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Planning for an unpredictable future: Transport in Great Britain in 2030

Kiron Chatterjee [a,*], Andrew Gordon [b]

[a] *Centre for Transport and Society, University of the West of England, Bristol BS16 1QY, UK*
[b] *Mott MacDonald, Stoneham Place, Stoneham Lane, Southampton, Hampshire SO50 9NW, UK*

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Abstract

This paper describes a research study, which explores alternative future scenarios for Great Britain in the year 2030 and the implications these have for travel demand and transport provision. Five alternative future scenarios are represented in the GB national transport model and forecasts are obtained for trip making, traffic levels, congestion and emissions in 2030. For all scenarios it is expected that there will be significant traffic growth. Traffic growth is restricted most in scenarios including distance-based road charging on motorways and trunk roads. However, congestion and carbon dioxide emissions are most effectively limited in scenarios with congestion-based road charging, major improvements to urban public transport and investment in new fuel technologies and in improving engine efficiency.

Keywords: Scenario planning; Forecasting; Travel demand; Traffic growth

1. Introduction

Transport policy making is usually informed by long term forecasts of travel demand and transport system performance. These forecasts will be based on the best possible estimates of future social, economic and technological trends. Sensitivity analysis is sometimes carried out to test the implications of variations in these trends. If, however, the future turns out to be completely different to that envisaged the adopted transport policies are unlikely to serve well. This paper describes a research study, which explores alternative future scenarios for Great Britain in the year 2030 and the implications these have for travel demand and transport provision.

In 1998, the United Kingdom Government published a white paper (DETR, 1998) setting out a new transport policy, which it referred to as an integrated transport policy. Since then various steps have been taken to put the policy into practice. Most notably, in July 2000 the Government published the 10 year plan (DETR, 2000a), an investment plan for surface transport for the period up to 2010–2011. It had the strategy to 'tackle congestion and pollution by improving all types of transport—rail and road, public and private—in ways that increase choice'.

The 10 year plan (TYP) was informed by forecasts reported in a background analysis paper (DETR, 2000b). Forecasts were made using the national road traffic forecasts (NRTF) framework of models which provided estimates of travel demand (passenger and freight), traffic, congestion, emissions and air quality in 2010 under different transport scenarios (baseline scenario without TYP, TYP scenario, three illustrative scenarios involving different assumptions regarding motoring costs, transport investment, take up of local congestion charging and workplace parking levy powers and introduction of inter-urban charging). The forecasted impacts of the scenarios played an important part in the formulation of the TYP. They were used to calculate the cost-effectiveness of TYP measures in tackling congestion and carbon dioxide emissions.

Inevitably, many assumptions have to be made in order to make long-term forecasts. The TYP itself states (chapter 9, page 85) that 'over the next decade, a number of developments—economic, social, environmental and technological, as well as those in transport itself—will bring change in ways that could well affect the assumptions and analysis which lie behind the plan. Inevitably, such developments cannot be foreseen and incorporated now into the measures we are setting out here. The plan will need to be reviewed and adjusted over time to

* Corresponding author. Tel.: +44 117 32 82032; fax: +44 117 32 83002.
E-mail address: kiron.chatterjee@uwe.ac.uk (K. Chatterjee).

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make sure what we are putting into place is in line with our overall aim of improving transport for everyone'.

In 2002, the Department for Transport[1] published a progress report on the TYP (DfT, 2002). This included some updated forecasts to 2010. The progress report presented 'low' and 'high' forecasts for TYP impacts which illustrated the combined impact of several major sources of uncertainty (GDP growth, sensitivity of travel demand to income growth and the effect of 'soft' transport policies).

As this paper is being written, a new transport white paper has been published by the Government (DfT, 2004) which sets out an updated investment plan up to 2014–2015 as well as re-organisation of aspects of transport management and a launching of a debate on national road pricing.

As one element of the review process of the TYP, the Department of the Environment, Transport and the Regions (DETR) commissioned the Transportation Research Group at the University of Southampton and Mott MacDonald to study the 'impact of future scenarios on integrated transport policies'. While the background analysis for the TYP considered alternative transport scenarios (and the progress report included a low and high range for forecasts of TYP impacts), it had not considered alternative scenarios for trends outside transport. The study had the aim of examining the robustness of DETR's transport policies (including the TYP) by considering longer term scenarios (20–30 years hence) for how the world might change and affect transport and travel demand in the UK. This paper describes the methodology and findings of the study. The study employed a novel approach, combining the qualitative methodology of scenario planning with the quantitative methodology of transport modelling. In the next section scenario planning is explained and the scenarios used are described. The subsequent section summarises the characteristics of the model used and the way in which the scenarios are represented in the model. The modelling results are then described before methodological and policy conclusions are provided.

2. Future scenarios

A number of approaches can be used to study the future. Fig. 1 from Ling (1998) illustrates the range of recognised approaches that can be employed when engaging in the study or prediction of the future. The approach selected will be dependent upon the context that is being studied. If the context is simple, predictable and largely controllable then the employment of planning methodologies such as forecasting and extrapolation may be appropriate. However, the more complex and unpredictable the environment under study (as is the case for GB in 20–30 years time) the less useful and appropriate such approaches become. An alternative approach in such circumstances is that of scenario planning (Schwartz, 1991, provides a thorough explanation of scenario planning and its role). Table 1 emphasises the value of scenario planning by comparing its attributes with those of forecasting. In essence, the benefit of scenario planning is that it recognises that when studying or predicting the future, to start with certainties is to end with doubts (Queensland, 2000).

In scenario planning the aim is to develop distinctive, divergent depictions of the future. Alternative scenarios are developed from the present situation for a desired time horizon. In a scenario planning exercise a number of driving forces will be identified. By making different assumptions about these driving forces or key influences, different 'stories' are formulated about how they interact. The scenarios are effectively these stories.

The challenging feature of this study was to combine the use of scenarios with quantitative forecasting. This has rarely been attempted previously in transport studies. The one example found describes work which has produced transport forecasts for the European Union in 2020 for three scenarios:—reference scenario, rapid integration scenario and sustainable policy scenario (Tavasszy et al., 2000). Qualitative assumptions (increase, decrease, stay the same) were made for a number of factors (GDP, employment, population, car ownership, transport times and costs) for each of the three scenarios. These were fed into a passenger transport model which considered inter-regional travel within the 15 European Union countries. The results showed traffic growth by 2020 of 30% for the reference scenario, 42% for the rapid integration scenario and 27% for the sustainable policy scenario. Tavasszy et al. (2000) demonstrate what is possible through combining qualitative scenarios with quantitative forecasting. For our study we wished to apply this approach to GB, exploring a wider variety of future scenarios and considering all types of travel (including local travel).

The study undertook a review of worldwide scenario planning exercises, considering 83 scenarios from 20 different scenarios planning projects. Across the reviewed projects it was found certain key influences and scenarios reoccurred. The decision was taken to select scenarios which reflected this homogenity and which also provided a set of scenarios with a broad range of outcomes. The environmental futures (EF) scenarios (DTI, 1999a) were selected on this basis as well as the fact that they were developed in detail and applicable to GB. The review and selection of scenarios are described in detail in a project working report (TRG, 2001a). The four EF scenarios are:

- World markets (WM);
- Provincial enterprise (PE);
- Global sustainability (GS); and
- Local stewardship (LS).

The four scenarios were developed considering social, economic and technological changes with particular reference to alternative possible environmental futures. The focus is upon the UK within a global context and the time horizon is 2010–

[1] There have been a number of re-organisations of government departments in the UK in recent years with the Department for Transport (DfT) being formed in 2002, replacing the Department for Transport, Local Government and the Regions (DTLR) which itself replaced the Department for the Environment, Transport and the Regions (DETR) in 2001.

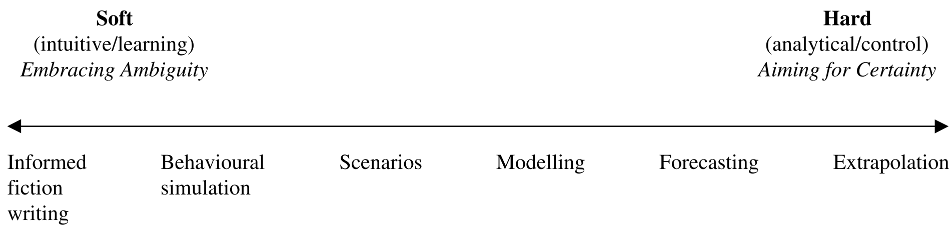

Fig. 1. Practices used in the study or prediction of the future (source: Ling, 1998).

2040. The four scenarios are determined by the interaction of two pairs of polarised key influences: consumerism versus community and globalisation versus regionalisation. The biaxial approach used as the basis for developing the scenarios ensured four distinctive, polarised scenarios were generated and that they encompassed a broad range of outcomes. The scenarios are illustrated in Fig. 2. A continuation of current trends ('business as usual' scenario) can be expected to lie somewhere near the centre of the axes.

The EF scenarios have been applied to long term planning in a number of fields of study with a recent paper in transport policy referring to their use in considering the carbon dioxide emissions from transport in 2050 (Tight et al., 2005). Summaries of each scenario are included in an appendix to this paper. These include a general description of the scenarios (taken from DTI, 1999a) followed by a description of the transport implications (taken from DTI, 1999b).

3. The national transport model

The model used for this study is known as the national transport model (NTM). It is a multi-modal model for Great Britain that has evolved from the 1997 national road traffic forecasts and from the framework of models used for the TYP. It has been used for the forecasts in the progress report on the TYP (DfT, 2002). The structure of NTM at the time of the research in 2003 is shown in Fig. 3. The version of the NTM used for this work has been updated and revised since we completed this analysis, although the basic structure as described below remains unchanged. A brief explanation of the model follows. A history and more detailed description of the model are provided in DfT (2003).

NTM consists of a number of sub-models. At its core it consists of a demand model and two separate supply models (road capacity and costs model and national passenger rail model). Inputs to the demand model are the car ownership model, which predicts how car ownership will change over time in response to incomes, household composition, land use patterns and licence holding, and the trip end model, which predicts trip rates according to different population types (e.g. employed male in two adult, one car household). The effect of local transport policy is represented through the spend impact database which translates income on transport expenditure into changes in generalised cost of each mode of transport.

The demand model uses the predicted trip ends and information on costs of travel to produce forecasts of person-trips by distance, purpose and mode. The model represents the structured choices of how far to travel (13 distance bands), what area type to travel to (nine area types from London to rural) and what mode of travel to use (six modes–car driver, car passenger, rail, bus, walk and cycle). The model generates mode share information and provides disaggregated outputs on rail trips for the rail network model and on car driver trips for the road capacity and costs model.

The road capacity and costs model (FORGE) takes as input the car driver trips obtained from the demand model as well as growth in freight traffic from the Multi-modal Freight Model. In the traffic network model car driver trips are assigned to a detailed representation of the national road network to obtain car traffic on links. In FORGE the effect of growth in car and freight traffic is predicted by comparing traffic levels to capacity on each link and resulting traffic speeds are calculated from speed/flow relationships. Changes in speed influence the costs of travel through their impact on fuel costs and time costs. As congestion grows and speeds on busy links fall, a series of elasticity-based rules are applied to re-distribute traffic between links on different roads and time periods. Having shifted traffic, the model recalculates speeds and produces new estimates of car journey costs. Outputs of FORGE are traffic levels, delay, emissions and speed. Iterations take place between the demand model and FORGE with car driver costs fed back from FORGE to enable mode share to be recalculated.

Road policies are represented through adjustments to link volume/capacity ratios and speed/flow relationships. Changes to fuel efficiency and characteristics of the vehicle fleet in response to fiscal policy, underlying price and technical trends are forecast through the vehicle market model.

In parallel with car trips being fed to the road capacity and costs model, rail passenger trips are fed into the national passenger rail model. Rail trips are assigned to a detailed representation of the rail network to obtain changes in generalised costs due to changes in train loadings and any resultant changes in rail route choice. The resulting generalised costs of rail travel are then passed back to the demand model, where the modal shares are re-estimated.

Table 1
Comparison of forecasting and scenario planning (source: Government of Queensland, 2000)

Forecasting	Scenario planning
Focuses on certainties and disguises uncertainties	Focuses on and legitimises recognition of uncertainties
Conceals risk	Clarifies risk
Results in single point projections	Results in adaptive understanding
More quantitative than qualitative	More qualitative than quantitative

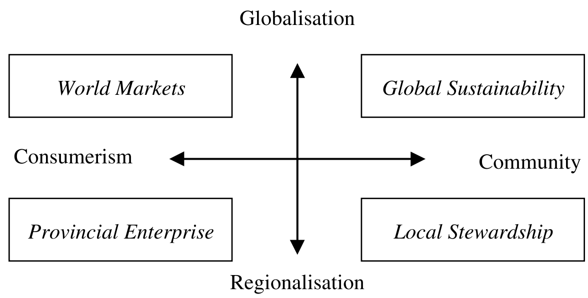

Fig. 2. Scenarios developed using two axes of influence (source: DTI, 1999a).

For this study a time horizon needed to be chosen for considering the impact of the future scenarios. 2030 was chosen. This is within the 2010–2040 period envisaged by the EF scenario authors and is far enough into the future to allow major change to occur while still enabling modelling to be practicable. The assumption was made for the reference case scenario that transport policy up to 2010 is as set out in the TYP and after 2010 is a broad continuation of TYP policy. Changes in transport policy were permitted for the EF scenarios. As this paper is being written it is becoming clear that some of the components of the TYP are unlikely to occur (e.g. eight urban congestion charging schemes, 25 urban light rail schemes).

The EF scenarios can be represented in NTM through setting appropriate values for model inputs and parameters. Table 2 summarises the main assumptions made to represent each scenario. It also sets out a definition of the reference scenario, against which the impact of each of the scenarios could be evaluated.

Careful note was made of the descriptions of the scenarios (as summarised in the appendix) in order to represent them as faithfully as possible in NTM. This meant, for example, that inter-urban road tolls were considered to be a feature of the WM and PE scenarios given the privatisation of public services stated to occur in these scenarios. In selecting specific values for model inputs the emphasis was placed on the relative values used for the future scenarios, compared to each other and to the reference case. A detailed explanation of how the model inputs were determined is presented in a project working report (TRG, 2001b).

Some characteristics of the EF scenarios proved difficult or impossible to represent in NTM. International and domestic air travel is not able to be considered in NTM, so, for example, competition between air and rail for the long distance domestic passenger market was not able to be taken into account. The introduction of new vehicle propulsion systems (electric, hybrid and fuel cell engines) is mentioned in the EF scenarios. This is not able to be directly represented in NTM but could be taken into account through assumptions made for fuel consumption. Differing outcomes for the distribution of economic wealth are outlined in the EF scenarios. Model tests were carried out adjusting income distribution but these made negligible difference to model outputs and were not pursued for the final model runs. Some mention is made in the EF scenarios of travel being substituted by information and communication technology (ICT) but research on this subject to date does not provide strong evidence that this is likely to be substantial (Salomon, 2000) and no adjustment was made to the trip rate relationships included in NTM.

4. Results

Results for the EF scenarios and the reference ‘business as usual’ 2030 scenario are compared to base year results for the year 2000. First results are presented for different indicators then the results for each of the 2030 scenarios are discussed. More detailed results are contained within a project working report (TRG, 2003).

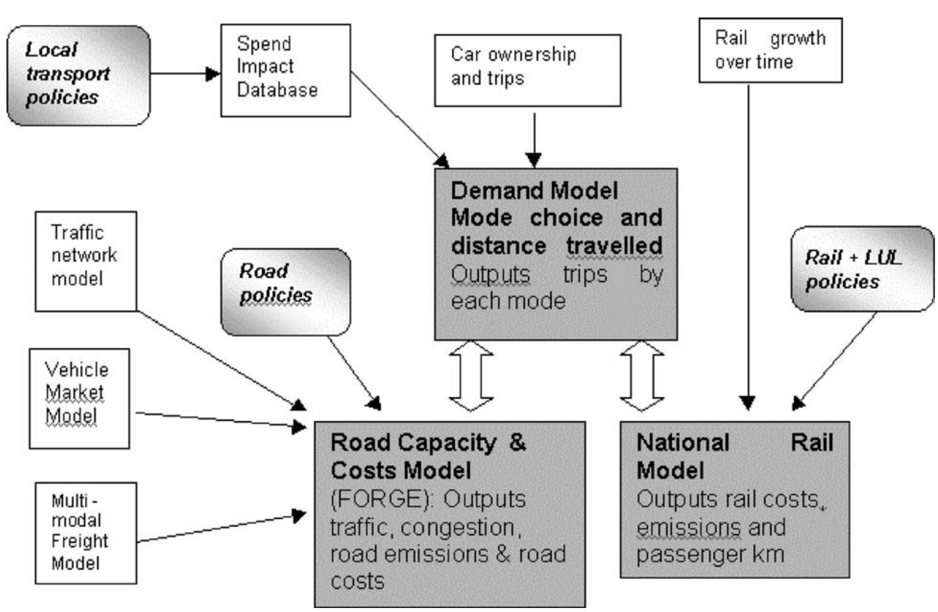

Fig. 3. Outline structure of NTM (source: DfT, 2003).

Table 2
Summary of NTM model inputs for 2030 scenarios

	Reference case	World markets	Provincial enterprise	Global sustainability	Local stewardship
Economics and planning					
UK GDP growth (p.a.)	2.25%	3%	1.5%	2%	1%
Population (GB)	61.86 million	68.05 million	61.86 million	60.79 million	59.08 million
Average household size	As TEMPRO[a]	Same as ref. case	↑ (as ref. case in 2020)	↑ (as ref. case in 2010)	↑ (as ref. case in 2010)
Employment total	As TEMPRO	109% of ref. case	85% of ref. case	93% of ref. case	90% of ref. case
Employment structure	As TEMPRO	Increase in services (+10%)	Same	Increase in services (+15%)	Same
Settlement distribution	As TEMPRO	Shift to suburban and rural	Shift to urban	Shift to urban	Shift to non-metropolitan
Transport					
Road building	TYP[b] plus 0.5 TYP rate for 2010–2030	↑ (TYP rate 2000–2030)	↓ (TYP rate 2000–2010 then 0.25 TYP rate 2010–2030)	Same as ref. case	↓ (TYP rate 2000–2010 then junctions improvements only)
Road tolls	22 UCC plus 24 WPPL[c]	Inter-urban distance-based tolls, eight UCC and 12 WPPL	Inter-urban distance-based tolls, no UCC or WPPL	Comprehensive UCC	Comprehensive UCC and inter-urban congestion-based toll
Vehicle efficiency	4.8 l/100 km	↓ (4.2 l/100 km)	↑ (5.3 l/100 km)	↓ (3.2 l/100 km)	↓ (3.4 l/100 km)
Fuel costs	Oil $16/barrel	Oil $10/barrel	Oil $20/barrel	Oil $30/barrel	Oil $25/barrel
Rail speeds	TYP forecast for 2010	↑ (20% for inter-city)	↓ (10%)	↑ (10%)	Same as ref. case
Rail fares	Increase slightly in real terms	↑ (10% for inter-city)	↑ (10%)	Same as ref. case	Same as ref. case
Bus speeds	TYP forecast for 2010	Same as ref. case	↓ (10%)	↑ (10%)	Same as ref. case
Bus fares	Stay same in real terms	↑ (10%)	↑ (10%)	Same as ref. case	↑ (20%)
Freight					
Tonnes lifted	GDP-related growth	Food +5%, raw materials/manuf. −10%	Same as ref. case	Food −5%, raw materials and manuf. −15%	All types −5%
Average length of haul	TYP forecast for 2010	All types +5%	Raw materials and manuf. −5%	Same as ref. case	All types −5%
Lifestyle					
Value of time	GDP-related growth	Same as ref. case	↑ (5%)	↓ (5%)	Same as ref. Case
Bus improvements	As TYP	↑	As TYP	↑	↑
Travel awareness intensity[d]	Medium	Medium	Medium	Medium	High
Slow mode policy intensity	Medium	Medium	Medium	High	High

[a] TEMPRO version 4.2 provides forecasts for household and employment in 1203 wards in GB for 2000, 2010, 2020 and 2030. See http://www.tempro.org.uk/.
[b] TYP, 10 year plan for road investment.
[c] UCC, urban congestion charging scheme; WPPL, workplace parking levy scheme.
[d] Travel awareness intensity increases reluctance to use car. Slow mode policy intensity increases willingness to walk and cycle.

4.1. Results for different indicators

Table 3 presents results for car ownership, trip rates and mean trip lengths. There are significant variations in the forecasted car ownership rates for the 2030 scenarios, although there is an increase over the base year in each case. The main determinant of car ownership is income and the car ownership results strongly reflect GDP growth. For example, WM is the only scenario with higher GDP growth than the reference case and it is the only scenario with a higher rate of car ownership.

Trip rates are shown in terms of trips per person for a 24 h period of an average day. Trips per household will be affected by, among other things, car ownership (the more cars, the more trips) and the size of the household, with the latter apparently more important. Trips per person, which are largely independent of household size, are very similar for all scenarios but are slightly lower in those scenarios with lower car ownership.

Table 3
Car ownership, trip rate and trip length forecasts

Scenario	Pop (millions)	Households (millions)	Cars per person	Trips per person	Mean trip length (km)
2000 Base	57.4	24.3	0.44	1.68	10.8
2030 Reference	61.9	29.1	0.59	1.71	12.2
2030 WM	68.0	31.9	0.61	1.72	11.2
2030 PE	61.9	28.7	0.54	1.70	10.9
2030 GS	60.8	27.1	0.55	1.71	12.1
2030 LS	59.1	25.1	0.51	1.69	11.5

Much of the increase in car ownership is for households that already have one car; according to the trip end model these second cars have only a small impact on trip rates. For the four EF scenarios the mean trip length is lower than the reference case, but higher than the base year.

Fig. 4 shows mode share in terms of person kilometres. The car maintains a dominant share in 2030. An interesting result is that the car driver share is lower for each of the EF scenarios than the reference case. This might be expected for PE, GS and LS, which have lower investment in road capacity (compared to the reference case), higher fuel costs (after changes in fuel efficiency and oil prices have been taken into account) and (for GS and LS) more extensive tolling. It is more surprising for the WM scenario which has a higher investment in road capacity and lower fuel costs.

Fig. 5 shows forecasts of traffic in terms of vehicle kilometres. The NTM forecasts a 51% increase in total traffic for the reference case. For each of the EF scenarios the increase in traffic is lower than this. Traffic growth is lower on roads in urban areas than roads elsewhere. On motorways and trunk roads an increase in traffic of 66% is forecasted for the reference case. For WM and PE very little change in traffic is forecasted on motorways and trunk roads compared to the base year.

Fig. 6 shows forecasts of congestion, defined as lost time (difference in time spent travelling compared to time spent in free flow conditions) in seconds per kilometre. A 68% increase in congestion is forecasted in 2030 for the reference case with the increase similar across the different area types. For all four EF scenarios the congestion increases are lower than the reference case. This applies to congestion in each of the area types. For WM and PE there are reductions in congestion on motorways and trunk roads of 45% compared to the base year. It was noted previously for WM and PE that traffic levels on these roads were about the same as the base year. A substantial reduction in congestion is achieved therefore without any reduction in traffic.

Fig. 7 shows forecasts of overall emissions (expressed as percentage changes compared to the base year). Each type of emission is related to traffic levels but carbon dioxide is also related to fuel efficiency and fuel type and nitrogen oxides and particulates (PM_{10}) are also related to vehicle emissions standards and fuel type. For all scenarios, including the reference case, nitrogen oxides and particulates (PM_{10}) are forecasted to decrease by at least 50%. A 19% increase in carbon dioxide is forecasted for the reference case.

4.2. Results for different scenarios

The reference case scenario represents a continuation of current trends and policies. Traffic is forecasted to be 51% higher than in 2000, congestion 68% higher and carbon dioxide road emissions 19% higher. The reference case results for 2030 provide no grounds for expecting a 'tailing off' of traffic growth after 2010 and show that the 10 year plan will only have short-term impacts on congestion. Clearly, the reference case scenario is not a welcome prospect and the implication is that current investments in roads and public transport and charging policies need to be continued beyond 2010, supplemented by additional measures to encourage shorter trips and a greater mode share for public transport. Urban congestion charging is assumed to be in place in all cities in 2030 but appears to have little effect at the level of charges imposed given the similar growth forecasted for congestion in cities compared to towns and rural areas. The increase in carbon dioxide for the reference case is explained by increased traffic and congestion levels and only modest improvements in vehicle fuel efficiencies.

WM is characterised by materialist social values and lack of emphasis on long-term sustainable development. Traffic growth is forecasted to be lower than the reference case which is a surprising result given its higher GDP and population growth. Traffic growth is forecasted to be only 33% higher than in 2000 and congestion to be 52% higher than in 2000. The low traffic growth is mainly accounted for by inter-urban distance-based road charging which results not only in proportionally fewer long distance car trips than the reference case but also than in 2000. In terms of traffic, congestion and emissions, this scenario is slightly more favourable than the reference case. It is debatable, however, whether some of the outcomes forecasted are realistic for this

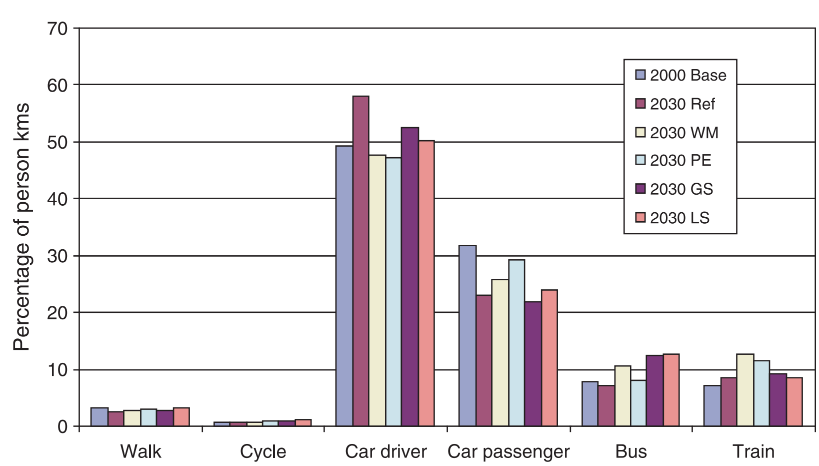

Fig. 4. Mode share by person kilometres.

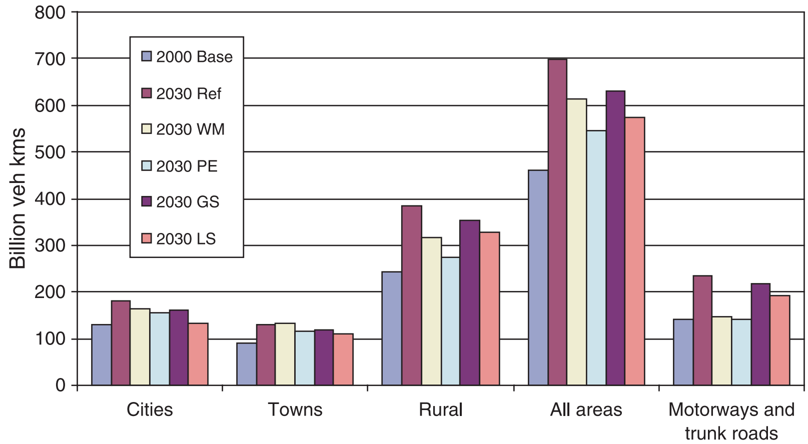

Fig. 5. Traffic in billion vehicle-kilometres/year. Note. Motorway and trunk roads are roads managed by the Highways Agency which predominantly are found in rural areas but also in cities and towns. In 2003 these comprised 3.3% of public road length in Great Britain.

scenario. A sensitivity test with congestion-based inter-urban road user charging (as adopted in LS scenario), instead of distance-based charging, is forecasted to result in traffic levels 64% higher than in 2000 and congestion levels 80% higher.

PE is characterised by weak economic growth and limited investment in new technology and public services. Traffic is forecasted to be 18% higher than in 2000 and congestion 45% higher. The low GDP growth in this scenario is one reason for these relatively low growth rates. Carbon dioxide road emissions are forecasted to be 9% higher than in 2000 which is an unwelcome outcome, especially given the low traffic growth. It can be explained by the lack of improvements in vehicle efficiency assumed in this scenario. Similar outcomes are forecasted regarding long distance car travel as the WM scenario. PE is the only 2030 scenario where traffic growth in cities is higher than the growth across all area types. It is also the only scenario without any urban congestion charging.

GS is characterised by the adoption of sustainable technologies and patterns of behaviour. Traffic is forecasted to be 36% higher than in 2000 and congestion 34% higher. The growth in congestion is about half that of the reference case. Without any inter-urban charging, this is a consequence of high fuel prices, urban congestion charging and public transport investment. Improvements in vehicle efficiency result in carbon dioxide road emissions 19% lower than in 2000. The car mode share is lower than the reference case with increases in mode share for walking, cycling and bus. In many ways, the outcomes of GS are preferable to those of the other scenarios, especially since these are achieved with reasonable GDP growth (2% per annum).

LS is characterised by conservationalist values. The LS scenario has forecasts of low traffic and congestion growth which is not surprising result given its low GDP growth and the presence of urban and inter-urban congestion-based road user charging. Traffic is forecasted to be 24% higher than in 2000 and congestion 10% higher. The forecasts for carbon dioxide road emissions are similar to GS. Car driver mode share is forecasted to be 8% less than in the reference case and reductions in car driver share are particularly marked for short journeys. While congestion is forecasted to grow by 36% overall in rural areas, it is forecasted to decrease on motorway and trunk roads, implying large increases in congestion on other rural roads. There is no change to congestion in cities compared to the base year.

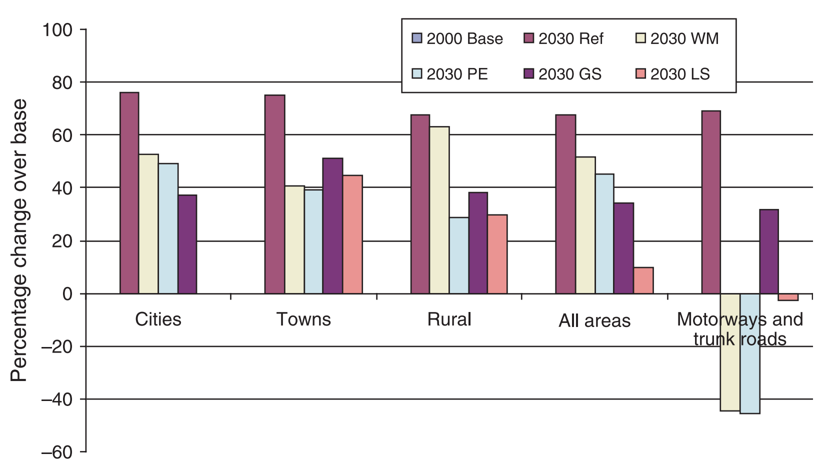

Fig. 6. Congestion expressed as percentage change over base. Note. Motorway and trunk roads are roads managed by the Highways Agency which predominantly are found in rural areas but also in cities and towns. In 2003 these comprised 3.3% of public road length in Great Britain.

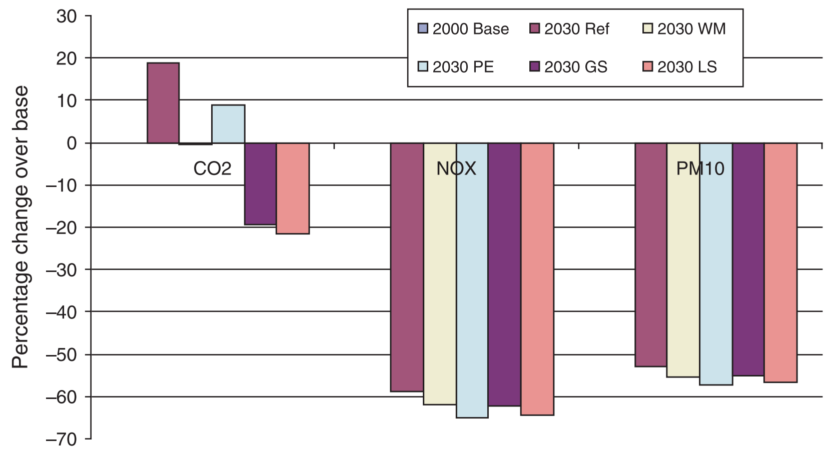

Fig. 7. Emissions expressed as percentage change over base.

5. Conclusions

5.1. Methodological conclusions

The following discussion restricts itself to consideration of the general approach reported in this paper (combined use of scenario planning and transport modelling) and does not consider the technical merits of the forecasting process used in comparison to other possible forecasting processes. Readers interested in learning more about different national transport modelling processes are referred to Daly (2000) and readers interested in a review of the state of the art in transport modelling are referred to DSC (2001).

The scenarios considered involve in some cases quite significant changes to society. Taking the concept of paradigm shifts introduced by Kuhn (1962) in ‘the structure of scientific revolutions’ (1962) such changes to society will not happen instantaneously (they are dependent on changes to human values and attitudes amongst other factors) and will typically require at least 20 years to come about. The time horizon of 2030 can be considered to provide just sufficient time for paradigm shifts to take place.

We attempted to represent the scenarios as faithfully as possible in determining NTM inputs. After conducting the modelling work we compared the forecasts with any transport outcomes mentioned in the descriptions of the scenarios. This highlighted that the differences in travel behaviour that are forecasted by NTM for the scenarios are less than anticipated by the scenario authors. One reason for this is that the assumptions made for the scenarios tended to result in outcomes that converged. In particular, the inclusion of distance-based road charging reduced long distance car trips in the high economic growth WM scenario (as noted, a different form of road charging was tested in the WM scenario and produced less convergent results). Another reason is that the travel behaviour relationships underlying NTM (estimated based on historic data) do not allow extreme changes in travel behaviour to be forecasted. For example, substitution of out-of-home activities by in-home activities are expected to have profound impacts in the GS scenario but were not able to be represented in NTM.

There is clearly considerable uncertainty associated with the quantitative forecasts from transport models, especially long-term forecasts. It is unusual for retrospective studies to be conducted examining the accuracy of past modelling forecasts. An important reason for this is that models tend to continually evolve and it can be seen to be of academic interest only to review forecasts. One case where there has been a review is the Netherlands national model, commissioned in 1983, where the general reliability of the model was confirmed but with specific areas of improvement identified (Daly, 2000).

The main sources of uncertainty in transport modelling are the model inputs and the model specification and parameters. Rather than being a concern, in this study the uncertainty in inputs has been what has been of fundamental interest. The NTM model specification and parameters have been developed to reproduce travel patterns for the base year and elasticities from econometric models. It is possible that future travel patterns will not be well explained by the specification and parameters used currently. However, it is considered that NTM gives a reasonable indication of the relative outcomes that can be expected for the different scenarios.

An alternative approach to modelling long-term scenarios has been adopted in the SCENES European project (SCENES, 2000). A system dynamics model, ASTRA, has been used to generate transport forecasts for the European Union in 2026 for a business-as-usual scenario and for an increased road investment scenario and higher car costs scenario. ASTRA comprises a macroeconomics sub-module, regional economics and land use sub-module, transport sub-module and environment sub-module.

System dynamics was first formulated by Forrester (1969) and seeks to represent all the relevant inter-relationships within a system. It requires a comprehensive conceptual model prior to development of the model, therefore an effective model is dependent on a good understanding of the inter-relationships within the system (Sterman, 2000).

The future pattern of land use is a key determinant of the future demand for transport. In our study, land use forecasts have had to be made 30 years ahead (based on the information given in scenario descriptions) and included as a model input.

The responsiveness of land use to changes in the transport system is not considered in NTM but it is considered in ASTRA. The modelling results from ASTRA have shown that road infrastructure expansion of 10% increases transport demand by 1% through land use second order effects. The realism of the land use inputs is likely to be of particular concern to us with the WM scenario where planning controls are likely to be less stringent, allowing land use to change in a way that may be quite different from that assumed.

Another advantage of system dynamics is that it generates interim outcomes up to the target time horizon. In our study, such information might have been used to compare outcomes in 2010 with those in 2020 and 2030. It needs to be appreciated, however, that system dynamics models, such as ASTRA, are designed to model the entire system of interest and therefore would offer an alternative option to the combined scenario planning/transport modelling approach used in this study, rather than a replacement for the transport modelling component. Given the complexity of our social and economic systems and their evolution it can be argued that we cannot hope to represent them reliably in a system dynamics model and that scenario planning may be a more appropriate approach for taking account of uncertainty in long term planning. We believe that the approach of using sector-wide future scenarios developed from a scenario planning exercise to study sector-specific impacts using a sector-specific model is an appropriate one given the aims of our work.

5.2. Policy conclusions

The reference case results show that sustained traffic growth can be expected up to 2030 if current transport policies are continued. Traffic is forecasted to be 51% higher than in 2000 and congestion 68% higher. The introduction of urban congestion charging has little impact with urban areas experiencing nearly as high traffic growth as rural areas. It is difficult to disentangle the various influences on the modelling outcomes for the four EF scenarios but some conclusions can be drawn on policy interventions.

Distance-based inter-urban road user charging, with a sufficiently high charge, has been found to have the potential to mitigate the impact on traffic growth of economic growth and increasing car ownership levels. In our modelling work, the impacts of inter-urban charging swamped the effect of other factors for the WM and PE scenarios. Some of the impacts of the charging that we tested are likely to be too severe, however, to be a feasible option. Congestion-based inter-urban road user charging has more modest impacts on traffic levels but is found to be effective at limiting congestion growth. Even large scale investment in road infrastructure (WM) fails to tackle congestion unless it is coupled with widespread charging.

Impacts of urban congestion charging have been found to be less dramatic than inter-urban charging but alongside public transport improvements have been found to be effective in restraining traffic and congestion growth in large cities. The relatively modest impact of urban congestion charging may be a consequence of the levels of charges imposed.

It should be noted that the assumptions for world oil prices in the scenarios varied from 10 to 30 dollars a barrel (1999 prices) with 16 dollars a barrel assumed for the reference case. In the light of recently experienced oil prices these may be seen as rather low values in which case the forecasted growth in traffic and congestion would be expected to be lower in reality. The GS scenario features large improvements in vehicle efficiency, an oil price of 30 dollars a barrel, large investment in public transport and congestion charging in all major cities. Traffic is forecasted to be 36% higher in 2030 than in 2000, congestion 34% higher and carbon dioxide emissions 19% lower. These outcomes might be seen to be desirable compared to those in the other scenarios and to indicate that government policies should adopt the characteristics of the GS scenario.

The results of modelling the 2030 scenarios demonstrate that congestion-based road charging could on its own be effective in restraining future traffic and congestion growth. If road charging is not politically acceptable then a combination of different transport interventions (including major improvements to public transport, which lead to more positive attitudes towards it by the public, as well as increased motoring costs through fuel prices) will be needed to arrest traffic and congestion growth. This appears to be true even for a future scenario of low economic growth. On the other hand, investment in new fuel technologies and in improving engine efficiency have the potential to significantly improve air quality and to reduce carbon emissions.

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Appendix. Summary descriptions of environmental futures (EF) scenarios

World markets

This scenario is based on the assumed prevalence of short-term consumerist values together with globalisation of governance systems. Social values are materialist, with resulting high levels of consumption and mobility. Working towards long-term sustainable development is marginalised as a political goal. There is a declining role for governments in economic management and in the provision of healthcare, education and other social services. Pressure grows to reduce taxes. Privatisation of public services leads to increasing inequalities in access and quality of health, education and social services.

In passenger transport, rapid growth of personal car use will continue. Cars will be predominantly based on the internal combustion engine, fuelled by petroleum products but battery, hybrid and fuel cell electric vehicles will be used in major metropolitan areas from 2010 onwards. Congestion will increase, but will be partially relieved by the greater use of in-car transport telematics. Autopilot, anti-collision and routing functions will become standard in the luxury car market from 2010 and by 2020 in the mid-car range. By 2020 access to some major roads will be restricted to cars with these features. Use of the Internet for work and shopping will also increase as congestion worsens. For longer distances, the high demand for mobility will lead to a continued growth in air traffic, both internationally and within the UK. Greater use will also be made of inter-city rail, although its economics will be driven by the needs of business passengers. Globalised markets for goods leads to a continued growth in air and road freight. The importance of transport systems for a globalised economy will ensure that major investments in airports, ports and roads continue to take place. There will be a relatively weak planning system. Energy prices will remain low in this scenario, with less priority attached to global environmental concerns.

Provincial enterprise

This scenario assumes individualistic consumerist values and the reinforcement of governance systems at the national and sub-national levels. Sustainability more or less disappears as a political objective. The dominant political values are conservative and inward-looking. Independence in economic and foreign policy is preserved, while the UK's relationship with Europe remains at arms-length. Globalising forces operating in the economic, political and cultural domains are constrained. Market values are dominant, but the scope of markets is limited by national and provincial boundaries. Economic growth is slow.

This is a car-dependent scenario, with little additional provision for public transport. Whilst energy prices remain low, car ownership and use increase more slowly than in the world markets scenario. Nevertheless, congestion and accidents increase because of public finance restrictions and objections to new roads. New technologies, such as telematics, are restricted to the very top end of the car market. With low investment, the average age of the car stock becomes greater and emissions from vehicles on the road are substantially higher than those for new vehicles, partly because of less maintenance. With a more slowly growing global economy, air traffic continues to grow but at a much lower rate than in the world markets scenario. Freight transport moves predominantly by road, as developments in the rail system do not take place. Investments in new infrastructure are very low under this scenario, but technological innovation focuses on low capital cost measures.

Global sustainability

This scenario assumes communitarian, long-term, conservationist values and the globalisation of governance systems. Stress is placed on balancing economic, social and ecological values resulting in the adoption of more sustainable technologies and patterns of behaviour. Governance structures become more global but also more distributed. There is greater co-operation and management within the international system and the role of national governments is primarily in the negotiation and enforcement of global economic, social and environmental agreements. Consensus about sustainable development is transmitted through participative, open, democracies worldwide. There is a growing role for local governments within more federal political systems. Growth is a little slower than in the 'world markets' scenario but closer public and private sector attention is paid to alternative measures such as the ISEW. (ISEW = index of sustainable economic welfare. The ISEW adjusts GDP per capita income to take account of spending to offset social and environmental costs, long-term environmental damage, the distribution of incomes, and the value of household labour).

Major changes take place in the provision and use of transportation systems which begin to address the twin goals of providing high quality access and low environmental impact. Integrated transport systems develop on a local, regional and national level. Road traffic growth continues, but at a much slower rate than in the past. Technology plays a major role in reducing environmental impacts, with a rapid market penetration of low emissions hybrid and fuel cell passenger vehicles, and heavy investment in public and mass transit systems. These changes are accompanied by rapid developments in transport telematics for overcoming congestion in both public and private transport systems. Freight transport shifts towards rail and water, with lower relative growth in road and air freight. From 2010, transport telematics begin to substitute for mobility. Air traffic continues to grow rapidly in a world in which many business professionals operate at a global level and eco-tourism expands to broaden people's direct experience of different cultures and locations. Renewable energy and emission free fossil fuel technologies become more widely available to help achieve sustainability targets.

Local stewardship

This scenario assumes communitarian and conservationist values and the reinforcement of diverse political and economic systems through the development of regionalisation. Social values encourage cooperative self-reliance and the conservation of resources. Within a long-term perspective there is a strong emphasis on environmental issues and, to an even greater extent, equity and social inclusion. Political systems are transparent, participatory, inclusive and democratic at a more local level. These are reinforced by a high level of public provision for health, education and social services. Regional and local cultural identities are revived and the family is strengthened as the primary social unit in the context of the local community. The flow of culture, people, capital, goods and services across economic and political boundaries is constrained. Decision-making power is devolved downwards in a more federal system of government in the UK. Conventional economic growth is even slower than it is in the 'provincial enterprise' scenario.

The transport sector is greatly affected by major slowdowns in the world-wide growth of trade and lower demand for mobility. There are sharp increases in the cost of transport due to high energy prices and the internalisation of external costs. There is an emphasis on avoiding the need for travel and on switching to walking and cycling, with the local planning system used to ensure that facilities are available close to people's homes. By 2010, co-operative car sharing, home deliveries and traffic management schemes begin to reduce absolute car ownership and car use. By 2025, cars based on alternative energy technologies—fuel cells, electric vehicles and hybrid vehicles—are the norm for shorter journeys due to environmental pressures. Longer journeys tend to be made by mass transit systems—rail, bus and air-many of which are publicly owned and managed. The growth in international freight movements levels off as trade in goods stagnates. tourism and leisure activities tend to be undertaken closer to home because of higher costs and greater consciousness of their environmental impacts.

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