the future. More detailed measures of travel (passenger km), energy consumption, including petrol and diesel, methanol, hydrogen, and electricity and the source of that energy (renewable or fossil fuels), and emissions (to include CO₂, NOx, VOC and PM₁₀) will be developed to measure the quantitative targets for 2030.
- The stage includes a workshop with key experts to discuss the literature review and targets set for the business as usual and the images of the future.

Stage 2: Images of the Future
- Images of the future will be developed to comply with the policy targets. These futures will be possible solutions to the perceived problems and be designed to initiate discussion; each alternative image taking a different emphasis. Two images will be identified: one based on a strong push on technological innovation (improved vehicle and fuel efficiency, alternative fuels) and the other with a strong behavioural perspective (using pricing, soft factors and land use policies). The external elements are taken as given in all images of the future, and the focus is on the strategic elements that are amenable to policy intervention.
- This stage includes a second workshop where experts in the technological aspects and behavioural aspects get together to discuss the draft images of the future.
Stage 3: Policy Packages

- Assembling policy packages and paths will use the backcasting methodology so that the mixture of policy measures that are available to get from “there to here” can be explored. The policy measures will be assembled as packages, as it is unlikely that a single policy will achieve the scale of change required in the scenarios, and the paths relate to the timing of the introduction of the alternatives.

This is an intensive discussion process, and the preliminary results will again be presented for discussion to the third focus group for comment and amendment.

The final part of the study is to develop policy actions and conclusions. This involves synthesis and evaluation where the alternative visions, together with their measures, packages and paths, are brought together as a coherent set of actions.

Climate Change, Global Warming and Transport Emissions

The phenomenon of climate change has been well documented in the literature. Research and debate on the particular contribution of human-induced factors has grown at a rapidly increasing rate. The Intergovernmental Panel on Climate Change (IPCC)\(^3\) provides evidence on scientific, technical and socio-economic information relevant to the understanding of climate change. Houghton (2004) provides a definitive review of much of this research; the IPCC (2001) ‘Climate Change: the Scientific Basis’ provides the primary source. Specifically focused on the UK, the Hadley Centre for Climate Prediction and Research\(^4\) has developed much of recent research on climate change monitoring and modelling, and the Tyndall Centre\(^5\) similarly develops trans-disciplinary research on climate change.

Levels of CO\(_2\) in the atmosphere have risen by more than a third in the UK since the industrial revolution. They are now rising faster than ever (since records began). Over the 20th Century temperatures have risen by about 0.6\%, largely due to increased greenhouse gas emissions from human activities. Houghton (2004) estimates that, in the absence of efforts to curb the rise in emissions of CO\(_2\), the global average temperature will rise by around a third of a degree celsius every ten years. This equates to around three degrees in a century. This predicted rate of change of three degrees is probably faster than the global average temperature has changed over any time over the past ten thousand years. Although the level of change appears small and insignificant, this is not so. A few degrees change in average temperatures can represent a huge change in climate conditions. There is a difference in global average temperatures of only five or six degrees between the coldest part of an ice age and the warm periods in between ice ages.

To obtain estimates about the future climate we need to estimate the future atmospheric concentrations of CO\(_2\). A number of scenarios have been developed by the IPCC; they are known as SRES scenarios (and are derived from the Special Report on Emission Scenarios, 2001). The scenarios are based on differing assumptions regarding human behaviour and activities, including population, economic growth, energy use and the sources of energy generation. Houghton (2004) gives a useful summary. The SRES scenarios are based on a set of four different storylines, and within each is a sub-set of further scenarios, leading to a total of 35 scenarios.

Houghton (2004) concludes that stabilisation at any level, even at the higher levels, requires that anthropogenic CO\(_2\) emissions eventually fall to a small fraction of current emissions. With constant emissions after the year 2000, the concentration of CO\(_2\) in the atmosphere would still approach 500 ppm by 2100. An upper limit of 550 ppm carbon dioxide has been advocated by both the European Commission (EC, 1996) and the Royal Commission on Environmental Pollution (RCEP, 2000). Others, such as the Global Commons Institute (GCI, 2002), advocate lower precautionary levels at around 450 ppm.

Castells (2002) makes an important point about current progress towards a sustainable future: “Resource consumption and environmental degradation continues. [As yet] we are only aware of the process by which our species is committing environmental suicide.”

There is thus a marked difference between increased awareness and action. The actual transformation of industrialised society towards a sustainable future is currently the subject of much of the relevant intellectual debate in this field. Key issues are the processes required in attaining a sustainable society, the nature of and necessary steps towards change, and what consequences such change would have on life in economic, social and environmental terms. The only consensus is (possibly) that sustainability requires major changes to industrialised societies in the long term. If sustainability is to be attained then integrated efforts will be required in many fields; and this includes the transport sector.

---

\(^3\) For further information see [www.ipcc.ch](http://www.ipcc.ch)

\(^4\) see [www.metoffice.com/research/hadleycentre](http://www.metoffice.com/research/hadleycentre)

\(^5\) See [www.tyndall.ac.uk](http://www.tyndall.ac.uk)
The underlying theme behind the VIBAT study is how to tackle climate change in the UK with a particular focus on the transport sector. We should keep in mind that the transport sector, including aviation, produces around a quarter of the UK’s total carbon emissions; road transport contributes 85% of this.

Traffic growth however continues to rise and is a source of major concern in the UK. Road traffic has grown at a fairly constant rate since the 1980s: by 77% since 1982 to 2002 (from 277 to 490 billion vehicle kilometres). Since 1990 growth has slowed slightly from that in the previous decade (a growth rate of 18% since 1990). Car ownership is increasing, and so is car use for most journey purposes. Urban sprawl, the use of the private car (as a relatively cheap and convenient vehicle for multi-purpose trips) and rising incomes, are all resulting in a new spatial pattern of movements and increased travel (Banister et al, 2000).

**Figure 4: Growth in Road Traffic in the UK**

Policy interventions are not having the expected impacts. Increased road capacity and traffic management measures often generate more traffic. Increased congestion and grid-lock style conditions in the traffic peak are being experienced in many cities and towns in the UK. Negative impacts are found in terms of accessibility, efficiency, image and, perhaps most importantly, quality of life. In addition to global climate change effects, road transport plays a significant part in local problems, such as air pollution and the associated detrimental public health effects.

Transport problems are well-studied. The more perceptive analyses are increasingly being perceived as the result of multi-faceted behaviours, combining socio-economic and cultural variables. The transport policy response hence has to be concerned not only with travel, but increasingly with technological change, lifestyles, behavioural issues and the time management of people. A sustainable future requires a wide range of measures, based on economic incentives and disincentives, fuel efficient vehicles, traffic demand management, an effective choice of travel modes, ICT and integrated transport and land use planning (Banister, 1998).

**Deriving the Transport Emissions Baseline**

The baseline for CO₂ emissions is available from Transport Statistics Great Britain (DfT, 2004 and earlier series) and Energy Paper 68 (DTI, 2003). Table 2 shows retrospective and prospective data for the years 1985/2000/2015/2030. This is derived from the published sources using linear growth between available data. Clearly there is a large increase in expected CO₂ emissions: for example, end user emissions for road transport are projected to increase by 88%, all transport by 73% from 1985-2030, compared to all emissions with an increase of 6%.

As an additional consideration, UK international air emissions currently amount to 8 MtC (9MtC including domestic). They are expected to rise to some 14-16 MtC by 2020 (and if extrapolated to 20MtC by 2030). This is despite an improvement in the fuel efficiency of aircraft of around 1.7% p.a. (DTI, 2003). International shipping is also not accounted for in the domestic projections.
Table 2: Carbon Dioxide Emissions Projection by End User and Source Category in the UK

<table>
<thead>
<tr>
<th>End user category</th>
<th>1985</th>
<th>2000</th>
<th>2015</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road transport</td>
<td>26</td>
<td>38</td>
<td>42</td>
<td>49</td>
</tr>
<tr>
<td>Railways</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Civil aircraft</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Shipping</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>All transport</td>
<td>30</td>
<td>41</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>All emissions</td>
<td>156</td>
<td>148</td>
<td>153</td>
<td>166</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source category</th>
<th>1985</th>
<th>2000</th>
<th>2015</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road transport</td>
<td></td>
<td>32</td>
<td>40</td>
<td>49</td>
</tr>
<tr>
<td>All transport</td>
<td></td>
<td>35</td>
<td>45</td>
<td>51</td>
</tr>
<tr>
<td>All emissions</td>
<td></td>
<td>148</td>
<td>153</td>
<td>165</td>
</tr>
</tbody>
</table>

Unit: million tonnes of carbon (MtC)
- data not available
End user emissions for transport: include a share of the emissions from combustion of fossil fuels at power stations and other fuel processing industries, but exclude activities emissions
Source categories: relate directly to the vehicle or other piece of equipment producing the emission (source categories data not available pre-1991)
TSGB 2004 low fuel price scenario used (a high fuel price scenario is also available)

Figure 5: Carbon Dioxide Emissions by End User in the UK

Towards Acceptable Targets

Surprisingly for a topic of such importance, targets for CO2 emissions have not been widely developed, certainly not in a directly comparable form to the TSGB and EP68 baseline data. Below we show a 60% CO2 emissions reduction target to 2030 - for the transport sector and for end users and source category - using a baseline of 1990. A number of comparator CO2 targets are available, for example:

- The UK Kyoto commitment is a 12.5% reduction in six greenhouse gases\(^6\) below 1990 levels over the period 2008-2012
- The UK domestic target is for a 20% reduction in CO2 emissions below 1990 levels by 2010 (DETR, 2000)
- A path towards a 60% reduction in CO2 emissions by 2050 has also been adopted (DTI Energy White Paper, 2003) following the recommendation of the Royal Commission on Environmental Pollution (RCEP, 1994)

Our 60% target was chosen following discussion with the study client: the UK Department for Transport.

\(^6\) The six greenhouse gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.
Table 3: Carbon Dioxide Emissions 60% Target by End User and Source Category in the UK

<table>
<thead>
<tr>
<th>End user category</th>
<th>1985</th>
<th>2000</th>
<th>2015</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road transport</td>
<td>26</td>
<td>38</td>
<td>26</td>
<td>13</td>
</tr>
<tr>
<td>Railways</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Civil aircraft</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shipping</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>All transport</td>
<td>30</td>
<td>41</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>All emissions</td>
<td>156</td>
<td>148</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source category</th>
<th>1985</th>
<th>2000</th>
<th>2015</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road transport</td>
<td>-</td>
<td>32</td>
<td>23</td>
<td>12</td>
</tr>
<tr>
<td>All transport</td>
<td>-</td>
<td>35</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>All emissions</td>
<td>-</td>
<td>148</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Unit: million tonnes of carbon (MtC)
- data not available/not projected

Figure 6: Carbon Dioxide Emissions Target by End User in the UK

How Do We Get There? Available Measures and Benchmarks

Such an ambitious emissions reduction target necessarily requires a number of radical and trend-breaking measures. These comprise of two main categories, as outlined below:

- Technological change: including fuel efficient technologies, etc.
- Behavioural change: including pricing, soft factors and land use planning

To help us judge the feasible scale of change a number of benchmarks can be identified from the literature:

- Importantly, many of the actions are available now that will help us reduce greenhouse gas emissions and will become important steps in a long transition to a low-emissions transport system. To achieve this long-term transition, it will be necessary to take certain actions very soon (IEA, 2004).
- The Energy White Paper (DTI, 2003), on the basis of existing policies, expects UK carbon dioxide emissions of 135 MtC in 2020. To be consistent with ‘demonstrating leadership in the international process’ the EWP aims for cuts in carbon of 15-25 MtC below that by 2020. These targets will be achieved by reducing the amount of energy consumption, together with a substantial increase in renewable energy. Central to this will be the carbon emissions trading scheme. The EWP vision is that “[in terms of the transport sector] hybrid vehicles will be commonplace in the car and light goods sectors, delivering significant efficiency savings. There will be substantial use of low carbon biofuels and hydrogen.”

Technological change

- Many technologies and strategies are available today that can significantly reduce transport CO₂ emissions over the short to medium term. These include ‘incremental technologies’ to make vehicles more technically efficient than they are today and lessen their fuel consumption/km travelled; technologies to make transport systems and infrastructure more efficient, reducing the need for vehicle travel, including more efficient routing, better in-use
fuel efficiency and mode switching; and new lower carbon fuels and fuels lower in greenhouse gas emissions on a ‘well-to-wheels’ basis’ (IEA, 2004).

- Dramatic reductions in emissions (in some cases over 90% reduction potential - see Tables 4 and 5) can be achieved by using available and emerging energy vehicle saving technologies coupled with propulsion systems that rely on cleanly produced biofuels, electricity produced centrally without accompanying emissions, and electricity from fuel cells powered by cleanly produced hydrogen (IEA, 2004). Importantly a number of these options are likely to be implemented sequentially, rather than simultaneously or indeed be in competition.

Table 4: Vehicle-Related Technologies Potential Well-to-Wheels CO₂ Emissions Reductions (per km of driving) by 2030

<table>
<thead>
<tr>
<th>Technology</th>
<th>Condition</th>
<th>Well-to-wheels CO₂ emissions reduction potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt;10%</td>
</tr>
<tr>
<td>Higher gasoline engine efficiency</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Higher diesel engine efficiency</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Hybrid engine</td>
<td>Largest efficiency gains in urban traffic</td>
<td>✓</td>
</tr>
<tr>
<td>Lightweight vehicle</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Electric vehicle</td>
<td>Using electricity produced from renewable or nuclear energy or from fossil energy with CO₂ capture and storage</td>
<td>✓</td>
</tr>
<tr>
<td>Fuel cell vehicle</td>
<td>Using hydrogen produced from renewable or nuclear energy or from fossil energy with CO₂ capture and storage</td>
<td>✓</td>
</tr>
<tr>
<td>Intelligent transport system</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes (IEA, 2004): Criterion can be met ✓  Criterion may be met ?  Criterion cannot be met x

Table 5: Alternative Fuels Potential Well-to-Wheels CO₂ Emissions Reductions (per km of driving) by 2030

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Condition</th>
<th>Well-to-wheels CO₂ emissions reduction potential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&gt;10%</td>
</tr>
<tr>
<td>Liquified petroleum gas (LPG)</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>Natural gas</td>
<td>Produced from natural gas</td>
<td>?</td>
</tr>
<tr>
<td>Dimethyl ether (DME)</td>
<td>Produced from natural gas</td>
<td>?</td>
</tr>
<tr>
<td>Ethanol, methanol (current technologies)</td>
<td>Produced from starchy crops (e.g. wheat, sugar beets); significant fossil energy in fuel chain</td>
<td>✓</td>
</tr>
<tr>
<td>Biodiesel (current technologies)</td>
<td>Produced from oil seed crops; significant fossil energy in fuel chain</td>
<td>✓</td>
</tr>
<tr>
<td>Advanced biofuels - ethanol, diesel, DME</td>
<td>Produced from lign-cellulosic biomass, primarily renewable energy in fuel chain</td>
<td>✓</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Produced from fossil energy (e.g. fossil powered electricity or directly from natural gas)</td>
<td>✓</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Produced from renewable or nuclear energy or from fossil energy with CO₂ capture and storage</td>
<td>✓</td>
</tr>
<tr>
<td>Electricity</td>
<td>Produced from renewable or nuclear energy or from fossil energy with CO₂ capture and storage</td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes (IEA, 2004): Criterion can be met ✓  Criterion may be met ?  Criterion cannot be met x

---

7 For a fair comparison of the emissions associated with different energy carriers, the total well-to-wheels fuel chain should be considered. The use of fuel in vehicles is only the last stage in this chain. The total fuel chain consists of feedstock production (the well), feedstock transport, fuel production, fuel distribution, and fuel use in vehicles (the wheels).
Since 1990 the average carbon efficiency of new cars entering the fleet - the distance travelled for a given amount of carbon emitted - has improved by 10%. In 2003 new car fleet average CO₂ emissions were 173 g/km, a fall from the 2002 level of 175 g/km. A range of current vehicle CO₂ emissions are shown in Table 6. Under a voluntary agreement between the EU and the car manufacturers, the motor industry (represented by ACEA for Europe and JAMA and KAMA for Japan and Korea) has committed itself to cut CO₂ emissions from cars, using a 1995 base of 190g/km, to 140g/km by 2008 (a reduction of around 25%) and by 2009 for the Japan and Korea. There are however potential pitfalls with this agreement: it covers the portfolio of models on offer and anticipated sales by model, excluding extra options bought by the customer, rather than [what might have been expected] on-the-road fuel use or CO₂ emissions from newly sold stock.

DfT, Defra and DTI (2004) suggest that family cars with carbon emissions of 100g/km (equivalent to 75m/gallons of diesel) or less may be achievable in the next 20 years. Improvements in the fuel efficiency of new cars are however being counter-acted by a trend for consumers to buy larger, heavier, less fuel-efficient cars (despite the graduated Vehicle Excise Duty), and wider uptake of additional features such as air conditioning (Bristow, 1996). Hence on current progress it is unlikely that the UK will reach the 100g/km target. There are difficulties associated with take-up: hybrid cars are still relatively expensive, few incentives are provided to buy high-efficiency vehicles. More effective labelling systems may prove effective and are the subject of some current debate in the UK.

### Table 6: Current New Vehicle Fuel Efficiency (Well-to-Wheels)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>CO₂ emissions (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Cars</td>
<td></td>
</tr>
<tr>
<td>Honda Insight Petrol/Electric Hybrid 1.0 IMA Coupe</td>
<td>92</td>
</tr>
<tr>
<td>Ford Fusion 1.4 Diesel TDCI</td>
<td>117</td>
</tr>
<tr>
<td>Renault Clio 1.5 80bhp Diesel</td>
<td>127</td>
</tr>
<tr>
<td>Smart City Coupe Pure Petrol</td>
<td>130</td>
</tr>
<tr>
<td>Toyota Prius 1.5 Petrol/Electric Hybrid</td>
<td>131</td>
</tr>
<tr>
<td>Ford Focus 1.6i 16V Petrol</td>
<td>167</td>
</tr>
<tr>
<td>Ford Mondeo Estate 2.0 TXi</td>
<td>201</td>
</tr>
<tr>
<td>Mercedes E Class Estate 240</td>
<td>283</td>
</tr>
<tr>
<td>Light Goods Vehicles</td>
<td></td>
</tr>
<tr>
<td>Small Vans</td>
<td></td>
</tr>
<tr>
<td>Peugeot New Partner Combi (2.0 Diesel)</td>
<td>152</td>
</tr>
<tr>
<td>Volkswagen CV Caddy Kombi (1.9 Diesel)</td>
<td>154</td>
</tr>
<tr>
<td>Fiat Doblo Range (1.9 Diesel)</td>
<td>176</td>
</tr>
<tr>
<td>Citroen Berlingo Multispace (1.9 Diesel)</td>
<td>181</td>
</tr>
<tr>
<td>Large Vans</td>
<td></td>
</tr>
<tr>
<td>Ford New Transit Torneo (2.0 Turbo Diesel)</td>
<td>209</td>
</tr>
<tr>
<td>Volkswagen CV Caravelle (2.5 Diesel)</td>
<td>213</td>
</tr>
<tr>
<td>Volkswagen CV Multi-Van (2.5 Diesel)</td>
<td>240</td>
</tr>
<tr>
<td>Volkswagen CV Kombi (2.8 Diesel)</td>
<td>289</td>
</tr>
</tbody>
</table>

(From Bristow et al, 2004; Foley and Fergusson, 2003; and various web searches)

---

8 (1) ACEA is the European Automobile Manufacturers’ Association and includes Alfa Romeo, Alpina, Aston Martin, Audi, Bayerische Motoren Werke, Bentley, Cadillac, Chevrolet, Chrysler, Citroen, Daimler, Ferrari, Fiat, Ford, General Motors, Jaguar, Jeep, Lamborghini, Lancia-Autobianchi, Land-Rover, Maserati, Maserati, Mcc (Smart), Mercedes-Benz, Mini, Opel, Peugeot, Porsche, Renault, Rolls-Royce, Saab, Seat, Skoda, Vauxhall, Volkswagen and Volvo.

(2) JAMA is the Japan Automobile Manufacturers Association and includes Daihatsu, Honda, Isuzu, Lexus, Mazda, Mitsubishi, Nissan, Subaru, Suzuki and Toyota.

(3) KAMA is the Korea Automobile Manufacturers Association and includes Daewoo, Hyundai, Kia and Ssangyong.

(4) The technological developments that contributed to the emissions reductions include mainly the introduction of High Speed Direct Injection Diesel (HDI) engines and to a lesser extent of Gasoline Direct Injection (GDI) engines. Further contributions are made from Continuously Variable Transmission (CVT), Variable Valve Lift (VVL), as well as other technical improvements, and Alternative Fuelled Vehicles (AFVs) and Dual Fuelled Vehicles (DFV).

9 Motorists in the UK can save up to £110 in VED each year by choosing the most efficient and least polluting cars. This level of saving does not greatly influence the choice of type of car.
Potential fuel efficiency improvements are estimated to be slightly less for freight vehicles. The DfT (2003) forecasts an improvement of 15% for LGVs and articulated HGVs and 12.5% for rigid HGVs by 2010 (DfT, 2003). The trend for LGV CO₂ emissions over time is not available. It is worth noting that much of the growth in HGV traffic is occurring in the largest articulated lorries.

The IEA (2004) gives guidance on the likely take up of new vehicle technologies:

- A 5% displacement of transport motor fuels across ECD countries could be achieved by 2010 with stronger national programmes, particularly those targeting liquid biofuels
- A 10% reduction in the fuel used for freight movement over the next ten years. Reductions in the order of 25-30% appear achievable in the freight sector over the next 15 to 20 years.

The Energy White Paper (EWP - DTI, 2003) similarly estimates the likely impact of transport policy on emissions. Current UK transport policy aims to reduce greenhouse gas emissions from transport by 5.6 MtC below trend by 2010. This would leave emissions from the sector slightly above 2000 levels. The EWP (Annex 4, DTI, 2003) predicts a reduction of 2-4 MtC in total from road transport by 2020. This assumes the introduction of 5% biofuels into petrol and diesel (as blends), which could save around 1 MtC by 2020; and that the current voluntary agreement with European car manufacturers will be extended to require the new car fleet to achieve an average of 100-115g/km in 2020. The EWP suggests that, taken together, the continuation of voluntary agreements on vehicle carbon dioxide performance, increased use of biofuels and other initiatives could improve carbon efficiency of transport by up to 10% by 2020. Carbon savings will increase further beyond 2020 as more fuel efficient cars spread progressively into the fleet. Deeper carbon reductions however require hydrogen (generated from non-fossil fuel sources) or biomass-based liquid fuels. The auto industry expects hydrogen powered fuel cells to move towards mass marketing around 2030.

In terms of achieving a sustainable, near-zero-emissions transport system there are only three current possibilities: (1) converting to a hydrogen fuel cell system, (2) moving to a purely electric vehicle system, or (3) relying on liquid fuels that are derived from biomass. Transition to such a transportation system is likely to take 40 years or more (IEA, 2004). The UK government has recently begun to develop a hydrogen energy strategic framework.

**Behavioural change**

Efforts to reduce the growth in vehicle travel are often related to goals other than saving reducing CO₂ emissions or saving energy, for example improving city living or quality of life. The literature on behavioural change - estimating the potential contribution of integrated pricing, soft factors and land use planning in reducing travel - is less developed than that on technological change, although there has been much research since the late 1980s. This is a major research gap; there is a need for a real push on the research effort here.

Figure 7 shows the main options available in terms of reducing vehicle kilometres (and CO₂ emissions): these being to remove trips, switch mode or reduce distance travelled.

**Figure 7: Behavioural Change Options**

![Figure 7](source: Banister and Marshall, 2000)

Traffic demand management is a generic term that covers many of the tools available to help reduce travel (see [www.vtpi.org](http://www.vtpi.org) for a detailed discussion of the techniques available). The major tools to influence travel include:
• Pricing for road use: The Commission for Integrated Transport (CiIT, 2002) calculates that a national road user charging scheme, implemented in 2010 and revenue neutral to 2015 (offset by reductions in vehicle excise duty and fuel duty) would yield a maximum 5% reduction in vehicle kilometres.

• Soft factors: measures such as workplace and school travel plans, personalised travel plans, car clubs and teleworking could lead to a reduction in peak period urban traffic of around 20%, a reduction of peak period non-urban traffic of around 14%, and a nationwide reduction in all traffic of around 11% (Cairns et al, 2004).

• Land use planning: the literature dealing specifically with the interaction of land use planning with travel behaviour has developed from the late 1980s onwards and has come to include a rapidly expanding literature. The academic debate as to the potential for structuring urban form and influencing travel behaviour has been mainly carried out in the UK, the USA and Australia. Key authors include Newman and Kenworthy (1989 and 1999), Cervero (1989), Headicar and Curtis (1995) and Banister et al (1997). The underlying theme of much of the research has been to evaluate the potential contribution of land use planning in reducing car-based travel. Few authors have managed to estimate the contribution that land use planning might play in reducing travel, partly due to the difficulty in isolating the effects of land use factors from other variables. Ecotec (1993) are most often quoted in the UK: suggesting that land use planning measures could achieve a 10-15% reduction in CO₂ emissions over 20 years in a large urban sub-region. Some authors in the USA have suggested much larger contributions. WS Atkins (1999) has suggested reductions in traffic of up to 2% could be achieved by 2010.

Opinion as to the likely impact of urban form on travel, for example, is varied. A number of topic areas have received considerable coverage in the literature, such as the influence of population size, density, public-transit orientated development, smart growth, urban sprawl, the provision and mix of local facilities, local neighbourhood design, the location of development, balance of jobs and housing and also wider socio-economic variables (see Hickman and Banister, forthcoming 2005, for a review). Some authors assert that urban form can and does impact on travel behaviour, and, critically, can be used to design more sustainable towns and cities (work drawing on empirical evidence mostly from compact city examples in Europe and Australia, e.g. Newman and Kenworthy, 1989 and 1999; and Cervero, 1989). Others are more sceptical and query the usefulness of planning interventions, and sometimes further, that the efficiency of ‘invisible hand’ market mechanisms leads naturally to a ‘co-location’ of residential and employment locations. They believe that adjustments occur over time – unrelated to planning interventions - which bring workplaces and homes closer together and reduce commuting costs and distances [and presumably CO₂ emissions]. Much of this work is based on research from suburban Los Angeles (e.g. Gordon and Richardson, 1997). The latter group broadly postulate that suburbanisation trends do not lead to the expected increases in traffic volumes (other variables, such as socio-economic factors, are perceived as more important) and there is little need to attempt to intervene and influence patterns of travel through modifying urban forms. Breheny (1992) has developed parallel views in the UK, also stressing that the trend towards counter-urbanisation may be too great to reverse by planning interventions.

Ewing and Cervero (2001) conclude that:

• Trip frequencies appear to be primarily a function of the socio-economic characteristics of travellers and secondarily a function of the built environment.

• Trip lengths are primarily a function of the built environment and secondarily a function of socio-economic characteristics.

• Mode choices depend on both socio-economic characteristics and characteristics of the built environment, though probably more the former.

Stead (1999) has recently brought a number of these areas together using regression analysis. For example, he suggests that socio-economic variables explain between 19-24% of the variation in distance travelled and land use variables up to 3% at the individual level of analysis. At an area-wide level this influence increases: socio-economic variables explain between 23-55% of the variation in distance travelled and land use variables up to 27%. Hickman (2005) suggests that land use can explain around 3% of the variation in energy consumption in the commute to work, compared to socio-economic (including attitudinal) variables of up to 29%. Critically a wide range of land use and socio-economic measures can be mutually reinforcing in contributing to travel reductions.

As an additional related topic, Hillman and Fawcett (2004) outlines the potential for carbon rationing. A system of tradable CO₂ emission permits would have several effects. Say, for example, that individuals are given a free yearly CO₂ budget (and are free to buy or sell permits at a market price); they may try to optimise their travel patterns within their budget. Possible effects are:

• A reduction in the number of passenger kilometres, depending on the total CO₂ budget for passenger transport and the price of buying extra CO₂ permits

• Less energy use per vehicle kilometre, with improved energy efficiency of cars and better driving behaviour, so that more vehicle kilometres can be driven with the same CO₂ permit
• Modal split changes, with the use of non-motorised transport increasing

Authors such as Hillman see carbon rationing as critical to meeting future CO₂ targets. The interesting issue for the VIBAT study is to identify the potential contribution of (integrated) technological and behavioural change, and the balance of effort that is required to help achieve the selected targets.

**Next Steps: The Imperative for Change**

Goodwin et al (1991) identified a *new realism* in transport planning, using the publication of the National Road Traffic Forecasts (DoT, 1989) as a watershed moment. The forecasts of economic growth and existing trends meant that traffic levels would increase by between 83% and 142% from 1988 to 2025. This scale of potential traffic growth meant that road building could not hope to keep up with demand. Whatever road construction policy was adopted, congestion would increase and hence the new requirement for policy was one of demand management.

The transport world has however moved on apace. A new determinant is now the global environmental imperative. The new realism in 2005 is that CO₂ emission targets necessitate radical change in the transport sector. We need to start implementing traffic demand management strategies across the UK, and critically to appraise transport investment plans against global environmental targets. There is little understanding as to how local transport plans and other investment strategies are likely to contribute to emissions targets. This appears to be a huge evidence gap.

Hughes (1983) memorably started his book 'Personal Transport and the Greenhouse Effect' with some classic John Wyndham prose:

"One day we walked down to Trafalgar Square. The tide was in, and the water reached nearly to the top of the wall on the northern side, below the National Gallery. We leant on the balustrade, looking at the water washing around Landseer's lions, wondering what Nelson would think of the view his statue was getting now ...

She took my arm, and we started to walk westward. Halfway to the corner of the Square we paused at the sound of a motor. It seemed, improbably, to come from the south side. We waited while it drew closer. Presently, out from the Admiralty Arch swept a speedboat. It turned in a sharp arc and sped away down Whitehall, leaving the ripples of its wake slopping through the windows of august Governmental offices."

Global catastrophicism maybe; but useful, at least, in articulating the scale of the problem. The difficulties of Popper still remain - we cannot anticipate today what we shall know only tomorrow - yet the imperative for reducing transport emissions is here. A critical issue should be borne in mind: (normally) a totally new idea or new knowledge will not be implemented immediately. There is a time span between the emergence of a new idea and it being widely applied in practice. The classic example here is fuel efficiency improvements in vehicles. Hence, existing knowledge and ideas may have a profound influence on future trends in the short term. Popper's indeterminacy problem is often only experienced in the long term.

Scenario building and backcasting provide a way forward empirically, and form the next stages of the VIBAT research through the development of images of the future and policy packages. The lack of progress in the transport sector towards achieving global environmental targets means that - if we are to meet medium and longer-term targets - we need to be agreeing policy pathways now. If global sustainability targets are to be achieved then the transport sector needs to make a contribution in terms of emissions reduction; this necessarily means action on both technological and behavioural fronts. And action needs to start now [in 2005] if a Wyndham-esque future is not to be realised.

---

10 From Wyndham, J. (1953) The Kraken Wakes
References

European Commission (1996)
Hickman, R. (Unpublished PhD draft) Reducing Travel by Design. London: Bartlett School of Planning, UCL.


