Motoring towards 2050
Roads and Reality

Technical Report

Banks, Bayliss & Glaister

in association with Arup

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Contents

1. Introduction

This report provides details of the technical analysis in support of *Motoring towards 2050 – Roads and Reality*. Its purpose is to document trends and forecasts, and the functional forms, source data and parameter values we have used in the modelling. The structure of the model is explained. Detailed results are set out. It is intended as a reference and is directed towards the reader familiar with economic modelling and evaluation[1].

2. Transport trends

This chapter looks at trends in domestic transport in Great Britain.

Travel and Gross Domestic Product

> The transport of movement and goods has grown broadly in step with the economy for many years and, although the relationship for freight has weakened of late future expansion of the national economy will create further growth in travel demand.

The amount of travel has grown as national wealth has increased. More economic activity has led to the increased movement of people and goods. More money has enabled people to participate in a wider range of activities outside the home requiring more travel; and more money has meant that they have been able to buy cars to give them a convenience and flexibility of travel beyond that possible with most forms of public transport. This has been a two way process with economic growth stimulating both passenger and goods travel and improvements to transport systems enabling new ways of working and patterns of leisure which, in turn, became contributors to subsequent expansion of the economy.

Looking back to the opening of the Motorway era, both passenger and freight traffic have grown at a similar pace to the Gross Domestic Product as illustrated in Figure 2.1. The relationship between the growth in travel and GDP is striking, except that the amount of freight shipped has levelled off over the last few years for reasons which are discussed below in the section on freight.

[1] The Foundation is grateful to the Independent Transport Commission for allowing the transport model, for which it has provided development funding, to be used in this study.

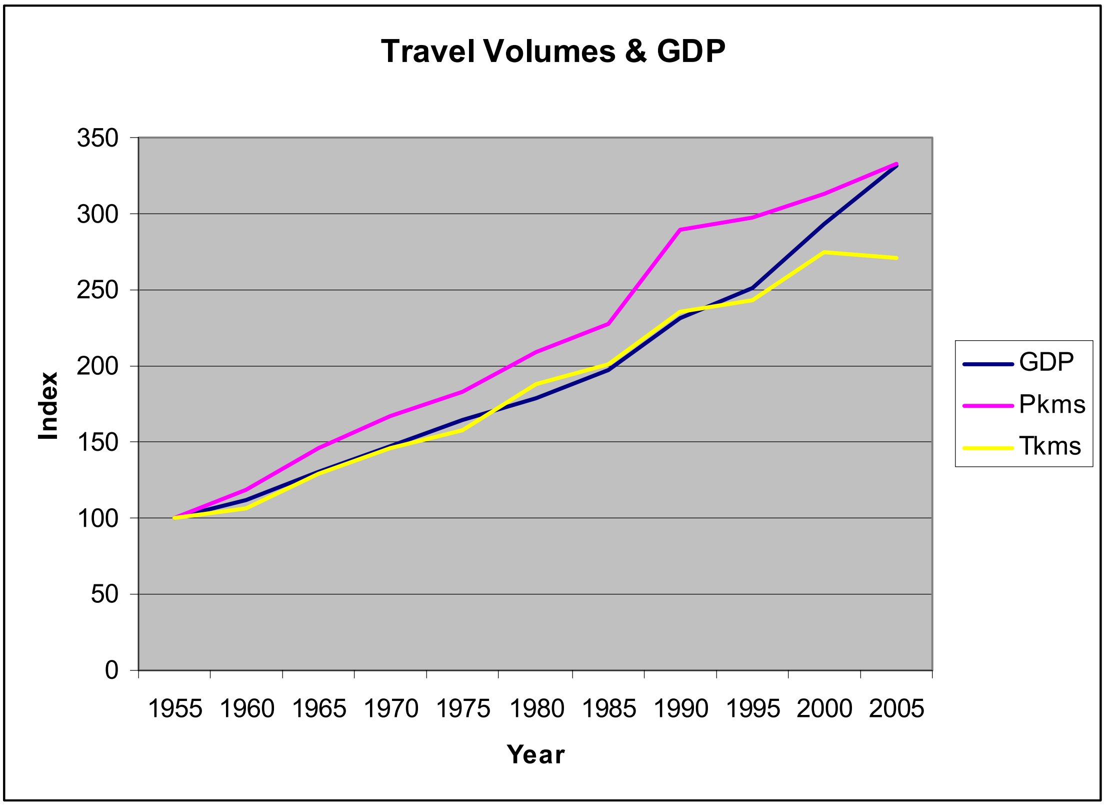

Figure 2.1. Growth of Passenger Travel, Freight Travel and Gross Domestic Product

Source: Department for Transport (2006a) tables 1.1 & 4.2 and National Statistics 2006a.

The Growth in Personal Travel

17% more people, 60% more families and six times as many cars have fuelled a more than trebling in personal travel over the last fifty years. Now three families out of four have a car and many more women and elderly people drive than used to. On average Britons spend over fifty pounds a week on private transport - nine times as much as they spend on surface public transport. Whilst the rate at which we make journeys and the time we spend doing this has altered little, our travel patterns are very different from thirty or forty years ago. Shorter trips on foot, by bike and bus have been replaced by longer trips by car, and to some extent train. Air travel has more than trebled in the last twenty years.

The spatial and temporal freedom of car travel, and the development of the Motorway network, has allowed linkages to develop that were never before practicable even with the best public transport networks; and the corresponding work, business and leisure travel patterns have become part and parcel of contemporary life. To varying degrees business and social behaviour and the built environment have adapted to exploit this freer mobility. Though rail use has grown strongly over the last few years, cars dominate the market for long distance journeys except for the very longest where air travel comes into its own - especially for the rapidly growing overseas travel market.

Personal travel has grown by a factor of 3⅓ since 1955[2]. This is for a variety of reasons. Firstly there are more people, and families than there were in 1955. From 50.1m in 1955 the population of Great Britain reached 58.4m in 2005[3] - a 16½% increase. Secondly the number of households has increased even faster from 15.1 million in 1955[4] to 24.2 million in 2005[5]. As a result, average household sizes have reduced from 3.3 persons to 2.4 persons. As some types of journeys serve households as a whole, rather than individual members (e.g. the weekly shop), the number of trips of a distance that requires motorised transport has increased faster than the population generally.

Secondly there are many more economically active Britons. In 1955 there were 24.3 million workers[6] compared with 30.5 million in 2005[7] - an increase of over a quarter. This is a larger increase than for the population as a whole, which means that there is now a higher proportion of people who are economically active. This increase in economic activity is largely as a result of more women working: up from 7.9 million in 1958 to 14.4 million currently[8]– an increase of four fifths. As well as a commensurate increase in the numbers of motorised journeys to and from work and in the course of work this means that there are more wages to spend; and spending these often involves travel.

Thirdly there are more cars and drivers. The convenience and speed offered by car transportation means that most people buy cars if they can afford them and are able to drive. Real disposable household income has increased by a factor of over five since 1955[9] and some of this increasing wealth has been spent on buying cars and travelling more. People currently spend over 3½ times as much on transport, in real terms, as they did in the mid 1950s[10] at £62.7 per family per week amounting to £82bn annually. Of this, 86% goes on the purchase and operation of private vehicles[11] (mainly cars).

[2] Department for Transport (2006a) table 1.1.
[3] National Statistics (2006b)
[4] National Statistics (2005) table 2.1.
[5] National Statistics (2006c) table 2.1.
[6] The Economist (1997) p 78.
[7] National Statistics (2006d) tables BCAJ & DYZN.
[8] National Statistics (2006d) table LOLB.
[9] National Statistics (2006c) figure 5.1 & The Economist (1997) p50.
[10] National Statistics (2005a) table 6.1 & The Economist (1997) p188.
[11] National Statistics (2006e) table 3.2e

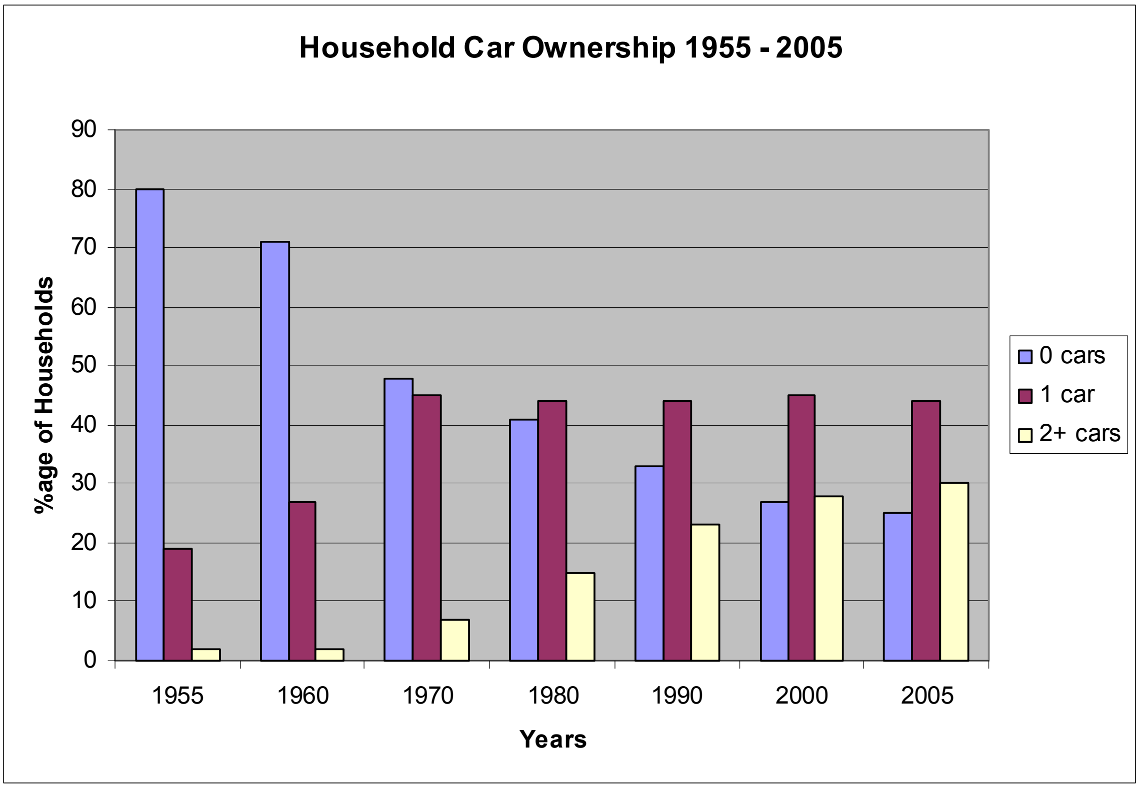

Figure 2.2. Household Car Ownership Trends in Great Britain, 1955 to 2004
Source: Department for Transport (2006a) table 9.14

The result of years of this growing expenditure on transport – mainly private transport - is the widespread ownership of cars. From just over 3.1 million cars in 1955 (itself a 57% increase over the figure in 1950) there are 26.2 million today[12] and three quarters of households have regular use of a car. In 1955 the situation was quite different with only a fifth of households with access to a car and four fifths without. Despite households getting smaller on average, the proportion with more than one car has increased from 2% in 1955 to 30% today[13]. The number of qualified drivers has also grown more than fourfold – from 7.52 million in 1958[14] to 33.3 million in 2005[15].

[12] Department for Transport (2006a) table 9.1.
[13] Department for Transport (2006a) table 9.14.
[14] Department of Transport (1975) table 57.
[15] Department for Transport (2006a) table 9.16.

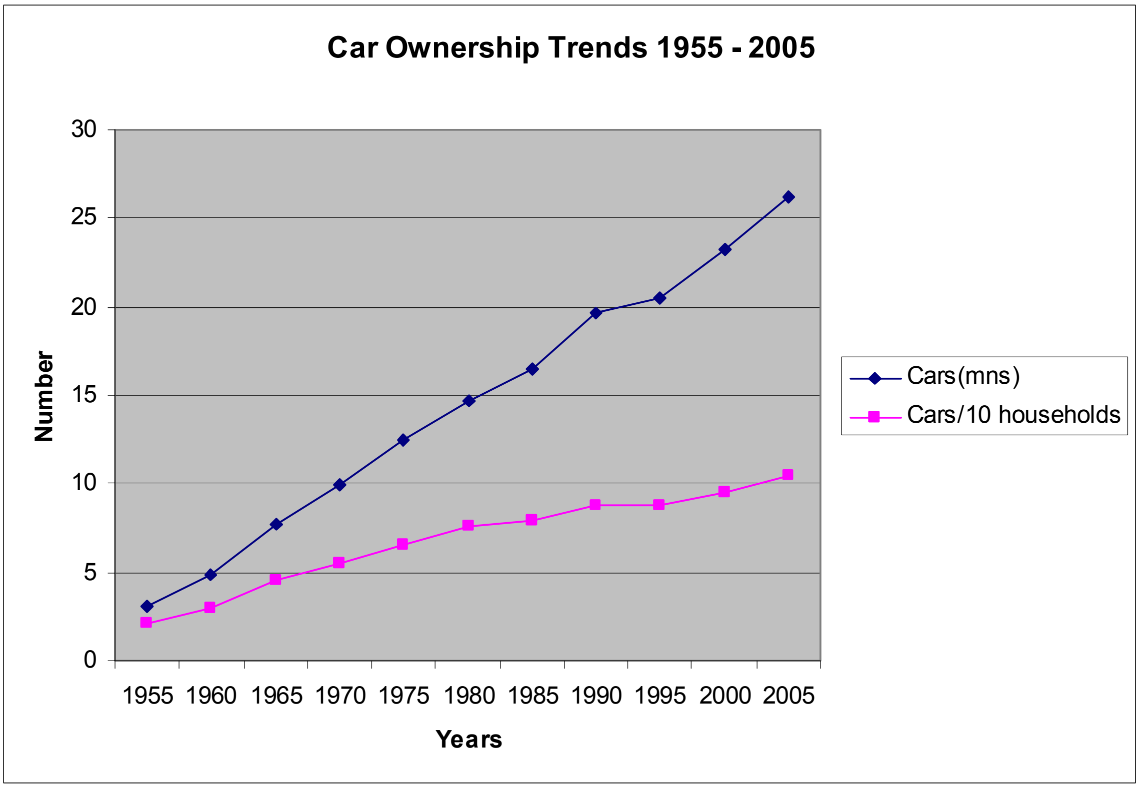

Figure 2.3. Car Ownership Trends in Great Britain, 1955 to 2005
Source: Department for Transport (2006a) table 9.1.

The transfer from non car owning to car owning status has two important effects on travel behaviour. Firstly, and primarily, the distance travelled increases each year (see figure 2.9) and secondly it reduces the reliance on, and use of, other forms of transport. Adults in households without cars make about 14 trips per week compared with those in car owning households who make about 20. Those in multi car owning households make about 22. When distance travelled is taken into account the contrast is even more marked with a change from 90 kms to 220 kms to 325 kms per week in multi car owning households[16]. These differences reflect both the additional mobility provided by car ownership as well as the fact that higher car ownership correlates with higher incomes – which are also associated with more travel. Thus in 2004/05 the wealthiest 10% of households spent £238 a week on recreation & culture, restaurants & hotels and miscellaneous goods and services compared with £55 for the poorest 10% – over four times as much[17].

Figure 2.4 shows how both the number of journeys and distance travelled by adults increases as households own more cars, with the biggest change coming when acquiring the first car. This also helps explain the apparent paradox that whilst rising car ownership

[16] Department for Transport (2006b) tables 4.3a & 4.4b.
[17] National Statistics (2006e) table 3.2e.

increases trip making rates, the total number of journeys changes little over the years. Whilst migration up the car ownership ranking tends to increase trip making, the trip rates for each car ownership rank have been slowly declining.

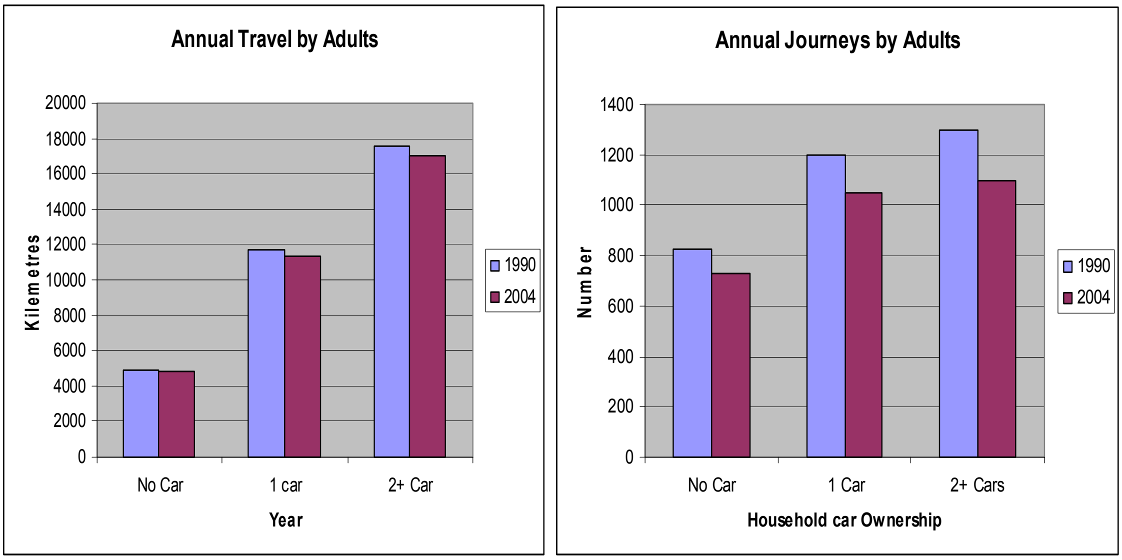

Figure 2.4. Travel by Adults According to car Ownership Status 1990 and 2004
Source: Department for Transport (2006b) figures 4.3 & 4.3b.

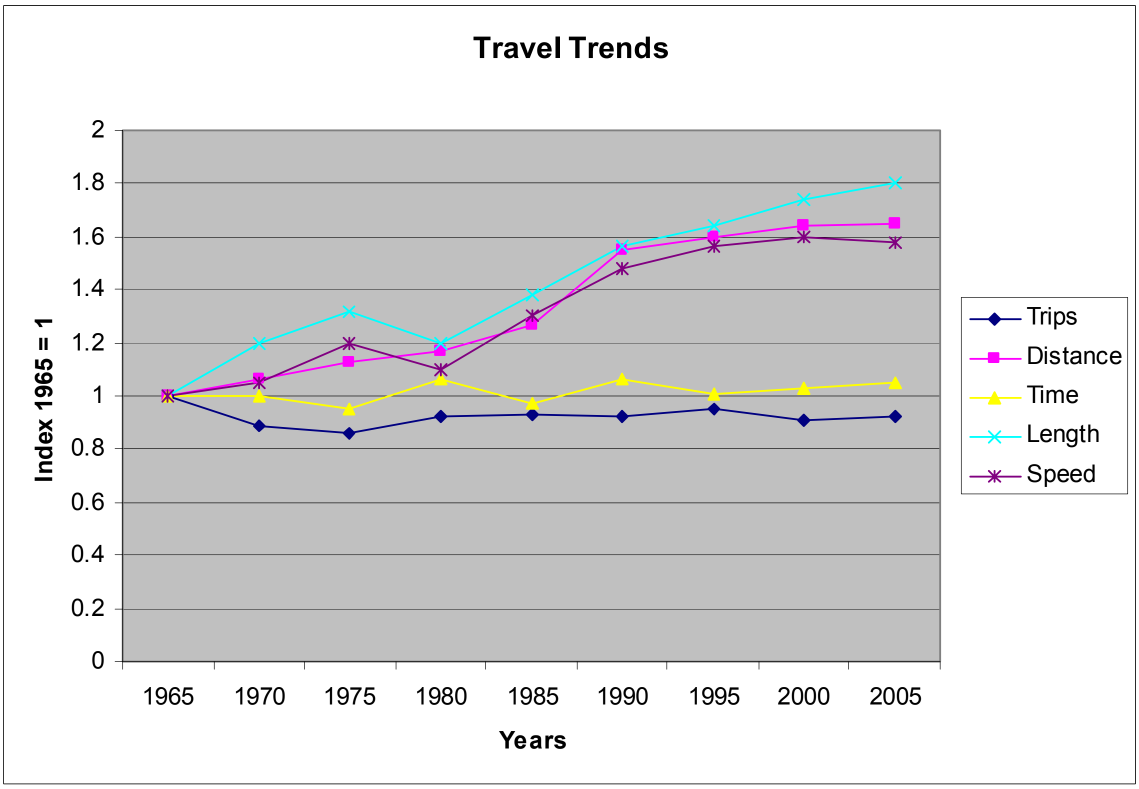

Figure 2.5. Changes in Personal Travel 1965 to 2005 (trips per person)
Source: Department for Transport (2006d) table 2.1. 1965 numbers are the authors' estimates based on limited data in Department of Transport (1993).

Figure 2.5 shows that the increasing shift towards car use has resulted in longer journeys, rather than more journeys. Because the modes of travel supplanted by car are mainly walking, cycling and bus travel – which are relatively slow forms of transport, the average journey speeds have increased – from less than 20 kph in the mid 1960s to around 30 kph today. Thus the increase in car ownership has allowed those who have access to cars to travel further and faster; so increasing the range of places that they can visit within a fairly constant time budget of about an hour a day. This table is derived from National Travel Survey data and the sample sizes are such that year to year variations should be treated with caution but the longer term trends are robust.

Improving mobility

These forces for greater mobility would be thwarted if the means to travel more were not available. Local bus services have reduced by 20% but non-local bus and coach services grown by 120% since 1960[18]. Train services have intensified by 50% over the last thirty years, with an increase in train kilometres run from 300m in 1975[19] to 450m in 2005/06[20] and the number of stations from 2,358 in 1975[21] to 2,510 today[22] (+6½%).

The most significant factor in increasing mobility is the growth in car ownership described above, but also the vehicles themselves have improved enormously over the last fifty years. Driving is safer, noise levels are lower, exhaust emissions are much reduced, fuel consumption has improved and on road performance is much better. Riding in cars is also much more comfortable than it was fifty years ago. The proportionately greatest improvement has been in reducing emissions, safety comes second and vehicle performance third.

[18] Department for Transport (2006c) Annex A table 4.
[19] Department of Transport (1983a).
[20] Office of the Rail Regulator (2006) table 1.4.
[21] Department of Transport (1983b) table 3.12.
[22] Department for Transport (2006c) table D.

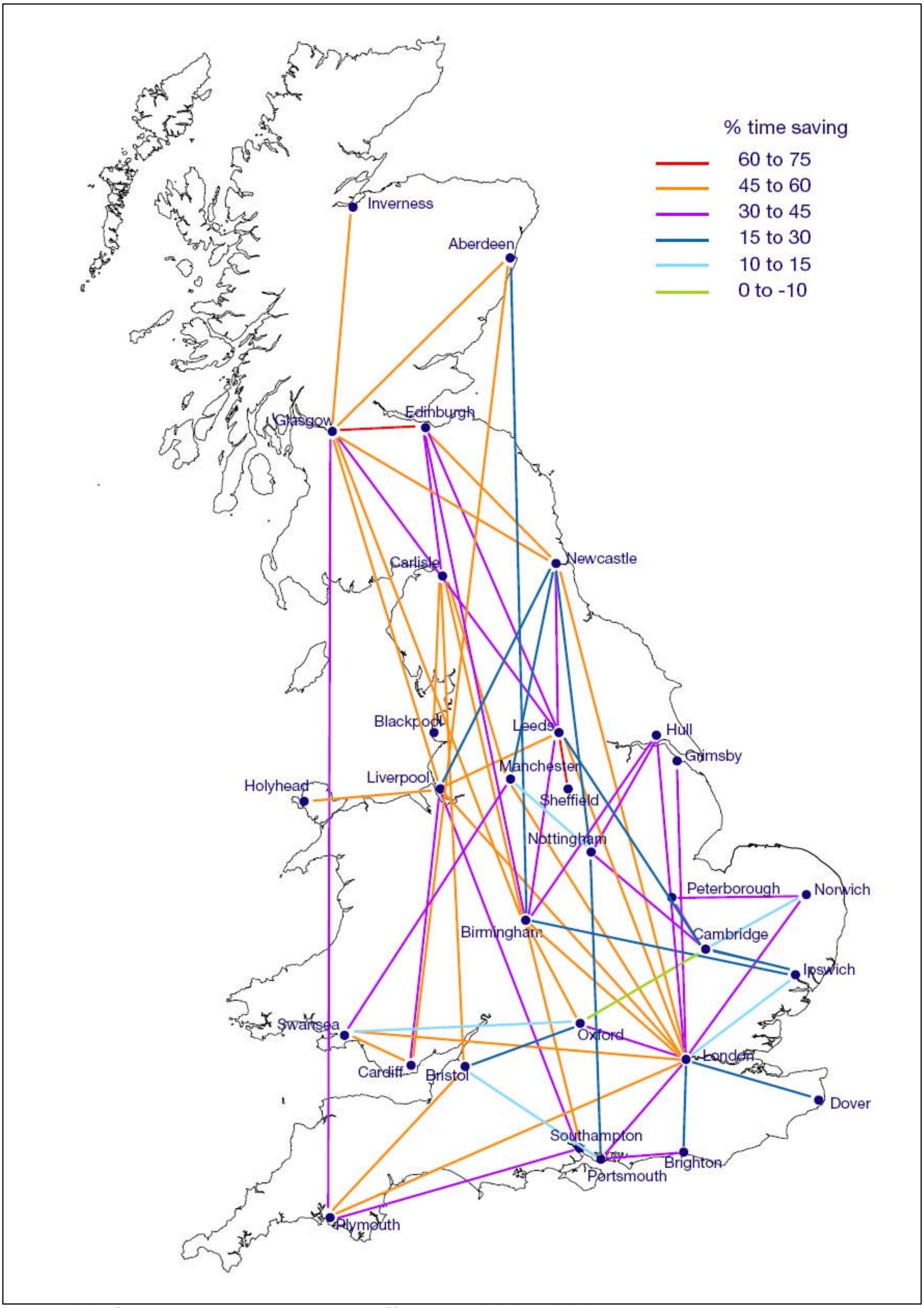

Figure 2.6. Coach Journey Timetable Differences 1959 – 2006

Sources: ARUP from National Express Timetables, 1959 and 2006, http://www.nationalexpress.com/home/hp.cfm. We are grateful to Mr Derek Roy for giving access to archived timetables.

The construction of the Motorway network has transformed long distance road travel. Comparative information on average journey speeds on the strategic road network in 1958 and today are not available but a comparison of inter-urban coach timetables for 1959 and 2006 shows that, of the 166 journeys analysed, only one took longer in 2006 – between Oxford and Cambridge where the Motorway network has little to offer. For the rest the improved travel times varied; but on average speeds were about 25 kph higher.

Since 1995 traffic speeds on Motorways have fallen slightly, as have those on all purpose trunk roads[23]. In urban areas traffic speeds have changed little since 1999/2000 apart from a slight deterioration in the peak[24].

Improvements in the mobility provided by the road network include both capacity and changes in speeds. Figure 2.7 gives an indication of how much the capacity of the strategic road network has changed over recent years. Between 1969 and 2000 its capacity grew by two thirds, mainly by the expansion of the Motorway network but also through improvements of all purpose trunk roads by 'dualling' and other measures. The reduction in capacity over the last few years reflects the government's 'de-trunking' programme, as a consequence of which it is not possible to plot 'like for like' capacity trends from published data.

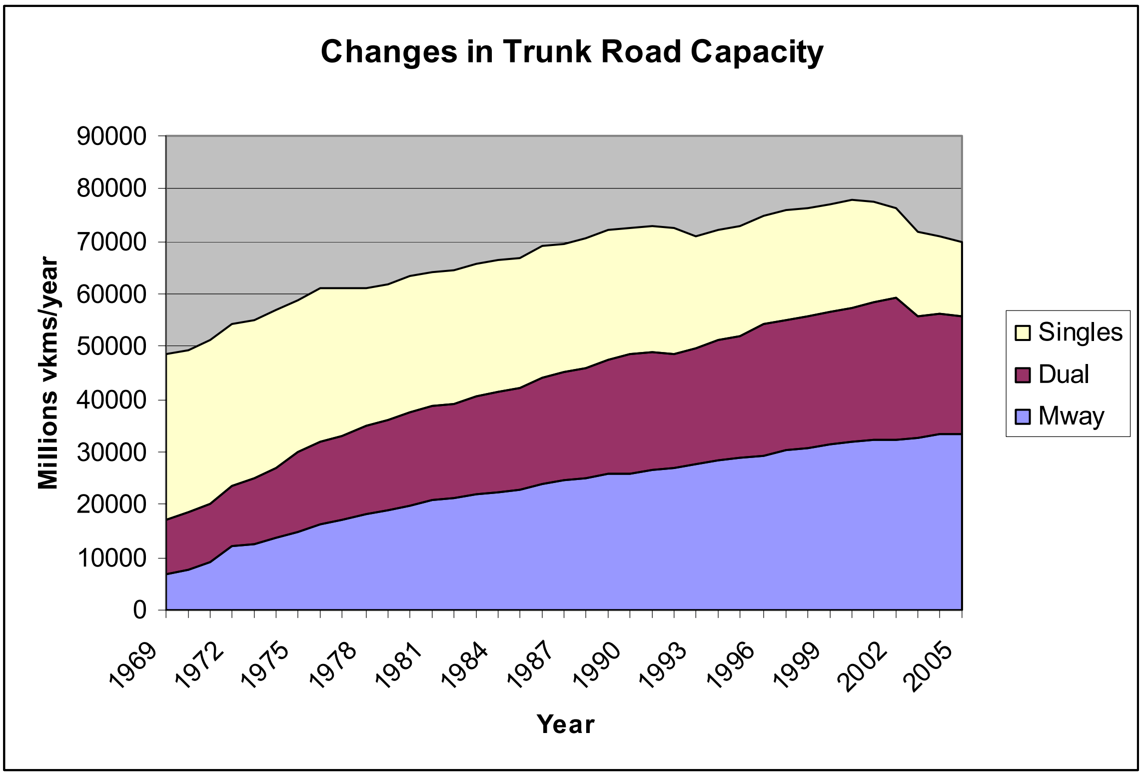

Figure 2.7. Estimates of Changes in Trunk Road Capacity 1969 – 2004
Sources, TSGBs 1964 – 1974 to 2006 and NTM Speed Flow Curves.

[23] Department for Transport (2004a) table 12.
[24] Department for Transport (2005a) table 6.

Accessibility of air travel has improved with an increase in the number of airports with scheduled services increasing from 40 in 1974[25] to 60 today[26]; and the number of flights increasing from 480 thousand in 1964, to 710 thousand in 1974[27] to 2,333 thousand in 2005[28].

Growth in Personal Travel by Purpose

The growth in personal travel has been broadly based, with all major travel purposes contributing. Figure 2.8 shows that whilst escort journeys (both for education and other purposes) have grown fastest they still comprise only a small proportion of total travel.

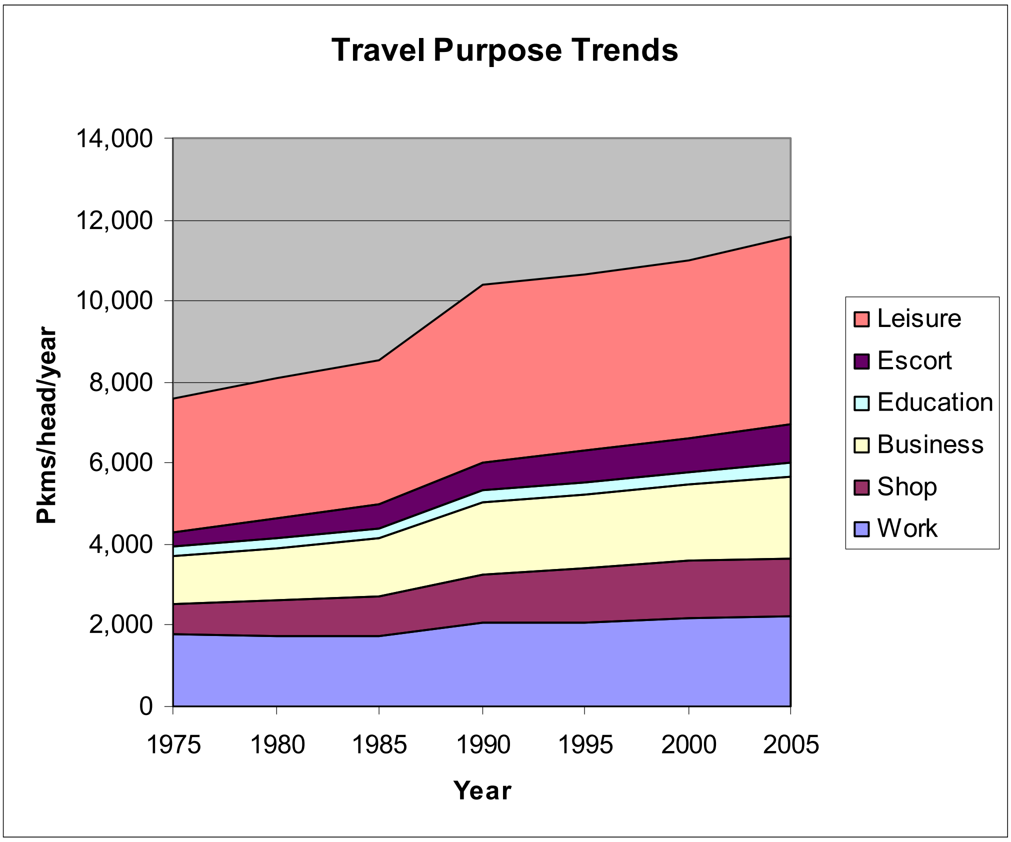

Figure 2.8. Changes in Personal Travel by Purpose 1957/6 to 2005 (Kms)
Source: Department for Transport (2006d) table 4.1, Department for Environment Transport and the Regions (2000) table 4.1, Department for Transport (2006b) table 1.8 & Potter s. (1997) table 3.9.

This disproportionate growth is significant however in that it indicates that the mobility of those unable to drive has increased as a result of getting lifts from drivers. In the mid 1970s there were approximately 500 kms of escort travel per non driver annually, by 2004 this had risen to over 2,000[29] thus, in this respect, non drivers have benefited from the increase in

[25] Department of Transport (1975) table 124.
[26] CAA (2006) table 01.
[27] Department of Transport (1975) table 124.
[28] Department for Transport (2006a) table 2.1.
[29] Potter S (1997) table 3.10 & Department for Transport (1987) table 2.12.

auto mobility to a significant extent. Escorted travel by car was about 570kms per capita in 2005 which was about the same as by all forms of public bus service and three quarters as much as rail travel[30]. So getting a lift in a relative's or friend's car is as important a source of mobility as some forms of public transport.

Shopping and business travel have also grown faster than average and have higher than average car mode share[31]. Leisure dominated the reasons for travel back in the mid 1970s and continues so to do. The one third growth in leisure travel has added 1,100 kilometres to the average annual travel budget over the last thirty years. Although the individual year's entries should be treated with some circumspection it appears that growth was strongest in the 1980s and so the resultant travel patterns are now well established.

Changes in Travel by Mode

The result of these changes in travel behaviour is a large growth in private personal transport associated with a much smaller reduction in the use of public transport, most of

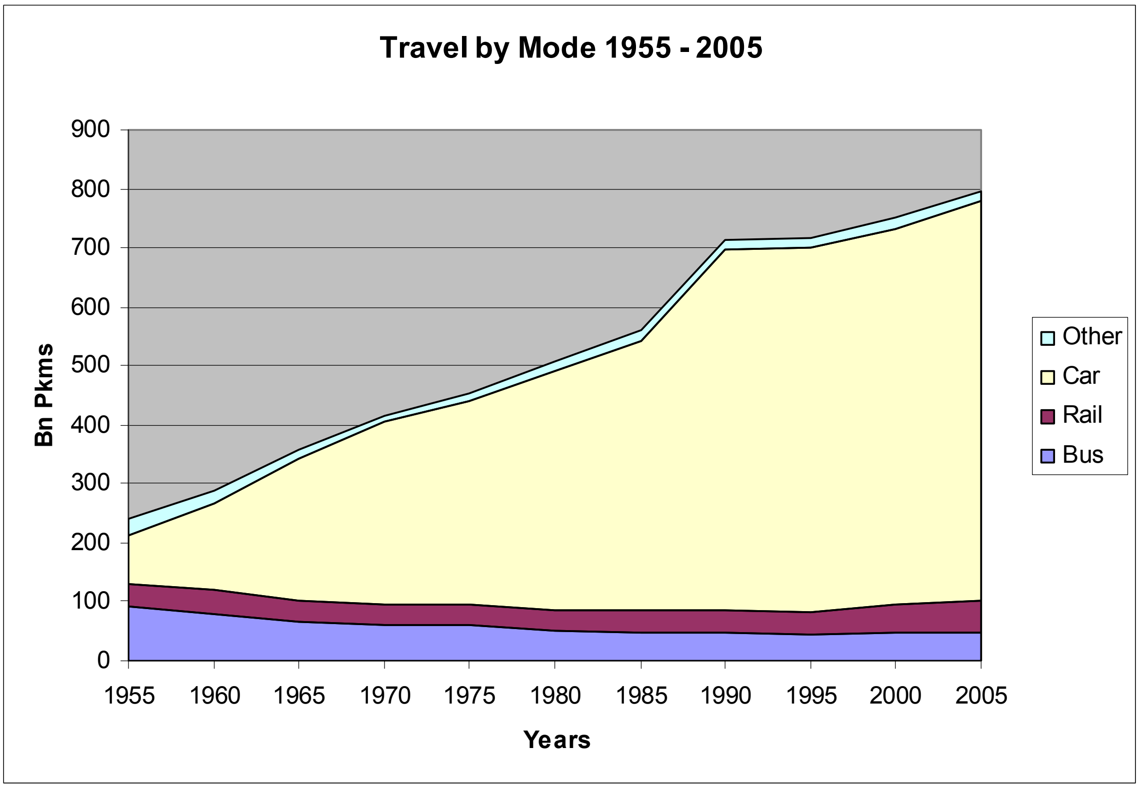

Figure 2.9. Changes in Modal Use for Personal Travel in GB -1958 to 2005 (bn pkms)
Source: Department for Transport (2006a) table 1.1 adjusted to allow for discontinuities.

[30] Department for Transport (2006d) tables 3.1, 4.1 & chart 7.2.
[31] Department for Transport (2006e) table 7.2.

which has taken place on buses and coaches as is shown in figure 2.9. All bus and coach use fell heavily during the 1960s partly reflecting a doubling in the car parc[32].

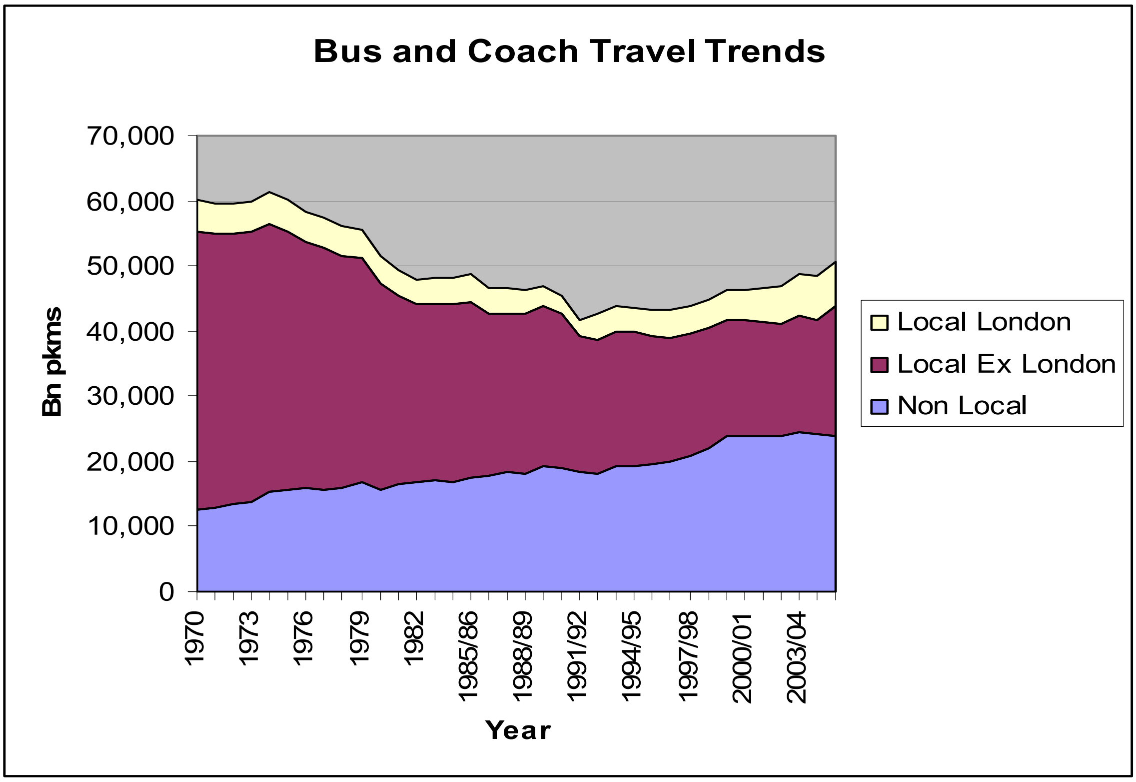

Figure 2.10: Bus and Coach Travel Trends 1970 – 2005/06
Source: Department for Transport (2006c) Annex A table 2 & LT Annual Reports 1970 – 1988/89.

The reduction in the use of coaches and buses since the mid 1950s appears to have been mainly on local buses, as between 1970 and 2005, local bus use halved whereas non local bus and coach use almost doubled and now non local bus and coach use travel (measured in passenger kilometres) is greater than that on local buses. Between 1955 and 1990/91 (the last year for which separate local and other bus journey data is available) local bus journeys fell by 63% whilst other bus and coach use increased by 84% (although the peak was in 1978)[33]. Non local bus and coach traffic has grown steadily over the years – from 12½bn pkms in 1970 to 24.1bn in 2005/06[34]. This long term growth in non local bus and coach travel fits well with the increase in leisure travel with which it is strongly associated.

Rail use also fell during this period, but by less, and then fell little further; indeed it has recovered strongly since the mid 1990s. The fall in rail travel during the 1960s was

[32] Department for Transport (2002) table 9.8.
[33] Department for Transport (2006c) Annex A table 1.
[34] Department for Transport (2006c) Annex A table 1.

exacerbated by rising car ownership, but the truncation of the passenger rail network by a third as a result of the Beeching review[35] must also have been a significant factor.

The decline in use of public transport has been encouraged by the growth in its costs to users relative to car transport, with cost of rail travel having risen by 45% more than that by car and bus by 85% more than by car since the mid 1960s (Figure 2.11)

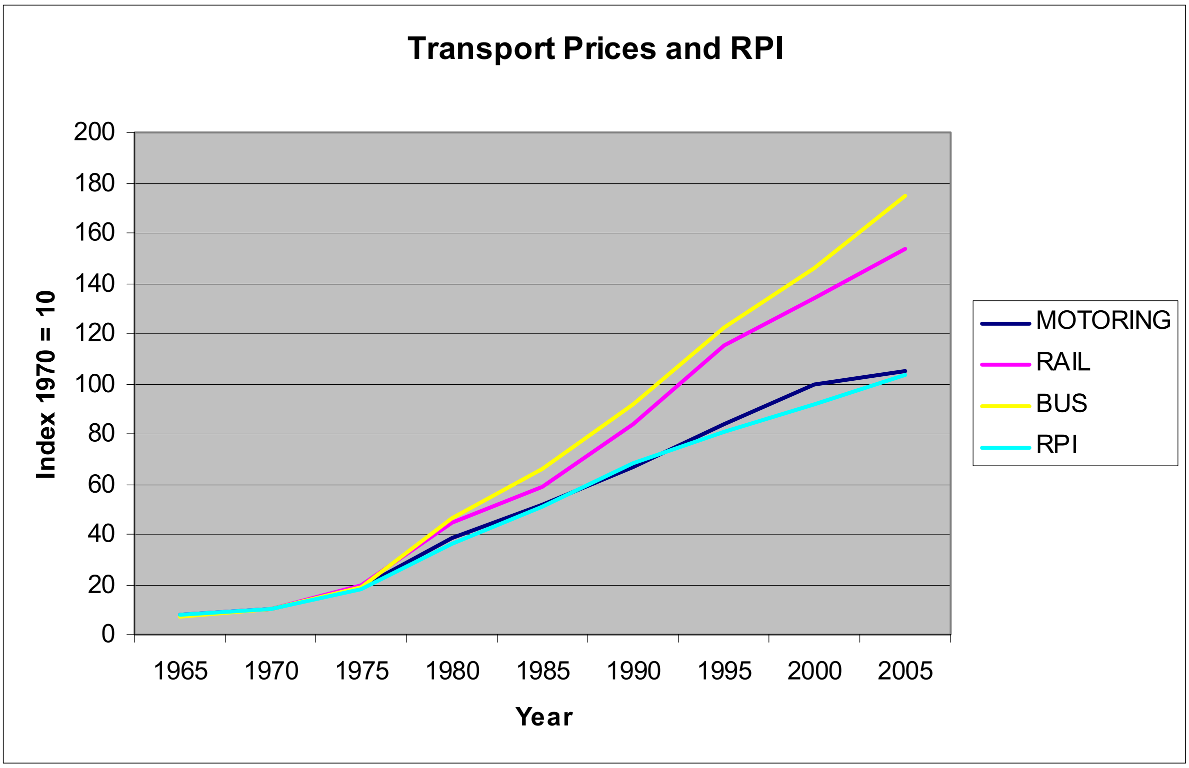

Figure 2.11. Growth in Transport and Retail Prices 1965 - 2005
Sources: Department of Transport (1975) table 8, Department of Transport (1984) table 1.12., Department of Transport (1996) table 1.21a & Department for Transport (2006c) table 1.19

It is easy to forget that all the trolley bus and all but one tram system that were operating in 1955 have been closed and invariably replaced by conventional buses. These electric systems carried 2.37bn journeys in 1955 – 18% of the bus traffic – so the reduction in local public transport use has been greater than that on buses alone. However the introduction of new light rail systems has boosted local public transport use, and if all modes are taken together the change in local public transport journeys, excluding national rail and Underground, between 1955 and 2005/06 was a reduction of 69% over the 50 year period[36].

With the increase in average trip length from about 6kms[37] in the mid 1960s to approximately 11 km today[38] (see figure 2.5) Britons must be taking more long distance journeys. It might

[35] Ministry Of Transport/British Railways (1963).
[36] Department for Transport (2006c) Annex A table 1.
[37] Department for Transport (1993) table 2.1.

be expected that rail and air, with their higher speeds, dominate the longer distance travel market but this is only the case for the very longest of trips as can be seen from figure 2.12.

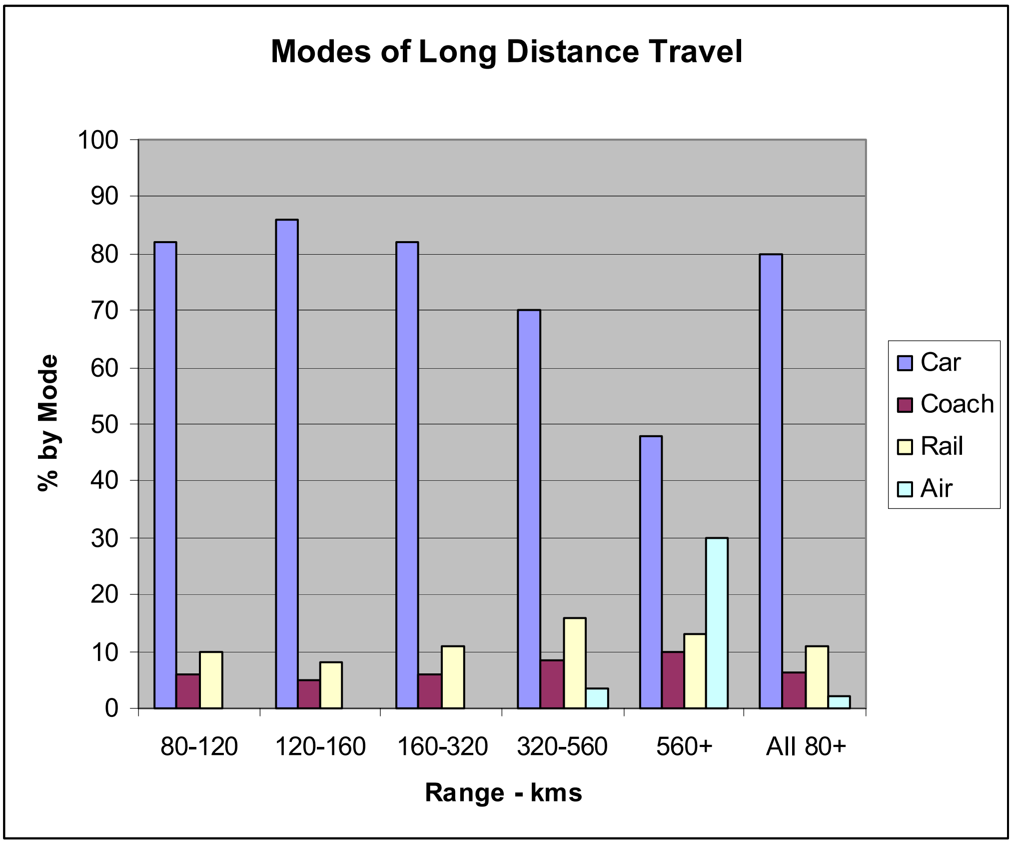

Figure 2.12. Modal Split for Long Distance Journeys in GB 2002-03/2005
Source: Department for Transport (2005c).

The most rapid growth in personal transport has been by air. Between 1955 and 2005/06 the number of passenger journeys on domestic flights grew twenty fold from 1.2 million to 25.1 million[39]. This has been because of the positive elasticity of air travel to rising incomes and, more recently, as a consequence of lower fares which can now be significantly less than rail for some journeys. Thus air travel now exceeds rail travel by a factor of ten or so between London and Glasgow. However this must be kept in perspective. Air travel is still only a fifth of that by rail (by distance) and less then 1½% of travel by car/van/taxi[40]. The dominance of car travel for all but the very longest journeys is undoubtedly caused by the inter urban Motorway network and the speed and comfort of modern cars. Today it is possible to drive from London to Glasgow in a day[41] whilst in the mid 1950s it would have required two.

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[38] Department for Transport (2006e) table 2.1.
[39] Department for Transport (2006c) Annex A table 1.
[40] Department for Transport (2006a) table 1.1.
[41] Phillips (2006) pIV.

Transport and Land Use

Greater mobility has allowed the spread of urban areas, lower densities and increased travel between settlements. In large towns and cities public transport plays an important part in meeting travel needs, especially in London, but less so in the suburbs and rural areas where most people now live. Suburban traffic has been growing and is expected to increase by a quarter over the next fifteen years.

Growth in travel demand and changes in travel patterns have been associated with changes in land use. Though one is not the direct cause of the other, the two go hand in hand with new patterns of accessibility enabling and stimulating new patterns of land use and activity, which in turn feed and reinforce the changing accessibility from which they derive.

The growth of private transport has enabled people to live in lower density suburbs and smaller settlements outside urban areas without undergoing unacceptable accessibility penalties. This is reflected in the higher use of private transport in smaller urban and rural areas (See Figure 2.10).

The spread of urban areas in Britain has been restrained by the planning system but their size and structure has been changing nevertheless. The growth of edge and out of town commercial and retail centres, along with extensions of suburbs into previously undeveloped peripheral land, has resulted in a high dependence of cars for mobility.

It is in the larger urban areas where public transport still carries a significant share of personal travel. Figure 2.13 illustrates this phenomenon and also shows that personal travel is higher in small towns and rural areas than in large towns and cities.

Consequently changes in the use of the different transport modes have not been uniform throughout Great Britain. Since 1982 bus use in London has grown by 74% but has fallen in all other areas. In the English PTE areas it has diminished by 44%, in the rest of England 26%, in Scotland by 31% and in Wales by 35%[42]. On the other hand between 1982 and 2005 the number of cars increased by 81% outside London - but only 25% in London itself[43].

Outside London, the variation in the number of motorised trips made between different types of settlements is small[44]. However the variation in distance travelled is substantial (see

[42] Department of Transport Local Government and the Regions (2001) table 2.1 & Department for Transport (2006c) table c.
[43] Department of Transport (1984) & Department for Transport (2006a) 9.5.
[44] Department for Transport (2005d) chart 6.9.

figure 2.13) with a steady increase in the less urban areas. People living in rural areas travel almost twice as far each year as Londoners, because trips in the more urban areas are shorter. Although more travel is on foot in urban areas and public transport is used more in large towns and cities, these small variations in use of different means of transport account for only a very small part of the differences in car use. The main reason is that people drive further in smaller and less urban areas.

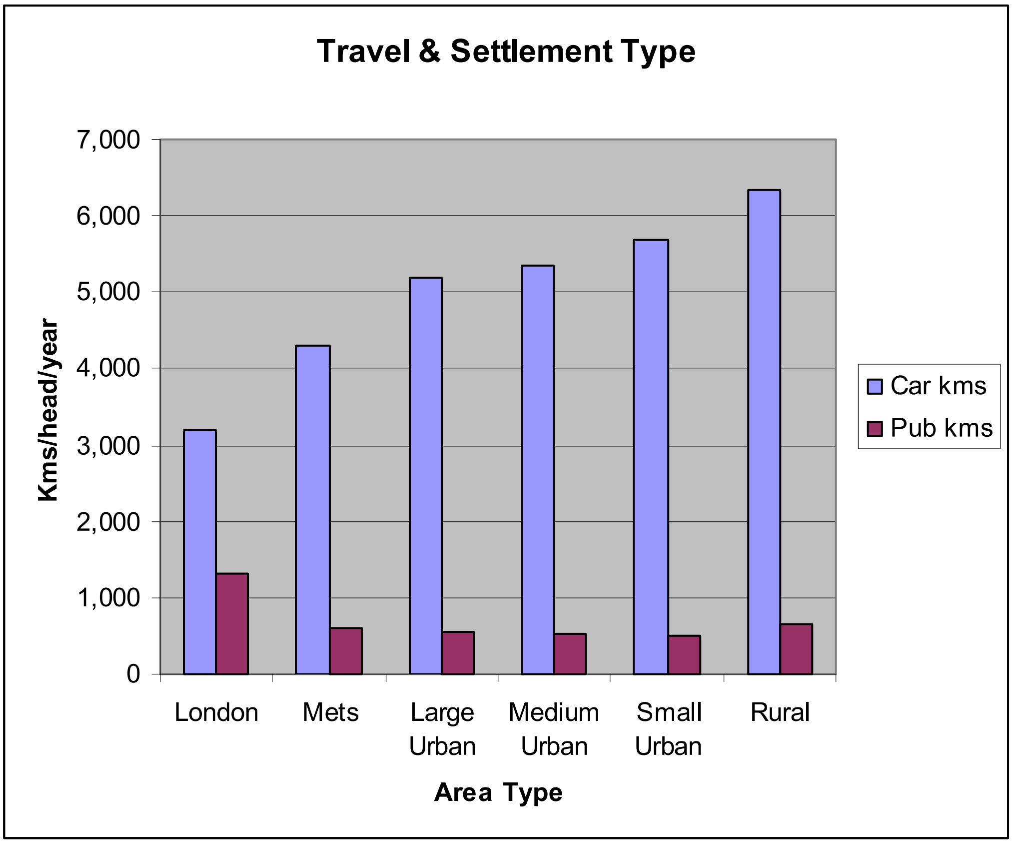

Figure 2.13. Variation in Travel by Mode by Settlement Type 2002/03
Source: Department for Transport (2005d) charts 6.9 & 6.10.

There can be little doubt that this propensity to drive further in less urban areas is the result of two interrelated factors. The first is that suburban and rural areas are, by their very nature, less dense so it is necessary to travel further to reach the same choice of jobs, shops and other facilities and activities than in urban areas. The second is that higher speeds (as more travel is by car) allow people to travel further to access services and facilities within their daily travel time budget of approximately one hour. The importance of car availability in this phenomenon is clear. The four regions with highest travel rates are also the four regions with the highest car ownership (SE, SW, EE & E Midlands)[45]. They are also amongst the fastest growing regions[46].

[45] Department for Transport (2006d) tables 1.2 & 1.11.
[46] National Statistics (2006f).

A primary feature of land use change has been the increase in the number of dwellings needed to accommodate the rapidly growing number of households. Over the last forty years the number of homes in England has increased from 14.89m[47] to 22.19m[48]. Many of these were built on previously undeveloped land resulting in large scale suburban extensions; although in recent years the proportion of new dwellings being constructed on previously developed land has been increasing, having grown from 55% in 1989 to 61% in 2001[49] with a government target of 60% or more in the future.

Nevertheless, at present, about 60% of people in England live in the car oriented suburban/rural areas[50] and most of the growth in population and traffic is expected to be in the suburbs/exurbs by 2021[51]. Traffic in the suburbs is expected to grow by about a quarter by 2021 and this will fuel traffic congestion which is already a problem in many suburban areas. In some instances this congestion spills onto trunk roads and in looking towards the future of the strategic road network the impact of suburban congestion will increasingly feature as a transport policy issue.

Growth in Freight Transport

The increase in freight traffic is a result of more goods being moved over longer distances. This has been caused by several intertwined factors. The structure of British industry and commerce has changed with a marked shift from agriculture and manufacturing to service industries. The decline of traditional industries, often located next to railways (and before them the canals) has been matched by new economic activity, much of it located well away from the railways, which require the faster and more flexible logistics provided by road transportation.

The performance of road freight has been improved by the construction of the Motorway network, the increase in the permitted size of lorries and the introduction of modern management and scheduling arrangements. In turn this has reinforced business practices that rely particularly on the type of service that road transport provides.

Other changes such as the movements of large volumes of petroleum products (and gas) have had their effect with the development of pipeline networks and coastal shipping which

[47] The Economist (1997) p188.
[48] Department for Communities and Local Government (2006).
[49] Department for Environment Food and Rural Affairs (2002).
[50] Independent Transport Commission (2004) figure 4.

has also benefited from the growth in the use of sea dredged aggregates. The development of the service and retail sectors, along with changes in business practices has cause a rapid growth in van traffic which appears to be encouraged by internet shopping. At the other extreme international trade has expanded enormously and much of the consequent traffic is moved by road to and from ports, airports and the Channel Tunnel.

Freight transport (measured in tonne kilometres) has grown by almost 2¾ times since 1955. This is as a result of both more goods being shifted (about 1⅔xs) and longer hauls (about 1⅔xs)[52]. The growth in goods lifted has been cause by the introduction of pipelines for the carriage of bulk liquids (mainly petroleum products), and increase in the use of inland and coastal waterways but mainly as a result of the growth in road freight.

The expansion of road freight was at its most rapid in the 1960s and the 1980s. Growth during the 1970s was more sluggish, no doubt partly due to the sharp increase in road fuel prices and economic effects of the 'oil crisis' in the mid 1970s. The pump price of fuel doubled between 1973 and 1976[53] , while Gross Value Added in the national economy barely changed between 1973 and 1977[54]. By 1980 the economy had stared to pick up again and the effects of the Motorway building programme, which doubled the length of the system during the 1970s[55], was making the long distance shipment of goods by road, cheaper, faster and more reliable.

Changes in Goods Carried and Modal Use

The structure of the economy has changed over the last half century. Employment in manufacturing has fallen from 9 million in the mid 1950s to 3.2 million today, whilst employment in service industries has almost doubled from 11 million to 21½ million in 2005[56]. This has resulted in a reduction in the movement of raw and semi-finished material to factories and more, lighter, service movements.

Some types of freight transport have particular affinities with particular products, so their use is strongly linked to the production and consumption of these. The most obvious examples are pipelines which, despite attempts to use them for the movements of solid materials, are used almost entirely for the transhipment of liquids and gas. Pipelines also transport huge volumes of water and sewage but this does not figure in national transport statistics – about

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[51] Independent Transport Commission (2004) p14.
[52] Department of Transport (2006a) table 4.1.
[53] AA (2006).
[54] National statistics (2006i).
[55] Department of Transport (2006a) table 7.6.
[56] The Economist (1997) p76/77 & National Statistics (2006c) figure 4.13.

150 tonnes/head/year of clean and waste water are transported by pipe networks compared with only 40 tonnes by all other modes. Also coastal shipping has expanded to shift sea dredged aggregates and to supply oil rigs.

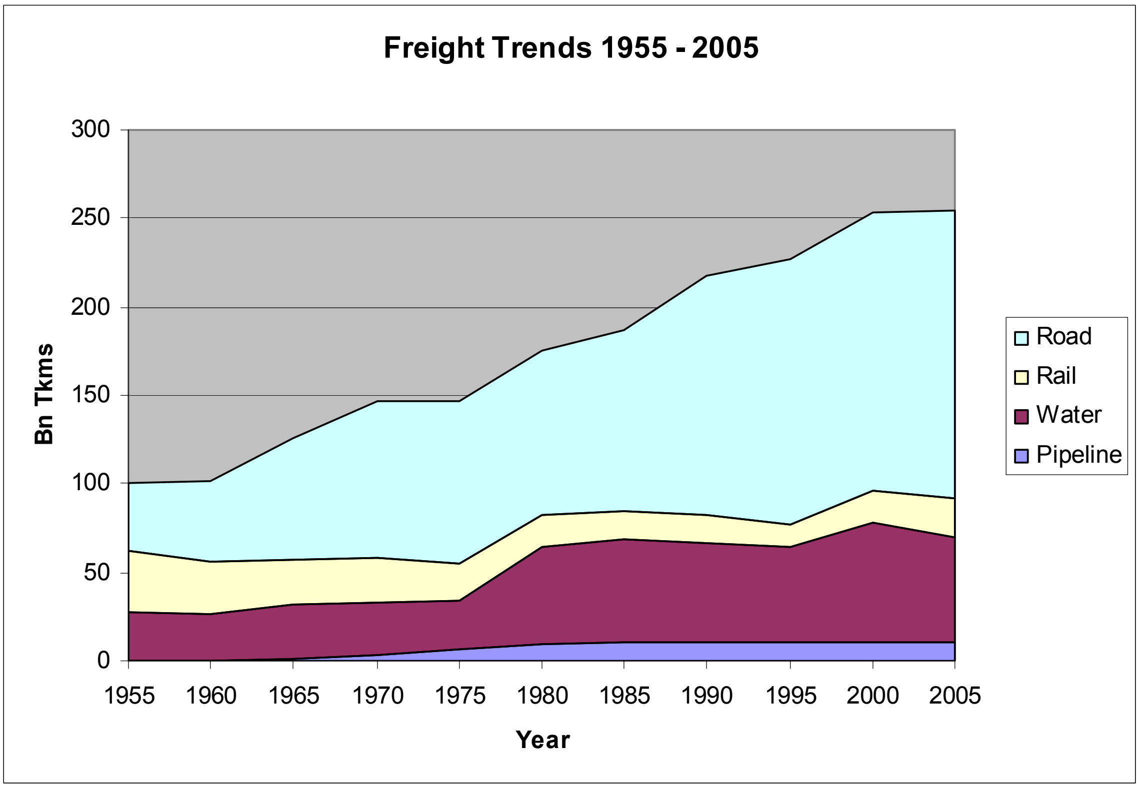

Figure 2.14. Changes in Modal use for Freight Transport in GB -1955 to 2004 (bn tkms).
Source: Department for Transport (2006a) table 4.1.

The relationship between products shipped and the modes used is illustrated in table 2.1. Taking coal as an example there were eight hundred and fifty underground mines in 1955 which produced about 210m tonnes that year. Today there are only 13 mines producing a little over 10 million tonnes annually[57]. As rail was the principle means of shipping coal from mines to power stations and local and regional distribution depots that decline has had serious implications for rail coal freight with it shrinking from 12.2 billion tkms in 1964 to 7 billion tkms in 2004. The pattern of traffic has also changed with the sharp reduction in shipments from domestic mines being offset by carriage of imported coal from coastal ports.

Incidentally the reduction in domestic fuel consumption with the spread of domestic central heating released railway sidings, used for the transhipment of coal from rail wagons to carts and lorries, for conversion to station car parks thereby stimulating 'park and ride' rail passenger traffic.

[57] The Coal Authority (2006).

PRODUCT	ROAD	RAIL	WATER	PIPELINES	ALL
Petroleum products	5.4	1.3	47.2	10.8	64.7
Coal & Coke	1.5	8.6	0.4	0.0	10.5
Foodstuffs & Fodder	34.9	-	-	-	
Machinery & Manufactured Products	64.2	-	-	-	
Metal Products	6.7	2.2	0.2	-	
Chemicals & Fertilizers	8.9		1.0	-	
Other	41.6	8.6	12.1	-	
Total	163.2	20.7	60.9	10.8	255.6

Table 2.1: Use of Transport by Product Type, (bn tkms), Great Britain 2005
Sources: Department for Transport (2006a) tables 4.2 & 4.3 & Department for Transport (2006f) table 1.2.

Over the last twenty five years the shipment of food products, minerals and building materials and machinery and manufactured products, where road carries the lions' share, has doubled; whilst that of other products has grown by only 15%[58].

The Growth of Road Freight

The increased use of road freight also reflects changes in logistics, with stock levels being reduced and shipment becoming an integral part of the supply chain for an increasing number of production and distribution activities: the ratio of stock to turnover fell by 40% between 1986 and 2004[59]. Also lorries have increased in size with changes to the maximum weight restrictions over recent years with the maximum weight of a six axle articulated lorry now 44 tonnes. Since 1980, when they were first permitted on Britain's roads, the number of lorries over 33 tonnes Gross Vehicle Weight (GVW) has increased to about one hundred thousand and comprise 23% of the lorry parc[60]. However these vehicles carry over 70% of tonne kilometres and with an average haul length of 124 kms[61] are natural users of the Motorway network - with 56% of travel on motorways compared with only 18% for other vehicles. Looked at another way, whilst articulated lorries form less than 3% of traffic generally, they make up over 8% of Motorway traffic [62].

Despite the image of lorries as a major cause of traffic congestion, their numbers have not changed that much over the years, with slow but steady growth up 'till the late 1960s, followed by a two decades of relative stability then a decade of decline, with some growth since the turn of the century. It is clear from Figure 2.15 that average distance covered by Heavy Goods Vehicles (HGVs) in a year has been increasing and now, at 68 thousand kms

[58] Department of Transport (1981) table 1.6 & Department for Transport (2006a) table 4.2.
[59] Department for Transport (2006h) chart 1.1.
[60] Department for Transport (2006g) table 1.7.
[61] Department for Transport (2006g) tables 1.4 & 1.6.
[62] Department for Transport (2006a) table 7.4.

a year, is 2¼ times what it was in the mid 1950s and the average lengths of haul have increased substantially[63] .

Heavy goods traffic now comprises barely 6% of all vehicle kilometres although its representation on trunk roads and Motorways is greater where it comprises 11% of vehicle kilometres, compared with only 3¼% on other roads[64], and an even higher figure if its Passenger Car Unit (PCU) [65] weighting is taken into account. It is also much higher on certain routes, particularly those serving ports, heavy manufacturing and concentrations of distribution depots.

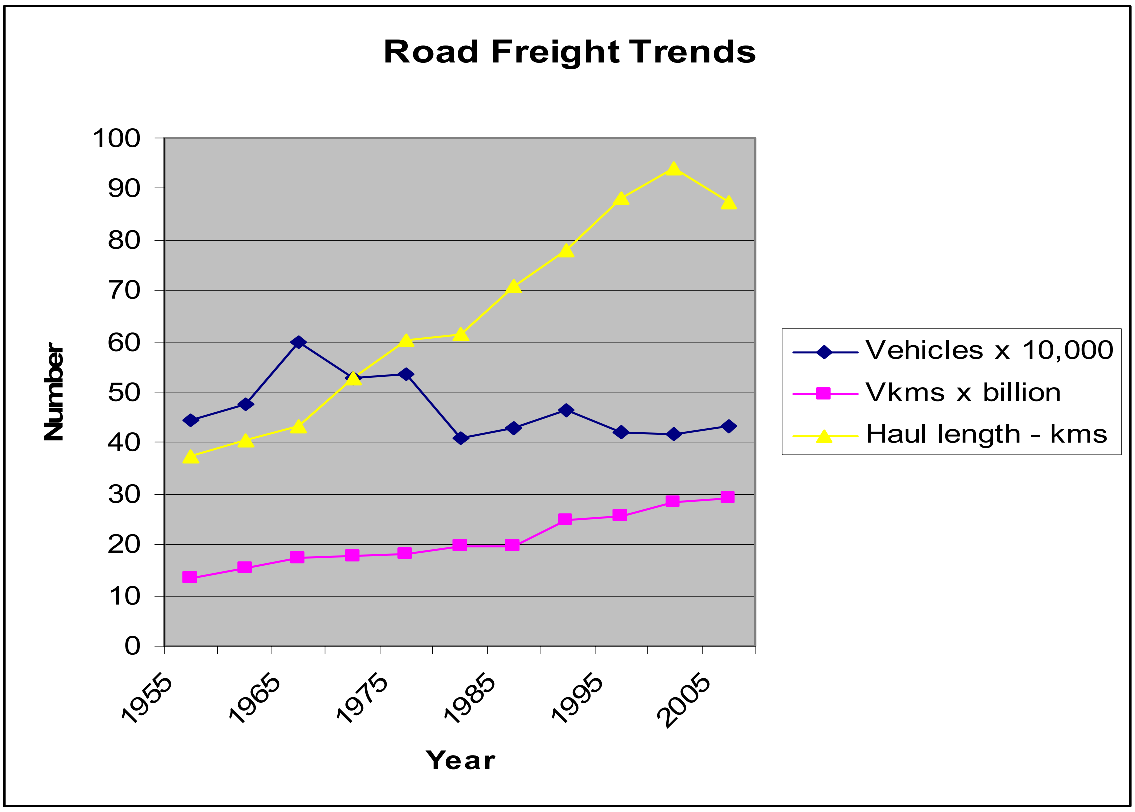

Figure 2.15. Road Freight Trends 1955 - 2005
Source: Department for Transport (2006a) table 4.1.

Of the 153 bn tkms of lorry traffic in 2005, 37% was for the carriage of miscellaneous goods (semi and fully manufactured articles, furniture, waste, equipment, post and parcels), 27% for food drink and tobacco (mainly agricultural products and packaged food), 27% for bulk products (mainly aggregates and building materials) and 9% for chemicals, petrol and fertilizer (mainly petroleum products)[66] with an average haul length of 87 kms[67]. However

[63] N.B. a change in the statistical series in 2004 means comparisons with earlier year should be made with caution.
[64] Department for Transport (2006a) table 7.4.
[65] Passenger Car Units are a means of weighting vehicle types to reflect their relative effects on road and junction capacities.
[66] Department for Transport (2006g) table 1.2.
[67] Department for Transport (2006g) table 1.4.

over half the goods lifted were carried less than 50kms, although road freight with haul lengths over 50kms makes up 87% of lorry tonne kilometres[68].

This growth in road freight has been associated with increasing sophistication of the road freight industry. More companies now use general hauliers who now carry 72% of road freight compared with 61% twenty five years ago[69]. Many of these are specialist logistics companies which provide integrated transport services and provide other value added activities. As such it is common nowadays for Third Party Logistics Managers (TPMLs) to operate as part of the 'production' process as well as handling shipments and distribution. These trends have led to 'lean' operations in manufacturing and commerce in which the flexibility of road transport has come into its own and, whilst other modes of land transport are used by TPLMs, the control and flexibility of road transport puts it at a distinct advantage for many shipment purposes[70].

With the growth in overseas trade, which the expanding European Union and European Free Trade Area have; stimulated, there has been an increase in shipments between Great Britain and the Continent and greater numbers of overseas based road vehicles using British roads. Over the period 1955 to 2005 imports and exports of goods increased from £6½bn at current prices to £490bn[71]- a real growth of 4½xs if adjusted for price increases. Between 1993 and 2003 the number of foreign lorries travelling to Great Britain increased by 232%[72]. These vehicles carried out 10.2bn tkms of freight transport in 2003[73] compared with a total of 159bn tkms for all road freight. Most of this travel (68%) was on Motorways which is not surprising given that their average round trip on British soil was 640 kms[74] in length and most drivers visit the UK less then once a month and so are less likely to be familiar with the general road system (although the increasing use of satellite navigation by foreign lorries may be changing this). Also 90% of the goods moved are carried by very heavy lorries (over 38 tonnes GVW).

These vehicles brought more goods into GB than they carried out – 20 million tonnes compared with 9.4 million tonnes[75] with carriage from France, Netherlands and the Republic of Ireland making up almost half the total[76]. The mix of goods carried differs from domestic traffic in that, whilst the proportions of food, drink & tobacco and chemicals, petrol & fertilizer

[68] Department for Transport (2006g) tables 1.26 & 1.27.
[69] Department for Transport (2006g) table 1.8.
[70] European Council of Applied Sciences and Engineering (2000) p181.
[71] National Statistics (2006g).
[72] Department for Transport (2003) Introduction para 1.
[73] Department for Transport (2003) table 2.1b.
[74] Department for Transport (2003) Summary.
[75] Department for Transport (2003) Summary.

are much the same, as would be expected, the proportion of bulk materials is substantially lower (18% compared with 27%) and miscellaneous products significantly higher [77] (47% compared with 37%).

Vans and Van Traffic

Whilst the use of heavy lorries for the shipment of goods has increased since the late 1950s a more recent phenomenon has been the growth in the use of vans. Figure 2.15 shows the growth in the number of light goods vehicles and their use since 1955.

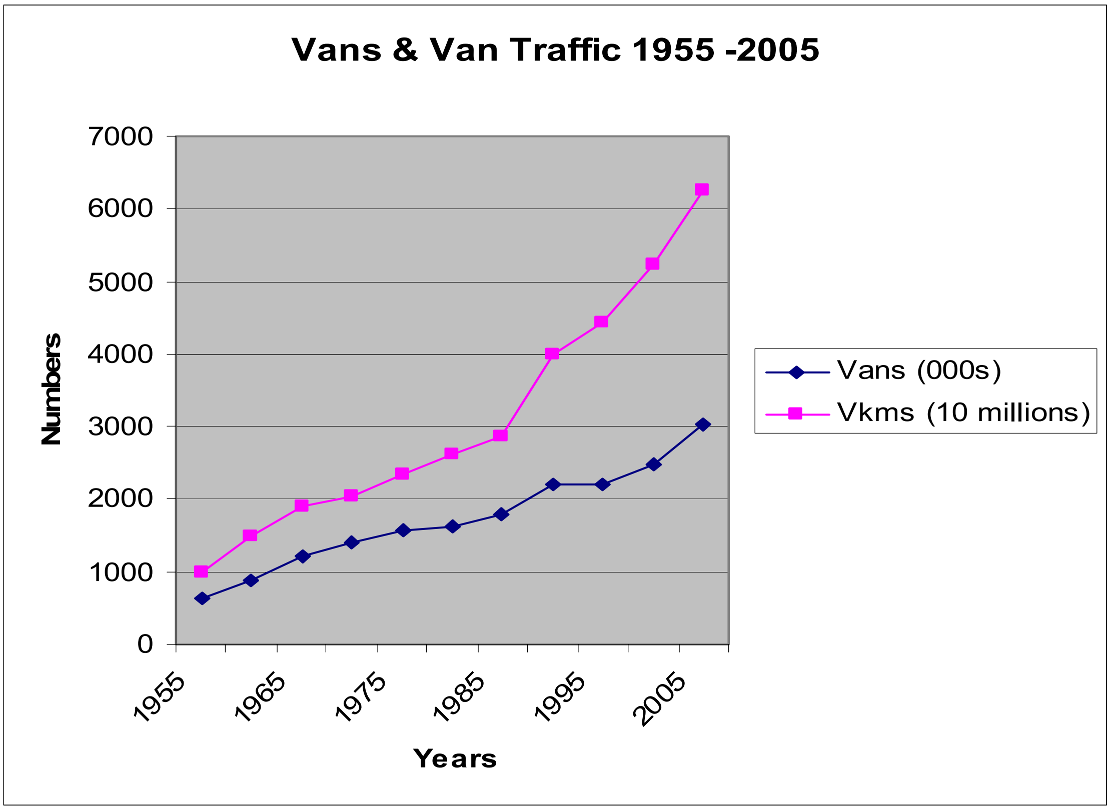

Figure 2.15. Number of LGVs and Volumes of LGV Traffic in Great Britain
Source: TSGB 2006 tables 7.1 & 9.1.

The definition of 'van' is not precise as the distinction between certain types of vehicles used as private cars and vans is difficult to make. Also with some Light Goods Vehicles (LGVs) weighing almost 3½ tonnes these can be regarded as small lorries. The number of company registered vehicle with van type bodies[78] was 1.375 million in 2004[79] and the number of

[76] Department for Transport (2003) table 2.1b.
[77] Department for Transport (2006a) table 4.4 & Department for Transport (2003) table 3.2.
[78] Department for Transport (2005e) – Definitions.
[79] Department for Transport (2005e) table A4.

privately owned vans in 2003 (Q1) was 0.99m[80] compared with the total number of LGVs of 3.0m.

The growth in the number of LGVs since 1955 of 4½ times compares with a slight decline in the numbers of lorries[81] and LGV traffic has grown 2⅓ times as fast as lorry traffic. The average distance driven by vans has also increased since 1955 from 15¼ thousand kms/year to 21 thousand. Of all van traffic, company owned vans comprise 73% and the remainder are privately owned[82]. Privately owned vans travel has a shorter average trip length of 18kms and 17% of use is for personal travel and 38% on business or travelling between jobs.

Many of these company owned vans are kept overnight at the drivers' homes and so almost a third of travel is driving between homes and places of work. A similar proportion is involved in the collection and distribution of goods, with a quarter of distance travelled in moving between jobs[83]. Over four fifths of private van travel is to and from work[84].

Construction activity leads the field of company owned van use with almost a third of van travel (10.6bn vkms), followed by wholesale/retail/repairs/hotels with a fifth[85]. Not surprisingly, given the importance of construction, the largest use of vans is for carrying tools, equipment and other materials with only miscellaneous products, mail & parcels and foodstuffs exceeding 4% of the total traffic, all showing how diverse are the purposes for which vans are used.

Household shopping, which might be expected to figure significantly given the recent rise in internet shopping, only accounts for 0.2% of the total; probably because most internet, telephone and catalogue shipments are classed as mail and parcels[86]. It is perhaps surprising that the average length of company van journeys is 36kms with some purposes (collection and delivery of goods), at 86kms, being much longer[87]. However it must be remembered that many van journeys are roundsman trips in which more than one delivery/collection is made en route.

[80] Department for Transport (2004b) table A3.
[81] Department for Transport (2006a) table 9.1.
[82] Department for Transport (2004b) table 8, Department for Transport (2005e) & unpublished data from the DfT.
[83] Department for Transport (2005e) figure 1.
[84] Department for Transport (2004b)
[85] Department for Transport (2005e) table 3.
[86] Department for Transport (2005e) table 4.
[87] Department for Transport (2005e) table 1.

The growth of Internet shopping has been enabled by the growth in home computers, with most homes now having at least one[88], and the spread of internet connections. In February 2006, 63% of adults had access to the Internet and 57% of households were connected to it. 69% of these connections were broadband[89]. Consequently Internet sales to households more than trebled from £6.2bn in 2002 to £21.4bn in 2005 of which over £16bn were physical products requiring delivery[90] and almost certainly exceed £30bn per annum currently. If the average value of each purchase were £50 this would require 600 million deliveries a year.

Although it is too early to be certain it appears that this may be associated with a reduction in the number of shopping journeys which have declined by 13% since the mid 1990s[91] after a period of relative stability[92]. The growth of van traffic during this period of Internet development has been particularly striking with an increase of almost 20% between 2000 and 2005, compared with only 5⅓% for other motorised road traffic; increasing their proportion of traffic from 10% to 13% since 1995[93].

Conclusions

The movement of people and goods has increased in line with the growth of GDP for many years, although it may be that this relationship is weakening at least in respect of lorry traffic. Higher incomes have meant that more people are able to buy cars and afford to use them. This has been the main reason for increasing personal mobility which has manifested itself through a complex pattern of changes in travel behaviour.

More older people and women drive and use cars as their principle means of transportation and non drivers benefit from car borne travel, as they now rely on cars as much as buses. Improvements to the road and rail systems have also stimulated personal mobility which has taken the form of longer and faster journeys but with little change in the number of trips made or the time spent travelling. This has been made possible through switching of journeys from the slower forms of transport (mainly bus and walking) to car.

Consequently, whilst car travel has grown over recent years, and so has rail travel, albeit to a lesser extent. Local bus travel has declined outside London but long distance bus and coach use has increases steadily. Of all the means of travel, flying has grown by far the

[88] Office of Communications, 2006 figure 3.58.
[89] National Statistics (2006i).
[90] National Statistics (2006k).
[91] Department for Transport (2006e) table 4.1.
[92] Department for Environment Transport and the Regions (2000) table 4.1.

fastest – by about twenty fold since the mid 1950s. Apart from escort journeys, the purposes for which people travel have not changed markedly.

The use of cars and public transport is different for those living in dense urban areas and the suburbs, smaller towns and in the country. Most people live in suburbs and smaller settlements and this is expected to continue. Here cars are firmly entrenched as the dominant means for travel.

Unlike personal travel, freight growth has seen a combination of both more goods being shipped and longer journeys. The underlying causes are increasing consumption as incomes rise, and changes in the structure of the economy with a rapid growth in the movement of road oriented food, construction materials and manufactured products shipped. There has also been a slower growth or decline in transport of heavier bulk products traditionally carried on rail or water. The extension of haul lengths - especially by road - reflects in part the growth of international trade which, in turn, has increased the number of foreign lorries on Britain's roads.

Since the mid 1980s van traffic has more than doubled and it appears that this is being fuelled by the recent growth of internet shopping, as well as the longer term movement to a more service orientated economy. The overall consequence is increasing traffic on Britain's road network, which in the last ten years has far outstripped increases in capacity.

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[93] Department for Transport (2006j) table 1.1 & chart 1.1c.

3. Prognosis and forecasts

In this chapter we set out the long term forecasts and our prognosis for the future. The analysis relies mainly on long run trends in demography and economic geography, but it is tempered by conclusions from academic literature on how the patterns of regional growth or decline, and of urbanisation, decentralisation and inter-dependence will develop over the next fifty years.

The overall demand for travel and the patterns of trips are predictable. For long term analysis, the most important issues are:

the size and distribution of population, which determines the total number of trips, and:

wealth, which determines people's propensity for motorised travel, trip length and to some extent also mode;

Peak travel is heavily influenced by the location of jobs and workers.

For quantitative forecasts, we rely mainly on the Department for Transport's TEMPRO Version 5.3 forecasting model[94]. TEMPRO population forecasts are based on Office for National Statistics (ONS) long term forecasts to 2028, and thereafter they are extended to 2041 using the Government Actuaries Department (GAD) national forecasts as a control total. They are "policy based" in that they have taken account of regional dwelling forecasts in consultation with regional planning bodies. TEMPRO employment forecasts are provided by Experian Business Strategies.

Economy

Figure 2.1, showed how travel demand, measured in passenger kilometres, has been increasing more or less in line with GDP. Overall, GDP/head is forecast to increase by an average of 2% p.a. across the economic cycles. This is approximately the average for the last 25 years. By mid-century the population will be more than twice as rich compared with today.

This change in wealth is gradual and long run, but it will have a transforming effect on standards of living and it will generate a continuing increase in the demand to travel. More affluent people are able to exercise more choice over home, work, education, and leisure, and will want to do so over a wider area to an increasing variety of destinations.

[94] Department for Transport 2006a TEMPRO provides forecasts for employment, households, age and trips to 2041 disaggregated to NTEM zone.

However, the growth will not be evenly spread. During the past 25-30 years there has been a widening growth gap between southern and northern regions. The differential growth rates have been caused by fundamental structural and geographic shifts in the economy. They have occurred despite growing congestion and cost pressures in the south, particularly in and around London, and higher levels of public spending in the north[95].

The most significant change both for the economy and for transport has been the decline in manufacturing employment and the growth in financial and business services. Manufacturing traditionally tended to employ large local labour forces, and gave rise to the industrial cities and conurbations. But for the last half century, manufacturing employment has been reducing, and for some time financial and business services (FBS) has been the fastest growing sector of the economy. Figure 3.1 shows its geographic distribution as a proportion of total employment.

A proportion of FBS is "high street" services to local communities. Employment in these activities is located throughout the UK in relation to the populations they serve. In contrast, the higher order national and international services have a strong propensity to cluster, particularly in relation to the distribution of highly skilled and experienced, often very specialised, workers, many of whom commute long distances to work. The concentration of FBS in and around London is one of the largest clusters in the world, but there are also smaller clusters in Birmingham, Manchester, Leeds, Edinburgh, Glasgow and Aberdeen.

The pattern of FBS location is one of the main drivers of regional variations in real income. The long term Oxford Economics[96] forecast for per capita real personal income is for an increase of around 2.2% p.a., compared with an average 2.3% p.a. from 1975 to 2003 (see Table 3.1). The forecast shows a widening of the income gap between northern and southern regions in the period to 2031, but it narrows somewhat in the longer term. The average person will be over 70% richer in 2030, over twice as rich in 2041 and 2.5 times as rich by 2050. However, what they spend their money on will probably change significantly, with proportionately more on leisure, travel, education and health.

[95] Arup et al. 2005
[96] Oxford Economics UK Macroeconomic forecasts, Oxford, Autumn 2006

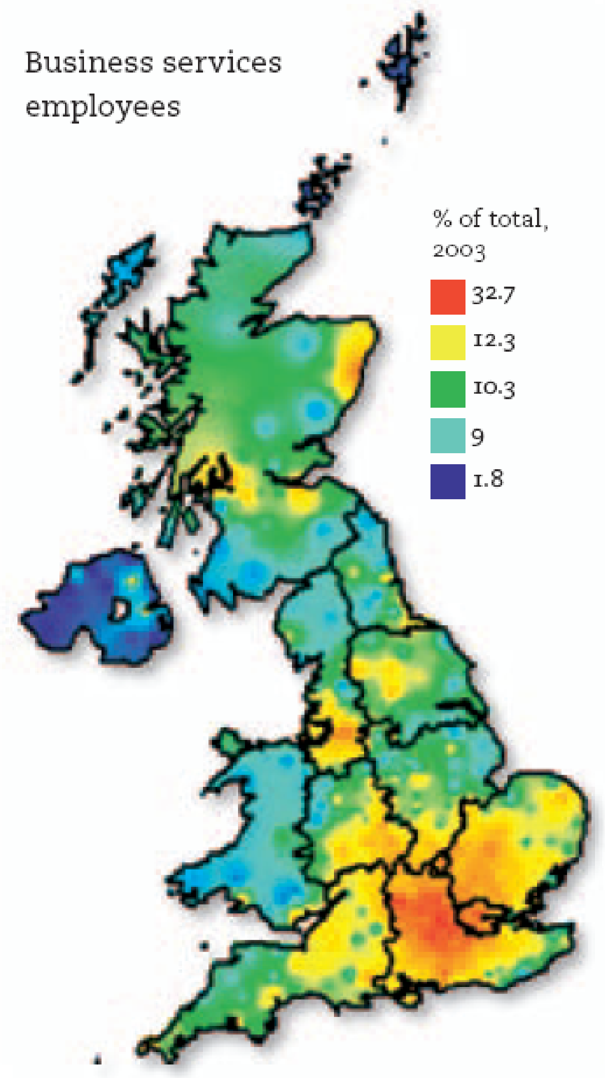

Figure 3.1. Percentage of business services employees
Source: Oxford Economics

	1975-2003	2003-31	2031-41	2003-41
United Kingdom	87.9	77.3	25.6	123
Scotland	78.3	85.8	30.6	143
North East	79.1	70.2	28.0	118
North West	73.7	74.5	27.7	123
Yorkshire & Humber	83.7	72.4	26.9	119
West Midlands	74.8	69.2	26.3	114
East Midlands	87.8	67.8	25.3	110
Eastern	118	77.3	24.8	121
London	79.6	81.6	21.6	121
South East	107	85.8	25.7	134
South West	92.7	69.8	24.2	111
Wales	79.3	69.9	25.6	113

Table 3.1 Real income per head of working age population (%change)
Source: Oxford Economics

In the future, the regions and cities that will grow fastest will be the areas with growth sectors and high concentrations of relevant skills within the workforce, though the picture could be more volatile if labour mobility increase dramatically. Clusters will develop around labour force skills. Other areas will have opportunities to "sell on price" as property and labour costs and congestion rise in the hotspots. Housing supply/price is also an important factor.

The current signs are that the growth areas at both regional and city level will continue to be those with strong private sector financial and business service sectors, especially London and its economic hinterland in southern England, probably increasingly extending to Birmingham/South Midlands, but also Leeds/Manchester and Edinburgh/Glasgow. Other locations, such as Cambridge, could experience continuing growth throughout the century as a result of clustering of technology specialisms, but only if planning policy permits them to expand.

TEMPRO population and employment forecasts

The forecasts for the planning data inputs to TEMPRO are shown in Table 3.2, expressed as percentage increases for the period 2003-41. In summary, total Great Britain population is expected to increase by around 12% (which may be conservative in relation to recent trends in international migration), workers by 16%, households by 32% and jobs by 21%[97]. The disproportionate growth in workers and jobs is largely due to more older people working and to the growth in part time work.

Area	Population	Households	Workers	Jobs
GREAT BRITAIN	**11.1**	**29.3**	**14.3**	**19.1**
Scotland	-9.8	9.3	1.3	16.3
North East	-3.9	15.5	1.3	5.9
North West	4.7	24.6	6.9	10.1
Yorkshire & Humber	8.5	27.1	12.8	17.0
West Midlands	7.6	23.9	12.0	16.2
East Midlands	16.1	34.0	13.5	18.7
East	22.9	43.7	15.3	20.0
London	17.9	33.6	33.3	22.6
South East	17.9	35.9	16.3	30.1
South West	20.5	39.8	17.9	24.0
Wales	5.2	22.3	5.5	10.4

Table 3.1 TEMPRO planning forecasts 2003-41 (%change)

[97] *TEMPRO relies on official 2003-based population projections. These estimates are conservative in relation to the considerably higher future populations in the recently published 2006-based projections* (National Statistics, 2007b*)*

Population

In the long run population change will follow the economy, and there is consequently a strong geographic similarity between the economic and population forecasts. The TEMPRO forecast is for an increase in Great Britain population of 10% by 2031, growing to 11% in 2041 (+6.3 million)[98]. The longer term GAD forecasts estimate, 16% in 2041, 17% in 2051 and 21% in 2074 TEMPRO has a marginally faster population growth rate to 2031 than the actual growth in the last ten years, but is below both the ONS and GAD forecasts on which it is based.

The two big issues for population change in the longer term will be international migration, which has been showing a rapid increase in the recent past, and the increasing numbers of older people.

International migration

International migration trends are influenced mainly by changes in relative economic prospects and by changes to regulations on travel, living and working. They can also be affected by political instability in “exporting” countries. Recently these factors have led to increases in both in- and out-migration. In 2005 an estimated 185,000 more people migrated to the UK than migrated abroad, compared with 223,000 in 2004 and 151,000 in 2003[99]. In the past in-migrants tended to be in their twenties and approximately 40-45% went to London. However, most of the recent growth is East European citizens following the accession of their countries to the EU in 2004. It is not yet clear where in the UK they are settling, but anecdotal evidence suggests that international migrants are more widely distributed than in the past.

There is evident short term turbulence in the current international migration figures, but the trend over the last ten years is sharply upwards. Over the longer term it is likely that the UK’s relative wealth and economic strength, and a progressive relaxation of restrictions on migration, will result in significant net immigration.

The GAD forecast assumes a constant net increase of international migrants of 145,000 per year from 2007 onwards[100]. Though this may be conservative in relation to the increasing trend and the last two years (see Fig. 3.2), it is similar to the average for 1998-2003 and

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[98] More recent estimates suggest that the growth could be double this figure, seehttp://www.gad.gov.uk/Demography_Data/Population/index.asp?v=Table&pic=2006|gb|totpop
[99] Source: National Statistics
[100] National Statistics 2006a

much higher than the 1980s or mid-1990s when net international migration in most years was in the 50-100,000 range.

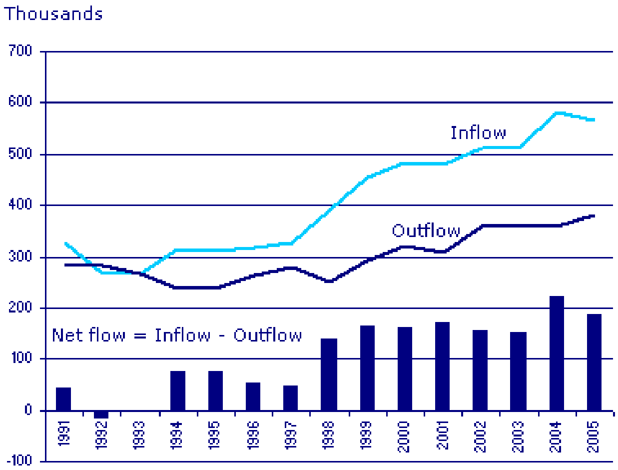

Figure 3.2. Total International Migration to/from the UK 1991-2005
Source: ONS

The ageing population

Long term population forecasts, including TEMPRO, show a striking change in the age structure (See Table 3.3). Overall, the number of people under 16 is forecast to fall by over 10% as birth rates remain below the rate of population replacement, with hardly any change to the working age population and an 84% increase in the over 65s. On average life expectancy is increasing by around 1.5 years every decade. This is one reason why household size is forecast to continue to fall from 2.3 persons per household in 2003 to 2.0 per household in 2028.

Area	< 16	16 - 64	65 +	Total Population
GREAT BRITAIN	**-10.6**	**0.1**	**84.3**	**11.1**
Scotland	-27.4	-21.5	59.7	-9.8
North East	-29.8	-17.0	79.4	-3.9
North West	-17.7	-5.7	76.7	4.7
Yorkshire & Humber	-13.4	-2.4	81.1	8.5
West Midlands	-12.3	-3.8	80.3	7.6
East Midlands	-10.6	0.3	114.1	16.1
East	-1.0	7.2	114.8	22.9
London	0.6	17.3	50.2	17.9
South East	-4.2	5.0	97.0	17.9
South West	-6.9	4.7	103.4	20.5
*Wales	-11.9	-2.6	54.0	5.2

Table 3.3 TEMPRO population forecasts 2003-41 (%change)

The increasing numbers of older people will undoubtedly affect demand for travel, including both travel patterns and times of journeys. Travel by the over 65s is likely to be more home based and dispersed, and less concentrated in the peaks. Older people tend to become progressively less mobile and more car dependent. But these changes may be less marked than the growth in numbers would suggest. People in their 60s and 70s will be fitter and more active, and more are likely to continue working after retirement age. They will have the health and wealth to travel.

Regional variations

TEMPRO forecasts also show a great regional variation in population change. By 2041 population in the East Midlands and southern regions, including London, is projected to grow in the range 16% to 23%, compared with -10% to +5% in Wales, West Midlands and the north. It should be noted that TEMPRO has a very pessimistic population forecast for Scotland. Though we have reservations about the likelihood of such a large fall in population, for consistency we have used TEMPRO throughout.

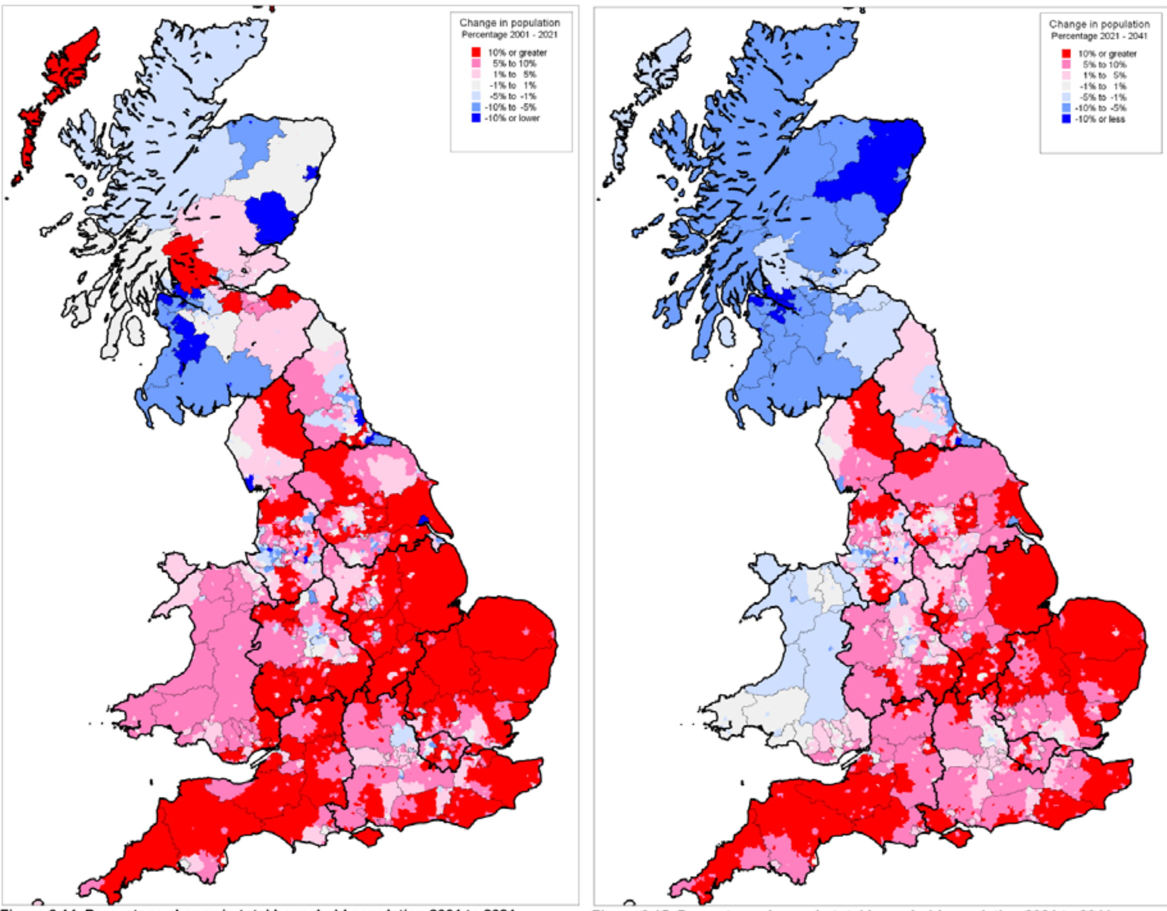

Figure 6.14 Percentage change in total household population 2001 to 2021

Figure 6.15 Percentage change in total household population 2021 to 2041

Figure 3.3. TEMPRO population growth, 2001-21 and 2021-41

Source TEMPRO Planning Guidance Note

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Figure 3.3 shows the change in twenty year time bands in more detail. In the period to 2021, the largest growth area is in a band from Cornwall to the Wash, with other growth areas on the south coast, central Scotland and in the more prosperous areas around conurbations. After 2021 the forecast is for Scotland's population to decline by approximately 8%, and for the fastest growth to occur on the east coast and in the south midlands and South West.

Regional distribution will still depend mainly on the economy, but increasing proportion of older people will be locating in relation to lifestyle. There are likely to be many more retirees in seaside towns and other attractive environments. Otherwise, older people will increasingly migrate to southern Europe.

One factor that could influence the distribution of population is the extent to which planning policy will retard/reverse past trends. Planning policy tends to be directed "against the flow", and will continue to do so if the current emphasis on protecting the environment and mitigating adverse effects of change persists. The present planning policy is to discourage development in the countryside and concentrate new housing at higher densities in urban areas and on previously developed land. Continuing growth pressures and rising house prices may render this policy increasingly difficult to maintain over the longer term, particularly in the south.

In July 2007, the Government published a new housing White Paper[101] which proposes a substantial increase in housing targets to deliver 2 million new homes by 2016 (increasing the annual target to 240.000 p.a, compared with current construction of 185,000 p.a.), and 3 million new homes by 2020.

Of the 2 million homes by 2016, 1.6 million are already in Regional Spatial Strategies, including the growth areas in the Thames Gateway, around Milton Keynes and Cambridge, and at Ashford, and should therefore be reflected in TEMPRO. Of the remainder around half will be provided for in RSS revisions and the rest will be concentrated in "New Growth Points" and five, or perhaps as many as ten, new "eco-town" schemes. Infrastructure plans to serve these concentrations of new population have yet to emerge, but will need to include capacity on the national networks as well as regional and local schemes.

However, these proposals have only a fifteen year timeframe. One scenario for mid-century might be that there will be several 100,000+ new cities developing in the south – such as in

[101] Communities and Local Government, 2007

the Cambridge area. This is not currently on the agenda, not least because regional planning policy only has a 20 year timeframe.

Lifestyle changes

Underlying these forecasts are a number of assumptions on lifestyles in the future that, like the forecasts themselves are based on trends already evident in society. In summary, they are:

- Richer people will want larger, better homes/neighbourhoods.
- There will be much higher spending on local services and amenities, suggesting an increase in local (which will have an increasingly wide geographic definition) and dispersed off-peak, evening and weekend trips.
- City centre shopping will change with more internet shopping for standard quality products – groceries, books, electricals etc. – much of it delivered directly to homes. But leisure, fashion, and comparison shopping will also increase and will continue to locate in large shopping centres. There will be more small offices, restaurants, coffee shops and entertainment in city centres or suburban malls.
- City centre living will continue to be fashionable, but numerically this is not a very big phenomenon. Overwhelmingly people will still live in suburbs and commuter areas.
- New types of settlement may develop, such as gated cities for the elderly, though not necessarily in UK.
- As now, travel will grow fastest for education, leisure and employers' business – mostly avoiding the peaks. The first two are very much part of suburban lifestyle changes. (see figure 1.6 of Causes of Growth).
- There will be more escorted trips, both children older people.

The cost of motoring may increase in real terms, both because of tax, and due to the extra cost of introducing clean vehicles and fuels. However, it has not done so in the past – the real costs of car travel has been slowly falling and the quality rising.

Transport and travel forecasts

One problem for long term transport forecasting is to disentangle demand from supply. Unless there is appropriate transport, travel cannot increase, and in the past the growth in demand for travel has been supported by improvements in both capacity and speed. However where supply has been constrained, such as for car use in London, growth has also been restricted. Here road traffic grew by less than 7% from 1992 to 2005 compared with over 21% nationally[102].

As has been explained, a modern economy is increasingly interconnected on a national as well as global scale, and in every field there are now increasing divisions of function as well as labour. This entails not only more electronic communication, but also more travel. Similarly, a modern lifestyle entails exercising more choice for more activities over a wider area.

In the short to medium term, there is some flexibility in the relationship between demand and supply for economic and lifestyle improvements to be accommodated. People and businesses can choose their locations and their travel to avoid the worst congestion or the high cost of using the networks. However, in the longer term these choices become less effective and ultimately less possible as congestion spreads and costs increase. Transport thus needs to improve in step with demand in order to support a modern economy and a modern lifestyle.

Network capacity increases are needed both within and between centres of population and employment, and journey times need to continue to reduce, as they have done over the centuries. In this way customer and labour catchments can become wider and deeper to support more variety and more higher-order activities. Otherwise growth cannot be sustained over the longer term.

The demand forecasts that we have used, and the prognoses for population, employment and lifestyle, are “unconstrained” in that they assume that the capacity and capability of the networks will improve to support the growing demand and changes in lifestyle. Because they are in the main trend based, they effectively assume a similar capacity constraint as in the past, and therefore a broadly similar level of network enhancement in the future. Supply constraints will be applied during the modelling process to varying degrees, depending on the options, to assess the implications of different approaches. This is described in Chapter 4.

Journeys and modes

TEMPRO takes the planning forecasts and converts them into trip forecasts by mode. Table 3.4 shows the percentage change in total trips for an average weekday by mode for the

[102] TFL (2006b), table 3.1.1.

period 2003-41 by region. For Great Britain, TEMPRO is predicting a 12% increase in total trips by all modes, with the trips per person unchanged. However, there are also some very significant variations by region and in modes.

In terms of total trips on an average weekday, walking increases by 1% and cycling decreases by 3%, Motorised travel, on the other hand, increases by 17% (the combination of a 26% increase in car drivers, 7% car passengers and 8% rail), but a 9% reduction in bus and coach travel. The regional mode shift is even more marked. In the north, there are large reductions in bus/coach and rail travel[103].

	Total Population	Car driver		Bus/coach		Rail	
		Productions	Attractions	Productions	Attractions	Productions	Attractions
GREAT BRITAIN	**11.9**	**26.4**	**26.4**	**-8.9**	**-8.9**	**8.2**	**8.2**
SCOTLAND	-10.1	10.3	10.3	-31.2	-31.2	-19.3	-19.3
NORTH EAST	-4.1	18.2	18.2	-27	-27	-14.3	-14.3
NORTH WEST	5.0	22.5	22.5	-15.6	-15.6	-4.5	-4.5
YORKSHIRE & HUMBER	9.1	27.9	27.9	-14.6	-14.6	-1.7	-1.7
WEST MIDLANDS	8.2	23.5	23.5	-14.6	-14.6	-2.3	-2.3
EAST MIDLANDS	17.5	29.4	29.4	-5.7	-5.7	4.8	4.8
EAST	25.1	31.8	34	7.2	8.4	12.3	16.5
LONDON	18.1	35.2	28.8	2.4	1.1	17.7	15.8
SOUTH EAST	19.5	27.9	31	1.4	2.5	10.9	15.8
SOUTH WEST	22.0	31.4	31.4	1.2	1.2	11	11
WALES	6.1	20.9	20.9	-12.1	-12.1	-2.1	-2.1

Table 3.4 TEMPRO forecast for total average weekday trip growth 2003-41 (% change)

The increase in car travel will be accompanied by growth in car ownership in all regions (see Fig. 3.4), and the proportion of households not owning a car will reduce from 26% to 20%. Geographically the lowest car ownership rates are in London and the conurbations, and in rural Scotland and Wales. This is an effect of low income and of congestion and better public transport in the densest urban areas.

Trips per person on an average weekday hardly change (a 0.8% increase in 38 years). Walking and cycling[104] are forecast to reduce by 9% and 13% respectively, probably mostly reflecting a combination of an ageing population and the demand to travel longer distances. For motorised modes, trips per person by car drivers increase 14%, whereas bus/coach declines by 18% and rail by 3%.

[103] We have moderated some of the TEMPRO forecasts in respect of public transport, see below.
[104] Note this is main mode.

There are also wide variations in regional trips per person. Wales, West Midlands and northern regions are forecast to experience a 15-22% increase in car driver trips per person (average weekday), compared with 7-11% in East Midlands and southern regions. Bus/coach per person decline 24-31% in the west/north and 12-19% in the east/south. For rail trips, the smallest declines in weekday trips per person are in and around London.

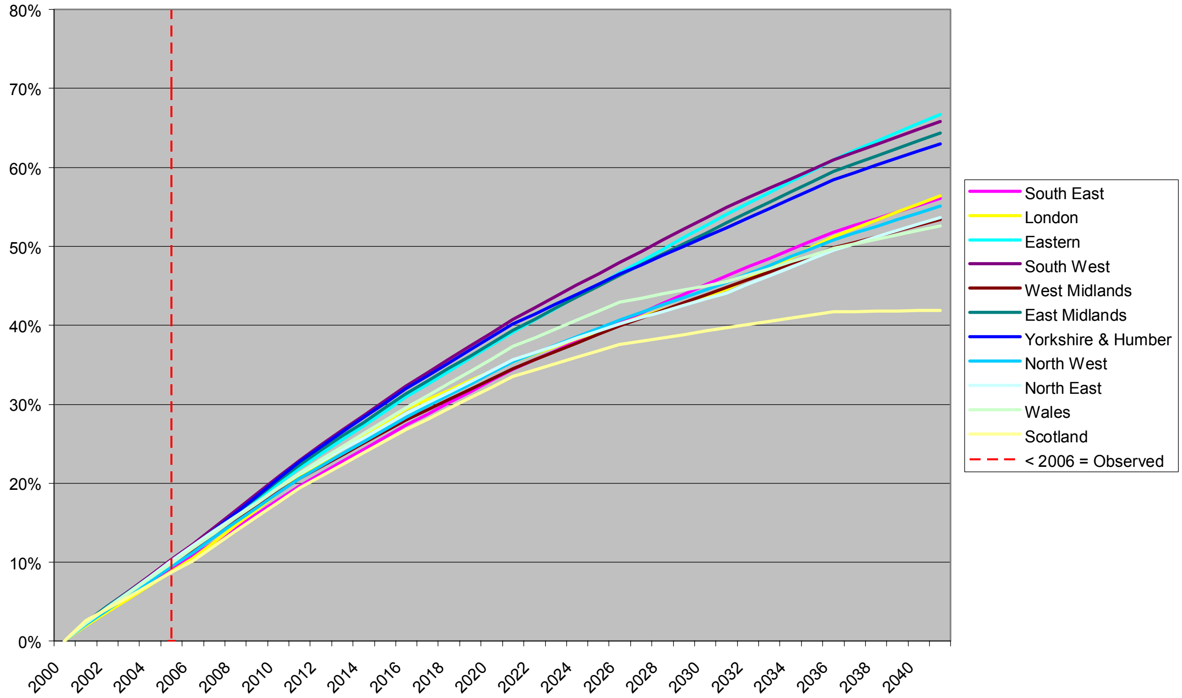


Figure 3.4. Cumulative Growth in Car Ownership
Source: TEMPRO V5

Car traffic

The next step is to estimate the change in average trip length to be applied to the TEMPRO trip growth factors to derive the forecast increase in traffic and congestion. Travel demand is sensitive to the ability of travellers to pay and to the cost of transport. Two further sets of assumptions are therefore necessary in order to forecast traffic growth – the growth in prosperity (real income per capita), and the per kilometre cost of motoring. The income forecast is set out in Table 3.1 above. The most important ingredients in the forecast cost of car travel are as follows. They are discussed in more detail in Chapter 4 and Annex 1.

- **Change in average fuel efficiency of vehicles** – The average efficiency of cars improved by approximately 0.75% p.a. 2002-4 and we have assumed that this rate of improvement continues until 2031 and a conservative assumption that there is no improvement thereafter. The result is that cars are estimated to be 23% more efficient per kilometre in 2041 than they were in 2003[105].

- **Cost of fuel** – The cost of fuel will be affected by the duty paid to exporting countries and domestic tax than as well as the cost of extraction, refining and delivery. Since 1947 crude oil has averaged $23.5 per barrel (2006 prices), and has only been above $30 between 1974 and 1986, and since 2003. The Stern review estimates that the stocks of hydrocarbons that can be extracted at $30 will last well beyond 2050 and is far greater than the maximum that can be consumed without dangerous environmental consequences.
- **Fuel tax** – UK diesel is currently the most expensive in Europe, and UK petrol is second most expensive (after the Netherlands). Tax comprises 67% of the cost of petrol/diesel and contributes 80% of all carbon tax currently levied. The Stern Review has estimated the price of carbon dioxide emissions at $85 (£45) per tonne. This equates to 14p per litre of fuel, compared with the current fuel duty (ex VAT) of approximately 45p per litre (see Chapter 4).

Taking all these factors into account, we have assumed an increase in fuel cost of 80% 2003-41 from 90p in 2005 to £1.55p in 2041. The resulting forecasts for increase in traffic (measured in vehicle kilometres) are shown in Table 3.5. Actual growth will be less, particularly in congested areas such as London.

Area	Car trips		Vehicle Kilometres
	Productions	Attractions	
GREAT BRITAIN	26.4	26.4	39.7
Scotland	10.3	10.3	25.5
North East	18.2	18.2	33.3
North West	22.5	22.5	36.4
Yorkshire & Humber	27.9	27.9	44.3
West Midlands	23.5	23.5	35.5
East Midlands	29.4	29.4	43.8
East	31.8	34	48.4
London	35.2	28.8	40.7
South East	27.9	31	40.0
South West	31.4	31.4	47.4
Wales	20.9	20.9	34.7

Table 3.5 Average weekday growth in car trips and distance travelled 2003-41 (% change)
Source: Trips: TEMPRO V5.3 database. Vkm: Arup

[105] Department for Transport 2007. This compares with the TAG petrol car fuel efficiency assumption of -0.85% pa 2005-10, -1.22% pa 2010-15, -1.48% pa 2015-20 (total -17.4% 2005-20) (TAG Unit 3.5.6)

Freight

Until 1998 road freight traffic grew broadly in line with GDP but, measured in tonne kilometres, the volume of freight traffic moved has changed little between 2000 and 2005[106]. However, it is too early to speculate that the link between GDP and freight traffic growth is significantly weakening. It has been estimated that there would be an extra 21bn tonne km on the roads if road freight had grown in line with GDP since 1998[107], but there are a number of explanations for this shortfall;

- A third is due to increased foreign registered traffic which is not included in these statistics;
- 22% is due to mode shift to rail, water and pipeline;
- 12% is caused by higher freight rates, mainly due to increased fuel costs;

The remaining third is a result of a variety of factors including declining manufacturing, rationalisation of distribution networks leading to transport efficiencies. One effect of these factors is that the average length of haul has not increased.

Some of these factors are likely to be short/medium term because there will be diminishing opportunities for deindustrialisation, rationalisation of distribution and mode shift. Of greater significance for traffic forecasts are the trends for different types of freight traffic. 68% of all freight traffic comprises vans and other light goods vehicles (LGVs) carrying less than 3.5 tonnes. It is these vehicles that have experienced the highest growth.

	Actual (TSGB)		**NRTF 1997 forecast 1996-2005**		
	(bn vkm) 2005	**Increase 1996-05**	**Low**	**Central**	**High**
Light goods vehicles	62.6	1.35	1.18	1.26	1.35
Rigid HGV	15.1	1.08	1.00	1.07	1.14
Articulated HGV	13.9	1.14	1.18	1.26	1.34

Table 3.6 Freight growth and forecasts to 2005

Comparing the recorded change with the National Road Traffic Forecasts Great Britain (NRTF) 1997 forecast for the period 1996-2005, light goods vehicles have increased as predicted by NRTF High, and Rigid HGVs by NRTF Central. Articulated vehicles are somewhat below NRTF Low, but these TSGB statistics do not include foreign registered vehicles and most of these are likely to be articulated vehicles, as these have a much longer average haul length.

[106] Department for Transport 2006a Table 4.1 (note: the figures for 2004 and 2005 are not strictly comparable with earlier years).
[107] A. McKinnon (2006),

For our forecasting, we have used the NRTF 1997 forecasts to 2031. These forecasts are high compared with the Great Britain Freight Model Figures used by the Eddington Study, but we have assumed no change 2031-41. The increase in light vehicles has been caused by changing patterns of distribution and servicing, including more specialised maintenance skills, and the growth in home deliveries and internet retailing. Many of these changes are quite recent, and it seems reasonable to assume that not only are they permanent, but also that they will continue for some time to come.

We have therefore used NRTF High for LGVs, NRTF Central for Rigid HGVs and NRTF Low for Articulated vehicles. The resulting 2005-31 traffic increases are shown in Table 3.7.

	2005-31
LGVs	+86%
Rigid HGVs	+27%
Articulated HGVs	+66%

Table 3.7 Freight forecasts

Reliability of trends and forecasts

Though there is some unpredictability in freight traffic trends due to changes in the UK's economic structure and logistics technology and patterns of distribution, forecasts for car traffic are predictable. And generally past forecasts have been reasonably accurate. Figure 3.5 compares official forecasts since Traffic in Towns in 1964 compared with actual growth.

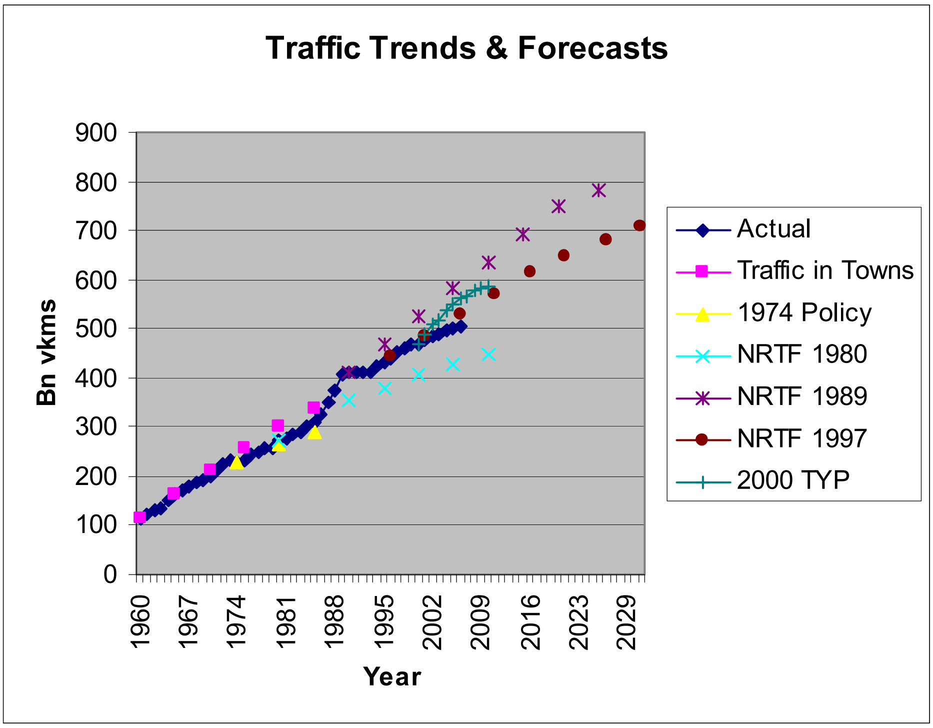


Figure 3.5. Past forecasts compared with actual growth.

For the period 2001-2031, the TEMPRO/Arup car traffic (vehicle km) forecast is very similar to NRTF97 Central. Table 3.8 shows how the growth rates compare. However, unlike NRTF, TEMPRO/Arup extends to 2041 and is disaggregated to regional level.

	NRTF Central	**TEMPRO/ Arup**
2001	100	100
2006	108	106
2031	140	140
2041		144

Table 3.8 Comparison of NRTF97 and TEMPRO/Arup forecasts

4. Modelling and results

The model and the data

The structure of the data

At various points in the following chapters reference is made to the classifications used in our modelling: road types, area types, Regions and times of the week. These are defined in the basic data kindly supplied by the Department for Transport from the FORGE model, and are set out in Tables 4.1 to 4.4:

Road Types

Road types vary by area type as described in the following table:

Road Type	London and Conurbations	Other Urban	Rural
1	Motorway	N/A	Motorway
2	N/A	N/A	Trunk Dual A
3	N/A	N/A	Principal Dual A
4	Trunk A	Trunk A	Trunk Single A
5	Principal A	Principal A	Principal Single A
6	B and C Rds	B and C Rds	B Rds
7	Unclassified	Unclassified	C & Unclassified

Table 4.1. Road Types

Area Types

The following two tables define the area types and give an indication of how the larger cities and towns are classified:

Area types	Description	Population
1	Central London	
2	Inner London	
3	Outer London	
4	Inner Conurbation	
5	Outer Conurbation	
6	Urban Big	> 250,000
7	Urban Large	>100,000
8	Urban Medium	> 25,000
9	Urban Small	> 10,000
10	Rural	

Table 4.2. Area Types

Nations and Regions

As shown in Table 4.3 the study area is made up of the 9 English Government Office Regions, together with Wales and Scotland.

Northern Region
Yorks and Humberside
East Midlands Region
Eastern Region
South Eastern Region
London Region
South Western Region
West Midlands Region
North Western Region
Scotland
Wales

Table 4.3. Regions

Conurbations

Table 4.4 identifies the conurbations which are the metropolitan counties together with London

Greater Glasgow
Tyne & Weir
Greater Manchester
Merseyside
West Yorkshire
South Yorkshire
West Midlands conurbation
London

Table 4.4. conurbations

Time Periods

The nineteen time periods within the week are as follows

Period	Day	Time	Period	Day	Time
1	Mon-Fri	00:00 - 06:00			
2	Mon-Fri	06:00 - 07:00	12	Saturday	00:00 - 09:00
3	Mon-Fri	07:00 - 08:00	13	Saturday	09:00 - 14:00
4	Mon-Fri	08:00 - 09:00	14	Saturday	14:00 - 20:00
5	Mon-Fri	09:00 - 10:00	15	Saturday	20:00 - 24:00
6	Mon-Fri	10:00 - 16:00			
7	Mon-Fri	16:00 - 17:00	16	Sunday	00:00 - 10:00
8	Mon-Fri	17:00 - 18:00	17	Sunday	10:00 - 15:00
9	Mon-Fri	18:00 - 19:00	18	Sunday	15:00 - 20:00
10	Mon-Fri	19:00 - 22:00	19	Sunday	20:00 - 24:00
11	Mon-Fri	22:00 - 24:00			

Table 4.5. Times of the week

Journey purposes

For cars there are six journey purposes:

HBW	Home based work
HBEB	Home based Employers Business
HBEO	Home based Essential Other (Education + Private Business)
HBDO	Home based Discretionary Other (Social + Holiday)
NHBWEB	Non Home based Work/Employers Business
NHBDO	Non Home based Discretionary Other

The remaining road vehicle types are

LGV	Light Goods Vehicles (less than 3.5 tonnes gross weight)
Rigid	Rigid Heavy Goods Vehicles
Artic	Articulated Heavy Goods Vehicles
PSV	Public Service Vehicles (Buses/Coaches)

The model

The generalised cost (g) to a user of a specific mode, in a particular place at a particular time of day is a measure of the total of all the costs faced per passenger kilometre:

$$g = p + \tau_v (1/s) + \tau_w w + t + \ldots$$

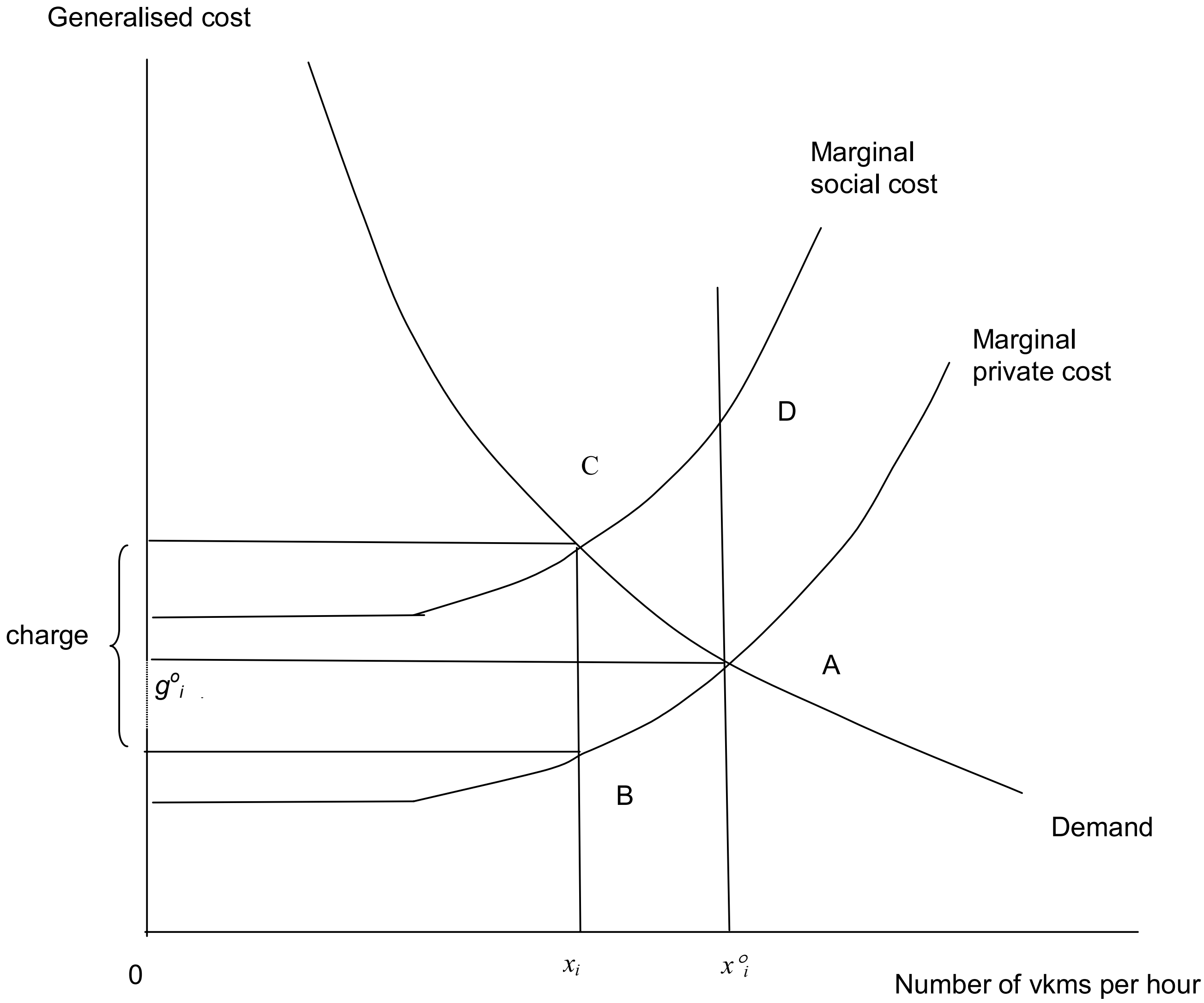
that is, per vehicle kilometre, generalised cost is:

money cost (p) + value of in-vehicle time (τ_v) x time per vehicle kilometre + value of waiting time (τ_w) x average waiting time (w) + charges (t) + any other relevant costs.

Figure 4.1 shows the relationship between costs and the amount of travel (the demand curve) and between the amount of travel and the costs of using the network (the cost curves). The vertical axis represents the generalised cost per passenger or vehicle kilometre and the horizontal the flow of passenger kilometres per hour. The marginal private cost is the cost to an individual of travelling one extra kilometre. The marginal social cost the cost to all individuals of one individual travelling one extra kilometre. The vertical distance between the lines represents (for any given flow) the difference between the costs borne by the individual user and costs imposed on everybody else.

For example, at the flow x_i^o the cost in terms of the value of time spent and money of an individual travelling one additional kilometre might be £0.10. But the act of making that extra kilometre will cause a little extra pollution cost to others, and slow down all the existing traffic a little. So the total cost to society of the extra trip might be the £0.10 plus £0.03: a marginal social cost of £0.13. (See also Newbery, 2002).

Figure 4.1



The base equilibrium

The Figure also shows a demand relationship, representing the way the demand is estimated to respond to changes in generalised cost. At the point A and flow rate x^o_i the cost to the private user, g^o_i is just matched by the private user's willingness to pay for an additional kilometre: it is the equilibrium flow rate in the absence of any intervention. In principle the answer to the question "what would be the best equilibrium (generalised cost and flow), given a free hand to adjust taxes and prices?" is given by the point where the benefit of an extra kilometre (the vertical height under the demand curve) is just in balance with the marginal social costs: point C, with the reduced flow, x_i. This can be achieved by imposing a unit charge given by the distance BC. Therefore, our aim is to estimate the point C.

The position of point C, and thus the magnitudes of the charges and the volume reduction required, is clearly critically dependent on the shape of the demand curve. Further, bearing in mind that the Figure only represents one of several competing modes of transport, the demand for any one of them will depend to some extent upon the generalised costs for all the others (through modal cross-elasticities).

A critical determinant of the shape of the demand curve is the response of demand to changing generalised cost at the base demand level - its slope, and how demand for one mode will be changed by a change in generalised cost for a different mode. These quantities are directly related to the own-price and cross-price elasticities of demand. That is why we have given considerable attention to the sources of evidence on elasticities.

Shapes of demand relationships

Knowledge of the slopes is not enough to determine the shape of the demand curves for anything other than a very small change. There is little conclusive evidence about the shape of the curves – it is hard enough to obtain evidence on the slopes, never mind the actual shape of the curve for large changes in costs and/or flows.

Candidates for the form of the demand relationships include the linear and the constant elasticity forms. A particularly useful intermediate form is the semi-logarithmic form: if x_i is the number of passenger trips per hour and x_i^o is the base number of trips, then

$$x_i = x_i^o \exp \{ \Sigma_j \lambda_{ij} (g_j - g_j^o)\}$$

Here the λ_{ij} are the constant parameters determining the responses of demand to changes in generalised cost. They relate changes in demand for any one mode to changes in generalised costs (including prices and taxes) for all modes. There is a simple relationship between the λs and the respective elasticities which enables the one to be calculated from the other. The form has the intuitively reasonable property that the implied own price elasticity is directly proportional to the respective price: as a price rises the mode becomes progressively less competitive, so the loss of market accelerates as the price continues to rise.

It is not reasonable to assume that the cross-elasticities in a particular area will necessarily be the same as a national average. For instance, if a particular area has very few rail services one cannot assume the national average percentage change in car trips as a result of a one per cent change in rail fares. We have modified national cross elasticities to reflect the local market shares.

Similarly we allowed own-price elasticities for the car users to vary by trip purpose with lower elasticities for home based work trips and business trips and higher elasticities for "discretionary" trips.

Time switching

In order to model the propensity of users to switch from one time of day to another in response to changes in relative costs and speeds the "base" values, x_i^o, were themselves allowed to vary in response to generalised costs relative to those at neighbouring times:

$$x_i^o = b_i^o \exp\{\Sigma_j \mu_{ij} (g_j - g_j^o)\}.$$

Here the b_i^o are the "raw" base values determined, as before, as the base values in the data: if all the g_i take their base values, g_i^o, then the x_i^o take their base values, b_i^o and, in turn, the x_i take their base values, x_i^o. However, as the generalised costs, g_i, deviate from their base values, g_i^o, the x_i^o respond in accordance with the parameters, μ_{ij}. This response in the base values is normalised in such a way that for each trip type the switching does not change the total base number of vehicle kilometres for each region, area type and road type. Thus the net effect of a new money charge or speed change on final demand at any time period, x_i is now a compound result of switching between times of the week and, as before, an elasticity with respect to generalised cost.

We have not been able to find good evidence to guide us on the magnitudes of time switching likely to occur in practice. Small (1982) and Burris, Konduru and Swenson (2004) report some relevant empirical evidence but it is not a great deal of help in our context. Therefore our approach has been to postulate several alternative magnitudes of switching and to investigate the sensitivity of our results.

We have imposed some *a priori* restrictions which are summarised in Table 4.6. In this Table a blank indicates that transfer will not occur and an "x" shows that it is possible. For example, transfer is assumed not to occur into or out of the very early mornings (period 1). But it does occur on week days between the pre-morning peak (period 2), the first morning peak hour (07:00 to 08:00, period 3), the second morning peak hour (08:00 to 09:00, period 4) and the first inter-peak hour (period 5). There is a similar (though simpler) pattern in the week day evenings. Transfer is possible between weekend mornings and afternoons, and between Saturday and Sunday during the day.

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1																			
2			X																
3		X		X															
4			X		X														
5				X															
6																			
7								X											
8							X		X										
9								X											
10																			
11																			
12																			
13														X			X	X	
14													X				X	X	
15																			
16																			
17													X	X				X	
18													X	X			X		
19																			

Table 4.6.The times of week between which switching is permitted

Commercial vehicles are assumed not to switch times of travel. This is a simplification because, in reality, commercial vehicles do have substantial flexibility. Some current night-time deliveries could revert to day time to take advantage of lower labour costs and greater convenience for customers. Equally, some peak deliveries could divert to off-peak times to take advantage of lower road charges. However it should be recognised that switching travel times will usually, all other things being equal, involve some loss of utility.

The equation above determines how different values for μ represent different propensities of drivers to switch times. In order to investigate the sensitivity of the system to different magnitudes of this switching parameter the following tables summarise the effects on the total numbers of the various types of car trip in the 2010 base, of levying a flat rate charge of £0.01 per vehicle km. in periods 4, 8 and 13 (that is, the second morning peak hour, the evening peak and Saturday mornings). This is done for all values of μ at 0 (no time switching), 0.1, 0.5 and 1.0. Note that costs of fuel for cars in the base are of the order of £0.05 per vehicle km. so the additional charge used here is equivalent to approximately a

20% increase in fuel prices. The results are not the same as the "pure" fuel price elasticities because the system has been equilibrated: an additional charge reduces traffic, which increases speeds, which reduces time costs, which induces some new traffic. The extent to which the time reduction generates new traffic depends on the respective values of time. As Tables 4.7 to 4.9 illustrate, the consequence of making a money charge is to change the mix of journey types in favour of those with higher values of time savings, as well as to reduce the total of traffic.

	HBW	HBEB	HBEO	HBDO	NHBWEB	NHBO	ALL CARS
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4	-4.4%	-1.9%	-6.9%	-5.2%	-2.7%	-4.9%	-4.3%
5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8	-4.3%	-2.3%	-6.8%	-5.4%	-2.7%	-5.1%	-4.5%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
13	-4.6%	-1.9%	-7.3%	-5.4%	-1.9%	-5.3%	-5.8%
14	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
17	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
18	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
19	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	-1.3%	-0.4%	-1.2%	-0.6%	-0.2%	-0.8%	-0.9%

Table 4.7. Changes in traffic, μ = 0 (no time switching)

	HBW	HBEB	HBEO	HBDO	NHBWEB	NHBO	ALL CARS
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2	-0.9%	0.2%	-0.4%	-0.2%	0.3%	-0.4%	-0.4%
3	2.8%	0.2%	1.2%	0.3%	0.2%	1.0%	1.6%
4	-7.0%	-1.7%	-8.4%	-6.7%	-2.6%	-6.6%	-6.3%
5	2.9%	0.4%	1.2%	0.3%	0.4%	1.0%	1.7%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	1.7%	-0.1%	0.7%	1.2%	-0.2%	1.3%	1.1%
8	-6.9%	-2.1%	-8.2%	-7.5%	-2.3%	-7.2%	-6.5%
9	1.9%	0.4%	0.8%	1.3%	0.4%	1.4%	1.3%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
13	-8.0%	-2.0%	-9.7%	-7.9%	-1.8%	-7.9%	-8.3%
14	0.7%	0.2%	0.4%	1.0%	0.1%	0.7%	0.7%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
17	2.2%	0.4%	1.6%	0.5%	1.3%	1.0%	0.9%
18	2.6%	0.3%	1.9%	0.6%	1.2%	1.2%	1.0%
19	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	-1.3%	-0.3%	-1.1%	-0.6%	-0.1%	-0.8%	-0.9%

Table 4.8. Changes in traffic, μ = 0.5

	HBW	HBEB	HBEO	HBDO	NHBWEB	NHBO	ALL CARS
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2	-1.6%	1.0%	-0.6%	-0.3%	1.5%	-0.6%	-0.6%
3	5.6%	0.1%	2.2%	0.5%	0.1%	1.8%	3.1%
4	-9.6%	-1.2%	-9.9%	-7.6%	-1.8%	-8.2%	-8.1%
5	5.7%	0.4%	2.2%	0.5%	0.3%	1.9%	3.2%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	3.3%	-0.2%	1.3%	2.3%	-0.1%	2.5%	2.2%
8	-9.3%	-1.7%	-9.5%	-9.5%	-1.5%	-9.1%	-8.3%
9	3.7%	0.5%	1.6%	2.7%	0.5%	2.8%	2.6%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
13	-11.3%	-1.3%	-11.7%	-10.1%	-0.1%	-10.1%	-10.4%
14	1.2%	1.2%	0.9%	2.0%	1.3%	1.3%	1.5%
15	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
17	4.5%	0.6%	3.2%	0.9%	2.4%	2.1%	1.7%
18	5.2%	0.3%	3.7%	1.2%	2.2%	2.4%	2.0%
19	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	-1.2%	-0.2%	-1.1%	-0.6%	0.0%	-0.8%	-0.8%

Table 4.9. Changes in traffic, μ = 1.0

Consider first row 13 of these Tables, which corresponds to Saturday mornings. In the case where μ = 0 and there is no time switching, we see a 5.8% reduction in car traffic, which is what we would expect from approximately 20% increase in fuel costs and the fuel price elasticity of around 0.3. In rows 4 and 8 we see a smaller overall reduction because at these times (weekday peaks) congestion is more of a problem so some of the traffic deterred by the new charge is replaced by traffic taking advantage of the improved speeds. This is apparent in the smaller reductions in the columns for Home Based Employers' Business (HBEB) and Non Home Based Non Work/Employers Business (NHBWEB) where the values of time are much higher.

In the case where μ = 0.5 some switching occurs. The overall traffic reduction in row 13 is greater at 8.3%, but there have been small increases in traffic on Saturday afternoons, Sunday mornings and afternoons. These phenomena are much more marked in the case where μ = 1. In each case tested the direct impact on the time charged is nearly twice as high as it was with no time switching. There is substantial transfer to the neighbouring periods.

Notice that when a charge is added in the later weekday morning peak, the traffic in the preceding peak hour rises as expected, but traffic in the hour before the peak falls slightly. This may be because of some users in the early morning switching into the charged peak to take advantage of the clearer roads.

Time switching makes demand more responsive to price at the time the price is raised. Therefore, charges to deal with congestion do not need to be so high.

Comparing $\mu = 0$ with $\mu = 0.5$, with no time switching car traffic fell by 4.3% and with it fell by 6.3%. Therefore the switching accounts for a 2% reduction over and above the pure price effect. Since this is caused by a charge approximately equivalent to a 20% increase in fuel costs, this represents elasticity due to switching of approximately 0.1. This is the same order of magnitude as the long term effects found by Burris et al (2004) – although their results are not definitive.

This analysis suggests that time of day switching could be a significant—though not overwhelming—factor in designing road pricing schemes. In practice substantial benefits can be obtained through persuading a few users to change their time of travel, thereby securing a more efficient use of the limited highway capacity.

In what follows we use of the case $\mu = 0.5$. In practice the net amount of estimated switching was small.

Response of car occupancy

Increasing charges would give an incentive to increase average occupancies. This could be an important phenomenon because increased average occupancies mean that the same number of people would be carried whilst consuming less road space and therefore causing less congestion. The Department for Transport's Feasibility Study (2004) and the Eddington Transport Study (2006) both confirmed that this consideration should not be neglected.

As with time of day switching we do not have suitable empirical evidence to guide us as to the propensity of people to switch between being drivers and being passengers – though casual observation suggests that it may be quite low. Experience on car sharing in California is said to indicate that sharing rises with journey distance – because the benefits of cost saving rise too. The propensity to share is also affected by the degree of trip chaining. As trip chains become more complex the more difficult it is for riders to share journeys.

One approach to the problem is to hypothesise several different propensities and evaluating the difference it makes to our results.

We assumed that occupancies of all commercial vehicles stay fixed.

For private cars we have assumed that the average occupancy is related to the occupancy in the base and money cost difference between the current situation and the base according to the following relationship:

$$Occupancy = 1 + 2(base\ occupancy - 1)/(1 + e^{\lambda\{cost - base\ cost\}})$$

where λ is a negative constant.

If the current cost is equal to the base costs then the occupancy is equal to the base occupancy. As the current cost rises above the base cost, so the average occupancy rises. The occupancy can never fall below one and it never rises above twice the base occupancy.

Tests documented in Glaister and Graham (2003) show that the results are, indeed, sensitive to the propensity to share cars. The higher it is, the less overall disbenefit there is to road users from road user charging, the greater the environmental benefits, the less the charge revenues (because congestion is relieved with lower charges) and the greater the overall net benefit from the scheme.

In the absence of empirical evidence we have chosen the value λ = -0.1 throughout the remainder of our work. However, the sensitivity tests do suggest that if it were thought that a different value was more appropriate then that would make an important difference to the overall results.

The numerical algorithm to search for the best price and tax levels

The steps for computing the movement from point A in Figure 4.1 to point C were:

- establish suitable national average own-price and cross-price elasticities;
- modify these to local conditions using local market shares;
- convert from the modified elasticities to the respective λ's;
- change a policy variable, such as a rail fare or a tax on petrol then
- calculate a new, *mutually consistent* set of speeds, generalised costs and demands.

Note that this last stage involves an iterative algorithm because of the interdependencies.

Having found the set of taxes and charges corresponding to point C this yields estimates of the revised volumes of travel and hence the changes to tax revenues and public transport costs, revenues and subsidies. An estimate is produced of the overall net effect on the public finances.

Numerical values used in the model

Road traffic and speed-flow relationships

The base traffic flow data relate to England for the year 2010. They were DfT's traffic data as collated in the FORGE Road Capacity and Costs Model, kindly supplied by the Department for Transport. These represent forecasts of the situation in 2010, assuming traffic increases likely to be generated by normal growth in economic activity but mitigated by the deterrent effect of worsening congestion, taking into account such extra capacity as is expected to become available by then.

The traffic flow data are expressed in terms of 11,124 “cases”. Each case relates to one of 11 regions, one of 20 times of day, a particular type of road and a “busy” or “non-busy” direction.

Car traffic demand for the year 2041 was estimated using the growth factors estimated by Arup and documented in Annex 1, below. These vary by Region and incorporate views on growths in regional incomes, car ownership and car use. Note that these are demand estimates on the assumption that journey times stay the same as in the 2010 base. The actual traffic that would appear on the roads is moderated by the deterrent effect of worsening congestion, using the generalised cost demand formulation documented above.

Speed-flow relationships were supplied by the Department for Transport and are similar in concept to those set out in the Design Manual for Roads and Bridges.

Public transport

Our representation of bus and rail travel is less satisfactory than that for car and lorry traffic, due to data limitations. Data for public transport were derived from published sources. Distances travelled by person by mode by Region, together with population by Region were used to estimate bus and rail passenger km by Region. Regional data on bus kilometre and revenues were used to estimate average bus fares paid. Whilst bus fares varied by Region rail fares did not because we could not secure satisfactory rail receipts data by region. A national average was used for rail.

We pro-rated bus travel within the Region to each of the cases in proportion to the amount of travel by car. Since we already had an estimate for the number of bus kilometres by case this implied an average load per bus by case. These loads were assumed constant: so a change in bus patronage was assumed to be matched by a proportionate change in bus vehicle kilometre and that would lead to a corresponding change in bus operating costs. This is plainly unrealistic at a fine level of detail, but it may be reasonable “on average”. If there is any bias in this method it will tend to overestimate bus operating costs slightly.

For rail we were unable to determine a defensible assumption on how rail costs might vary with rail traffic. We therefore assumed that train services and hence train costs would be unchanged throughout, changes in patronage being accommodated by changes in average train loadings. In cases where rail demand falls this may be realistic. In cases where it rises then it is unrealistic because the railway is already at or near full capacity in many cases (for instance, in the London commuter market). Any bias in this method will tend to underestimate changes in rail operating costs - so to some extent counterbalancing the overestimation of bus operating costs.

Elasticities of demand for travel

Own and cross price elasticities of demand

The elasticity of demand for mode *i* with respect to the price of that mode is

$$\eta_{ii} = \frac{\partial x_i}{\partial p_i}\frac{p_i}{x_i}. \qquad (2)$$

where x_i is the demand for mode *i* measured in passenger kilometres and *p* is the money cost or fare.

The cross-price elasticity between modes *i* and *j* is

$$\eta_{ij} = \frac{\partial x_i}{\partial p_j}\frac{p_j}{x_i}. \qquad (3)$$

At the national level we have information available that allows us to evaluate the magnitude of these elasticities for the modes under consideration (rail, bus, car, and underground).

National elasticity values

The elasticity values we have used at the national level are shown in Table 4.10 together with their sources.

Elasticity	*value*	*source*
Car traffic with respect to fuel price	-0.310	Graham & Glaister (2002b)
Bus (passenger kms) with respect to bus fare	-0.900	Dargay & Hanly (1999)
Rail (passenger kms) with respect to rail fare	-1.000	ATOC (2001)
Freight traffic with respect to fuel price		Graham & Glaister (2002b)
Bus (passenger kms) with respect to fuel price	0.035	Calculated
Rail (passenger kms) with respect to fuel price	0.112	Calculated
Traffic (car km) with respect to bus fare	0.005	Calculated
Traffic (car km) with respect to rail fare	0.016	Calculated
Bus (passenger kms) with respect to rail fare	0.340	Grayling & Glaister (2000)
Rail (passenger kms) with respect to bus fare	0.918	Grayling & Glaister (2000)

Table 4.10. Elasticity values used in the model.

Variation in car travel elasticity values by journey purpose

The values of the car travel elasticities are allowed to vary by Journey purpose (i.e. home based work, home based employers business, home based essential other, home based discretionary other, non-home based work / employers business, and non home based discretionary other). de Jong and Gunn (2002) provide evidence based on an extensive literature survey of how road traffic price elasticities vary by broadly compatible trip purposes. The aggregate elasticity of road traffic with respect to fuel price is actually a weighted average of the trip purpose elasticities, where the weights are given by the relative share of each trip purpose in total car kilometres. We have taken the trip purpose elasticities given by de Jong and Gunn (2002) but scaled according to our own figures on the share of each trip purpose in total travel. Table 4.11 shows the car own-price elasticities

HBW	HBEB	HBEO	HBDO	NHBWEB	NHBDO
-0.25	-0.22	-0.43	-0.31	-0.28	-0.31

Table 4.11. Own price elasticities of demand for cars

Calculating local own and cross price elasticities

Below we set out a simple framework that allows us to make inference about the likely magnitude of local elasticities, given national values and local mode shares.

Due to symmetry of the compensated cross partial derivatives, for modes *i* and *j* we have the following relationship at the national (*N*) level

$$\frac{\partial x_i^N}{\partial p_j} = \frac{\partial x_j^N}{\partial p_i}. \tag{4}$$

If consumers behave everywhere in the same way then we can assume that the following relationships hold

$$\frac{1}{x^N}\frac{\partial x_i^N}{\partial p_j} = \frac{1}{x^N}\frac{\partial x_j^N}{\partial p_i} = \frac{1}{x^L}\frac{\partial x_i^L}{\partial p_j} = \frac{1}{x^L}\frac{\partial x_j^L}{\partial p_i}, \tag{5}$$

where *x* is the demand for all modes and the superscript *L* refers to local demand.

Prices are assumed to be constant across space. Therefore if η_{ij} denotes the price elasticity of *i* with respect to *j*

$$\eta_{ij}^N \frac{x_i^N}{x^N}\frac{1}{p_j} = \eta_{ji}^N \frac{x_j^N}{x^N}\frac{1}{p_i} = \eta_{ij}^L \frac{x_i^L}{x^L}\frac{1}{p_j} = \eta_{ji}^L \frac{x_j^L}{x^L}\frac{1}{p_i}. \tag{6}$$

Thus,

$$\eta_{ij}^L = \eta_{ij}^N \frac{x_i^N / x^N}{x_i^L / x^L}, \text{ and } \eta_{ji}^L = \eta_{ij}^L \frac{p_i}{p_j}\frac{x_i^L}{x_j^L}. \tag{7}$$

Suppose that there is a single mode of interest, which we will denote by the subscript *o*, then following Acutt and Dodgson (1996) we propose identities that relate the own price elasticity of that mode to the cross-price elasticities of other modes

$$\eta_{io}^N = \eta_{oo}^N \frac{x_o^N}{x_i^N}\cdot\frac{dx_i^N}{dx_o^N}, \tag{8}$$

and

$$\eta_{jo}^{N}=\eta_{oo}^{N}\frac{x_{o}^{N}}{x_{j}^{N}}\cdot\frac{dx_{j}^{N}}{dx_{o}^{N}}. \tag{9}$$

Note that the terms dx_i^N / dx_o^N and dx_j^N / dx_o^N, referred to by Acutt and Dodgson as the 'diversion factors', measure respectively the amount of mode *i* or *j* passengers who divert to or from mode *o* when the price of travel on mode *i* or *j* changes.

Since we must constrain the above relationships to keep η_{oo}^N the same in both (8) and (9), then

$$\eta_{oo}^{N}=\eta_{jo}^{N}\frac{x_{j}^{N}}{x_{o}^{N}}\cdot\left(\frac{dx_{j}^{N}}{dx_{o}^{N}}\right)^{-1}, \tag{10}$$

and substituting (10) into (8)

$$\eta_{io}^{N}=\eta_{jo}^{N}\frac{x_{j}^{N}}{x_{o}^{N}}\cdot\left(\frac{dx_{j}^{N}}{dx_{o}^{N}}\right)^{-1}\frac{x_{o}^{N}}{x_{i}^{N}}\cdot\frac{dx_{i}^{N}}{dx_{o}^{N}}. \tag{11}$$

Thus, the necessary condition for the consistency of (8) and (9) is

$$\frac{dx_{i}^{N}\big/dx_{o}^{N}}{dx_{j}^{N}\big/dx_{o}^{N}}=\frac{\eta_{io}^{N}}{\eta_{jo}^{N}}\frac{x_{i}^{N}}{x_{j}^{N}}. \tag{12}$$

At the national level we have information on cross and own-price elasticities for each mode and we can therefore use equations (8) and (9) to evaluate the diversion factors. We do not, however, have such rich information at the local level.

In establishing local relationships we proceed in the following way. We assume that the relationship (8) holds at the local level. We further hypothesise that diversion factors are proportionate to mode share such that

$$\frac{dx_{i}}{dx_{o}}=\alpha_{o}\eta_{io}\frac{x_{i}}{x}\text{ and }\frac{dx_{j}}{dx_{o}}=\alpha_{o}\eta_{jo}\frac{x_{j}}{x} \tag{13}$$

where α_o is a constant of proportionality.

Thus, at the national level we have the identity

$$\eta_{io}^{N} = \eta_{oo}^{N} \frac{x_o^N}{x_i^N} \cdot \left(\alpha_o \eta_{io}^{N} \frac{x_i^N}{x^N} \right). \tag{14}$$

Therefore,

$$\alpha_o = \frac{x^N}{x_o^N} \cdot \frac{1}{\eta_{oo}^{N}} \ . \tag{15}$$

At the local level

$$\eta_{io}^{L} = \eta_{oo}^{L} \frac{x_o^L}{x_i^L} \cdot \left(\alpha_o \eta_{io}^{L} \frac{x_i^L}{x^L} \right) , \tag{16}$$

and substituting (15) into (16)

$$1 = \eta_{oo}^{L} \frac{x_o^L}{x^L} \cdot \frac{x^N}{x_o^N} \cdot \frac{1}{\eta_{oo}^{N}} . \tag{17}$$

Therefore, the local own price elasticities of mode *o* can be expressed as

$$\eta_{oo}^{L} = \eta_{oo}^{N} \cdot \left(\frac{x_o^N / x^N}{x_o^L / x^L} \right). \tag{18}$$

Values of time

Perceived values of working, commuting and leisure time for 2002 were taken from TAG 3.5.6[108] Tables 1 and 2. Using real growth factors from Table 3 and the GDP inflator these were converted into the 2010 values at 2005 prices shown in Table 4.12.

[108] See www.webtag.org.uk

HBW	HBEB	HBEO	HBDO	NHBWEB	NHBO	LGV	Rigid	Artic	PSV pax	PSV driver	RAIL pax
6.3	28.5	5.6	5.6	28.5	5.6	11.0	11.0	11.0	6.3	11.0	11.6

Table 4.12. Values of time per occupant, 2010, (£/hour, 2005 prices)

Two transformations were applied to these values of time. First they were made to deviate from the central values Region-by-Region, *pro rata* with deviations from the national average of Regional GDP per head in 2005: shown in Table 4.13.

	Ave	E Ang	E Mids	London	NE	NW	SE	SW	W Mids	Yorks & Humber.	Scot-land	Wales
GDP (£)	19.7	21.7	19.0	22.3	17.3	18.7	22.9	20.7	18.7	18.6	18.8	18.5
Propor-tion of average	1	1.10	0.96	1.13	0.88	0.95	1.16	1.05	0.95	0.94	0.95	0.94

Table 4.13. GDP per capita by Region, 2005

Then the regional values of time were increased in proportion to expected real income growth in the respective Region between 2010 and 2041, as shown in Table 4.14.

E Anglia	E Mids.	London	NE	NW	SE	SW	W Mids	Yorks & Humber.	Scotland	Wales
137	125	161	110	116	138	130	115	119	113	118

Table 4.14. Real income growth by Region, 2010 – 2041 (%)

For evaluation purposes value of time savings were expressed at market prices. Work-related savings were scaled by 1.21 (see TAG Unit 3.5.4, Section 3 and TAG Unit 3.5.6 paragraph 1.1.8).

Vehicle Operating Costs

The Transport Analysis and Guidance (TAG Unit 3.5.6, Department for Transport, October 2006) separates vehicle operating costs (VOCs) into fuel VOCs and non-fuel VOCs.

Fuel VOCs

Fuel consumption is estimated using a cubic function

$$L = a + bv + cv^2 + dv^3$$

where L is fuel consumption (litres / km), v is the average link speed (km / hr), and a, b, and c are parameters defined for each vehicle category.

Non-fuel VOCs

The non-fuel elements of VOCs are expressed by the formula

$$C = a^1 + b^1 / v,$$

where C is the cost in pence per kilometre travelled, a^1 is the parameter for distance related costs, and b^1 is the parameter for vehicle capital saving.

The elements making up non-fuel VOCs include oil, tyres, maintenance, insurance, depreciation, and vehicle capital savings (only for vehicles in work time).

We used the 2002 vehicle operating cost parameter values specified in TAG Unit 3.5.6 for "average" vehicles, which, amongst other things averages between petrol and diesel vehicles.

Table 4.15 shows our assumption of the reduction in fuel used per vehicle km between 2002 and 2041.

Car	Light goods vehicle	Rigid goods vehicle	Articulated goods vehicle	Public service vehicle
14	14	14	14	8

Table 4.15. Reduction in fuel used per vehicle km. 2002 to 2041 (%)

For comparison Table 4.16 shows the efficiency gains implicit in Table 13 of TAG Unit 3.5.6 for 2002 – 2020 (a period twenty one years shorter).

Average car	Average Light goods vehicle	Other GV2	Public service vehicle
23	10	6	0

Table 4.16. TAG Unit 3.5.6. Reduction in fuel used per vehicle km. 2002 to 2020 (%)

For the average car part of the improvement in fuel consumption will come from a switch from petrol to diesel engines.

Vehicle Occupancy and passenger car units

Vehicle occupancies were taken from TAG Unit 3.5.6 which shows estimates for 2010. We assumed no change between 2010 and the 2041 base, although the TAG expects there to be some reductions between 2000 and 2010.

HBW	HBEB	HBEO	HBDO	NHBWEB	NHBO	LGV	Rigid	Artic	PSV pax
1.13	1.19	1.80	1.80	1.13	1.80	1.25	1	1	12.2

Table 4.17. Vehicle occupancy, 2010.

The traffic weight of different vehicle types (measured as Passenger Car Units) was also taken from TAG. unit 3.5.6 and are shown in Table 4.18.

HBW	HBEB	HBEO	HBDO	NHBWEB	NHBO	LGV	Rigid	Artic	PSV
1	1	1	1	1	1	1	1.9	2.9	2.5

Table 4.18. Passenger car unit equivalence

Bus and Rail demand.

For predictions of bus and rail passenger base demand in 2041 we took the growth specified in TEMPRO Version 5.3. However, we felt that these were generally likely to understate the growth, so we added an extra ten percent in most cases. In the case of Rail in London we replaced the TEMPRO 11% growth with a 30% growth on the basis of recent work on London (see Transport for London, *London 2025*, 2006). Further, in no Region did we allow bus travel to fall by more than 10% and we did not allow rail travel to fall at all. Table 4.19 displays the growths we used.

	E Anglia	E Mids.	London	NE	NW	SE	SW	W Mids.	Yorks & Humber.	Scotland	Wales
Bus	16.2	4	14.7	-10	-3	12.4	11.5	-1	-1	-10	-2
Rail	19.1	12.8	30.0	0	5.7	17.5	18	8.2	7.9	0	6.9

Table 4.19. Growth in Bus and Rail travel by Region, 2010 – 2041 (%)

Environmental costs

The costs that are to be imputed to environmental damages such as accident risk caused to others, air pollution and climate change are uncertain but they are important determinants of the transport pricing policies discussed in this study. We rely on the comprehensive study of road and rail transport costs in Britain by Sansom *et al* (2001) of the University of Leeds, summarised in Table 4.20.

Cost or revenue category	Marginal cost	
	low	high
Costs:		
External accident costs	0.82	1.40
Air pollution	0.34	1.70
Noise	0.02	0.05

Table 4.20. Comparison of 1998 road sector costs and revenues (pence per vehicle km), Great Britain, 1998 prices and values.

To incorporate the main factors underlying variation in cost the authors disaggregated their analysis by location of travel, road or rail infrastructure type, vehicle or train type, and the time period of travel.

The disaggregations for the road framework are:

- 11 area types (3 for London, 2 for conurbations, 5 other urban, rural)
- 3 road types (motorway, trunk and principal, other)
- 5 vehicle types (car, light good vehicles, rigid heavy good vehicles, articulated heavy good vehicles and public service vehicles)
- 2 time periods (weekday peaks from 0700-1000 and 1600-1900 and other times)

We took the high marginal cost values, converted them to 2005 prices and then, in order to obtain 2041 values, we scaled them in proportion to average real income growth.

In doing this we erred throughout on the side of overestimation of the environmental costs: we took “high” rather than “low” or average values. We assumed a direct proportionality with income. We neglected the virtual certainty that accident rates, noise and emissions performances of vehicles will continue to improve in the future. (But note that fuel efficiency improvements are taken into account in the vehicle operating formulae although overall we were more conservative on this account than the guidance given in TAG).

Fuel prices

As noted elsewhere we used a set of car vehicle km. growth numbers, by Region which for the national total cumulates to 47% growth from 2000. These are lower than some of the forecasts. Note that this is the *demand* growth, unconstrained by any network capacity issues—as the model estimates, *actual* traffic growth is much less in congested areas.

This was consistent with an assumed increase of 79% in pump cost of fuel to the user net of vehicle efficiency gains on a 2005 price of £0.80 per litre. We therefore used a price of fuel of £1.55 per litre gross of efficiency gains in 2041.

This is a reflection of strong growth in demand and increasing costs of extraction and or synthesis.

Cost of carbon and carbon taxes

In this section we consider what would have to be included in motor fuel prices to reflect a particular level of carbon taxation.

In 2004 road transport in Britain emitted 32.5m tonnes of carbon (TSGB 2006 table 3.8). This is at source; it is assumed that upstream emissions will be taxed at each stage in the production/distribution process. In doing this it produced 498.6bn vehicle kilometres (TSGB 2006 table 7.1) and consumed 43.3m tonnes of petroleum spirit (Digest of UK Energy Statistics tables 3.8 & 3.9). This means that, on average, each vkm produces 65gms of carbon so, for every £1 per tonne carbon tax, a charge of 0.0065p per vkm should be charged.

The Stern Report (2006) suggests a price for carbon dioxide at $85 per tonne. We translated this into £190 per tonne of *carbon* at 2005 prices. At £190 per tonne the tax should be 1.235p per vkm and, taking cars with an average fuel consumption of 8.7 litres per 100 kilometres (TSGB 2006 table 3.4), this would have to be 14.2p per litre.

Alternatively, the sales of road fuels in 2004 was 49 billion litres (UK PIA Statistical Review 2005 figure 3.2). If the 32.5m tonnes of carbon are related to this, each litre of road fuel (a combination of petrol and derv) produces 663 grams of carbon. So for each £1 per tonne tax the levy would be 0.0663p. At £190 per tonne this comes to 12.6p per litre. We settled on a carbon tax of £0.14 (plus VAT) per litre of fuel.

In the efficient pricing scenarios we assumed that fuel duty would be removed, though the carbon tax component would remain.

As noted, we assumed an increase in the price of fuel at the pump from £0.80 per litre in 2010 to £1.55 in 2041 (at 2005 prices). We sub-divided this into an increase in the wholesale price from £0.21 to £0.71 and an increase in fuel duty and VAT from £0.59 to £0.84 per litre. The future price of oil and future policy on fuel duty are plainly uncertain and alternative views could have been taken. The particular assumption we have used embodies a more than threefold increase in wholesale fuel prices—perhaps reflecting a significant tightening of world oil markets—mitigated to an extent by a less rapid increase in fuel duty.

Had we assumed a constant pump price of fuel in real terms then our traffic forecasts and congestion levels for 2041 would have been higher, and therefore the congestion benefits of road pricing and additional capacity would have been higher. To an extent, the increase in the pump price of fuel that we have assumed reduces (but does not remove) the need for road pricing to mitigate congestion in the busiest circumstances. This phenomenon is reinforced by the fact that we have "priced in" high environmental charges which themselves fulfil some of the function of pure congestion charges – so benefits are attributed to environmental gains rather than to decongestion.

Table 4.21 summarises our assumed components of the price per litre of fuel to the user in the 2010 base and the 2041 base with and without efficient pricing. It also shows the corresponding yields calculated from our model

	2010 Base	2041 no pricing	2041 pricing
Fuel price ex VAT, ex Duty	0.211	0.711	0.711
Duty ex vat	0.47	0.608	-
Carbon tax	-	-	0.14
Sub total	0.681	1.319	0.851
VAT @ 17.5 %	0.119	0.231	0.149
Price to end user	0.80	1.55	1.00

Table 4.21. Fuel price, duty and VAT (£ per litre)

One implication of our fuel tax and price assumptions is that the spend by road users on fuel increases from about £34 bn in 2010 to about £85 bn in 2041 and the duty and VAT component of this would rise from about £24 bn to about £43 bn a year. (These figures include an allowance—see below—for reclaim of VAT by commercial users.) In all our scenarios the additional expenditure on new road capacity is much less than this increase in Exchequer tax revenues.

An alternative to our approach would have been to assume an unchanged oil price and tax regime. Then similar forecasts of traffic demand to those we have used could only have been the result of assuming a weakening of the relationship between real income growth and traffic demand. Such a weakening does appear to be a feature of the forecasts employed by the Department for Transport. In these circumstances the benefits of road pricing would be higher because the initial fuel price base would have been lower. The full range of effects would be complex and it would require remodelling to investigate the detail.

	2010 Base	2041 no pricing, base capacity	2041 pricing, base capacity
Fuel ex VAT, ex Duty	9.18	41.57	35.29
Duty ex vat	21.1	35.0	-
Carbon tax	-	-	7.0
Sub total	30.29	76.57	42.29
VAT @ 17.5 % of which 63% non recoverable	3.34	8.44	4.66
Duty + Carbon + VAT	24.44	43.44	11.66
Spend by end-user	33.62	85.01	46.95
Traffic (PCU km)	632	819	703

Table 4.22. Spend on fuel, duty, carbon tax and VAT (excluding PSV) (£ bn pa)

Recovery of VAT on road transport fuels

The final price of fuel at the pump includes the standard 17.5 percent VAT. However, some users can reclaim VAT so it is not part of the cost to them. We made an approximate allowance for this when calculating the net effect on taxes paid by road users and received by the Exchequer. (However, we did not allow for this in modelling behaviour and this is an inconsistency.)

Type of Transport	Petrol	Derv
Cars & taxis	17.91	4.27
Vans	0.50	4.77
Motorcycles	0.13	-
Goods Vehicles	-	9.22
Buses	-	1.18
All	18.54	19.44

Table 4.23. Road Transport Fuel consumption 2005 (m tonnes)

Source: TSGB table 3.1

VAT paid on road transport fuels in 2005/06 amounted to £6.1bn[109]. Road transport fuel consumption in 2005 was as shown in Table 4.23.

Almost all commercial vehicles (lorries, vans and a high proportion of taxis) are fuelled by diesel engines, but most cars are fuelled by petrol. Most of the diesel fuel used by public transport is not subject to VAT so not all the 19.44m tonnes should be included in splitting the £6.6bn between petrol and diesel. Weighting the total of 19.44m tonnes by distance travelled and fuel consumption rates gives an estimate of 5% of DERV used by buses and coaches.

The price of diesel is higher then that of petrol so VAT paid per unit of fuel will be higher. In 2005 diesel cost approximately 2% more then petrol[110]. Applying these factors to the total of £6.6bn, £3.08bn was paid on diesel and £3.02bn on petrol.

In 2005 there were 26.208m private cars of which 5.399m were diesel and 20.762m petrol (only 21 thousand were powered by other means such as LPG or bio fuels).[111]

Of these 'private' cars a proportion are provided by companies for their employees. In 2005 the proportion of cars which were company cars was 8.84%[112]. The proportion of cars that are company cars has been declining in recent years because of increasing tax liabilities. It is also probable that the proportion of company cars that are diesel powered has been increasing, partly because of the greater fuel efficiency, partly because of the tax rules and also because of improvements of diesel car performance.

In 2005 company cars averaged 31,360 kms compared with 14,450 for private cars and 20,965 kms for self employed business users' cars[113]. Travel by the 533k bus and goods vehicles is likely to be all 'commercial' and 99%+ of this is diesel powered. 38% of travel by the 2,434k company cars is on business – about 29bn vkms a year of which say 40%[114] is diesel. About a third of van travel is for journeys to and from work or on personal business[115]

We estimate that company car travel on business is 29bn vkms out of a total of 76.3bn vkms – say 11.6bn diesel miles and 17.4bn petrol miles.

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[109] UK Petroleum Industries Association Statistical Review 2006, figure 1.2.
[110] Petrol Prices 1896 to Present AA Motoring Trust.
[111] TSGB 2006, table 9.4.
[112] Vehicles Licensed 2006 table1.
[113] TSGB 2006, table 9.17.
[114]Twice the car fleet average.

We estimate that of the 62.6bn vkms of light van traffic in 2005, 42bn are on business making say 38bn diesel vkms and 4bn petrol vkms. Buses and coaches made 5.2bn vkms practically all of which were diesel and goods vehicles made 29.0bn vkms[116] practically all of which were diesel.

We start by assuming all VAT of diesel is recoverable and that VAT on petrol is not and then correct for non recoverable VAT on DERV and recoverable VAT on petrol.

Diesel VAT (£3.08bn). Non recoverable VAT:

- Buses: none
- Goods Vehicles: assume that virtually all use is in the course of business, or at least claimed as such, therefore none.
- Vans: the one third of travel on commuting and personal business (21bn vkms)
- Company Cars: 21% of cars are diesel powered and these are likely to be higher mileage vehicles therefore it assumed that 30% of car mileage is powered by diesel. Assuming a higher than average proportion of these to be company cars the number of diesel company cars would be 1m out of a total in 2005 of 2.434m. Non business travel by these cars would therefore amount to 20bn vkms a year.
- Private Cars: of the 26,208m private cars 5.399m were diesel. Business mileage was 1,160 kms year leaving 12,274 kms per car for other purposes. This amounts to 66.27bn non business private car kms.
- Taxis: it is assumed that all mileage is, or is claimed to be, VAT recoverable.

Using average fuel consumption figures of 13 kms/litre for cars and 10 kms/litre for vans this none eligible mileage would consume 8.73bn litres a year (2.1bn for vans, 1.53bn for company cars and 5.1bn for private cars). At 75p/litre (ex VAT) this comes to £6.55bn and VAT amounts to £1.146bn.

On this basis recoverable VAT on diesel fuel would be £1,934m a year. However not all enterprises are VAT registered and therefore are not able to recover VAT. The amount of VAT paid by unregistered enterprises is not known but we assume this to be a nominal 3%[117] as most diesel fuel is used by goods vehicles and their operators will almost all be VAT registered. On this basis recoverable VAT on diesel fuel in 2005/06 is estimated to be £1.88bn.

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[115] Survey of Van Activity 2004 table 1 & Private Van Survey September 2002 to October 2003 table 2.
116 Traffic by vehicle type from Road Traffic Statistics 2005, table 1.1.
117 6% of employees in Scotland are in non VAT registered companies, Scottish Economic Statistics 2006, table 2.A.

Petrol VAT (£3.02bn). Recoverable VAT:

- Buses: virtually none
- Vans: about two thirds of the 6bn vkms of petrol driven use – 4bn vkms
- Goods vehicles: virtually none
- Company Cars: the 1.434m company cars are estimated to travel 11, 900 kms each a year on business totalling 17bn vkms
- Private Cars: the 30.36bn vkms of business travel by private cars includes 24.3bn vkms by petrol engined vehicles.

Using average fuel consumption figures of 13 kms/litre for cars and 10 kms/litre for vans this eligible mileage would consume 3.05bn litres a year (0.4bn for vans, 1.31bn for company cars and 2.34 for private cars). At 75p/litre (ex VAT) this comes to £2.288bn and VAT amounts to £400m. Again not all of this is incurred by VAT registered enterprises and we assume that 6% is not recovered as a result of this, leaving £376m.

On this basis, out of a total of £6,100m VAT on road transport fuel in 2006/06 £2,256m would be recoverable. We adopted this average rate of recovery throughout.

The costs of implementing national road pricing

The merits of transport policies are determined by the balance between the streams of their benefits and their costs. Therefore we needed estimates of the likely costs of the introduction and operation of a national electronic road pricing scheme

The costs of a direct charging scheme will depend on a range of factors but particularly its scale and the technology used. The London Congestion Charging Scheme has annual operating costs of £90m a year[118] and the set up costs were roundly £200m[119.] However this was a pioneering scheme using an obsolescent Automatic Number Plate Recognition (ANPR) for vehicle identification and these costs are unlikely to be typical of a national scheme.

It would appear that a national scheme may use some form of satellite based system with vehicles identified and automatically billed or with some form of stored credit depletion. Either of these would require an on-board electronic device for identification and/or charge

[118] Transport for London (2006) table 9.2.
[119] Transport for London (2002).

transaction. In the feasibility carried out by then Department of Transport (DfT) in 2004 the capital cost of equipping vehicles was suggested as about £3bn and the operating costs were thought to be perhaps between £2n and £3bn a year – or £5bn with optimism bias.

A more detailed investigation of potential costs was carried out as part the DfT study by Deloitte and this provided a range of costs for alternative road pricing scenarios and this produced the results in Table 4.24.

	Set up Costs	Average Annual Running Costs
Low	£10.2bn	
Medium	£16.2bn	£2bn - £2.7bn
High	£26.9bn	

Table 4.24. Deloitte Estimate of Charging System Costs (2010 traffic levels and 2004 prices excluding optimism bias).
Source: Deloitte (2004) section B tables 4.1 & 5.11.

This appears to be the most careful assessment to date of the costs of a national road pricing scheme so provides the best base for estimating the cost of the pricing proposals in the study. The table applies to 2010 and so is suitable to be used directly for the 2010 scenario with a small adjustment for prices to bring them up to 2005-06 levels as shown in Table 4.25.

	Set up Costs	Average Annual Running Costs
Low	£10.7bn	
Medium	£16.9bn	£2.1bn - £2.8bn
High	£28.1bn	

Table 4.25. Estimate of Charging System Costs (2010 traffic levels and 2005-06 prices excluding optimism bias).
Source: As Table 4.24 & National Statistics (2007a) table CZBH.

The vehicle population will have grown by 2041 and so will the numbers of on board units and transactions. The latter will vary according to which scenario is taken but, for the sake of simplicity we take that with efficient pricing with some road expansion. In this the amount of traffic increases by about 16% over the 2010 base. The on vehicle component of capital costs appears to be small (About £3bn in the DfT report) so the set up costs are not likely to be that much greater than for the 2010 vehicle parc – say a medium value of £18bn. If the operating costs vary by 50% of the amount of traffic then these would come to a median figure of £2.65bn.

We took £4.5 bn as our estimate of the annual costs of a national road pricing scheme in 2041, including an element for capital costs. It is possible, given the pace of innovation in the relevant technologies, that actual costs could be significantly less.

The costs of constructing and maintaining additional road capacity.

Road Type	London	Lkm - new	Lkm - widened
1	Motorway	270	550
2	N/A	-	-
3	N/A	-	-
4	Trunk A	200	330
5	Principal A	200	330
6	B and C Roads	120	200
7	Unclassified	-	-

Table 4.26. Annualised Costs (£000s per Lane Kilometre) of Additional Capacity in London
Source: Based on Archer & Glaister (2006) Table 20.

The source for these estimates is the work done by Archer and Glaister (2006). In order to allow direct comparisons with benefits, costs are presented as annual costs including both capital (discounted at 3½% over 100 years) and revenue charges. The costs are presented by the road types used in the main analysis and uplifted to 2005-06 price levels.

Road Type	**Provincial Conurbations**	**Lkm – new**	**Lkm - widened**
1	Motorway	220	300
2	N/A	-	-
3	N/A	-	-
4	Trunk A	100	250
5	Principal A	100	150
6	B and C Roads	70	140
7	Unclassified	-	-

Table 4.27. Annualised Costs (£000s per Lane Kilometre) of Additional Capacity in Provincial Conurbations.
Source: Based on Archer & Glaister (2006) Table 20.

Road Type	**Urban**	**Lkm – new**	**Lkm - widened**
1	Motorway	170	230
2	N/A	-	-
3	N/A	-	-
4	Trunk A	80	200
5	Principal A	80	120
6	B and C Roads	50	100
7	Unclassified	-	-

Table 4.28. Annualised Costs (£000s per Lane Kilometre) of Additional Capacity in Urban Areas.
Source: Based on Archer & Glaister (2006) Table 20.

The Highways Agency (HA) have provided relative cost data for some of their (rural) projects and this shows some differences from the Archer and Glaister estimates. The differences in construction and land costs are approximated as percentages in brackets in Table 4.29. This suggest that the cost for Motorways and trunk dual carriageways should be reduced but by how much depends on the weight of construction and land costs in the annualised figure.

Road Type	Rural	Lkm - new	Lkm - widened
1	Motorway	85 (-60%)	150
2	Trunk Dual A	60 (-60%)	150
3	Principal Dual A	60	150
4	Trunk Single A	70 (+20%)	150
5	Principal Single A	60	130
6	B Roads	60	130
7	C & Unclassified	-	-

Table 4.29. Annualised Costs (£000s per Lane Kilometre) of Additional Capacity in Rural Areas.
Source: Based on Archer & Glaister (2006) Table 19.

The HA data do not extend to urban areas but a rule of thumb of 3 times is suggested for the higher costs of urban schemes. Making allowance for the differences between the HA and the Archer and Glaister rates for rural roads the factor of three seems to fit reasonably well with the urban rates in Archer and Glaister estimates.

One factor in Eddington's analysis is the capital costs of roads which are taken as £8.1 m/lane km (whole life costs - which we assume capitalises streams of costs such as maintenance and policing) but he appears to round these up to £10m including an allowance for landscape costs. This would give a cost of £60m per km for a D3 Motorway - which seems on the high side.

Road Type		
1	Motorway	0.688
2	Trunk Dual A	0.375
3	Principal Dual A	0.313
4	Trunk Single A	0.250
5	Principal Single A	0.150
6	B Roads	0.188
7	C & Unclassified	0.163

Table 4.30. Annualised capital and maintenance costs of various road types (£m pa per lane km)

Table 4.30 displays the costs per lane km that we used throughout.

So as not to understate annual road capital and maintenance costs we took (the higher) widening costs in all cases. We added a margin of 25% partly to bring the costs to market prices and partly to make some allowance for increasing real maintenance costs in the future.

We did not vary unit costs by region.

Road capacity scenarios

The scenarios test increases in capacity with and without a national efficient pricing scheme. The base scenario includes the Eddington Study estimate of strategic road building 2003-2015 (totalling an extra 1,594 lane kilometres in England) which equates to the Highways Agency's Targeted Programme of Investment projected forward.

The main road capacities used in the different model runs drew on the work done for the Eddington Study. Table 4.31 shows the 2003 and capacity expected to be added by 2015.

		2003 Network*	Additional lane km 2003 - 2015**	2015 Network	2010 Base Network
Outer London	Motorway	367	52	419	397
Outer conurbations	Motorway	3,272	179	3,451	3,376
	Trunk	1,105	39	1,144	1,128
Other Urban	Trunk	2,928	61	2,989	2,963
	Principal	16,749	3	16,752	16,751
Inter-urban rural	Motorway	13.059	442	13,501	13,317
	Trunk	12,251	768	13,019	12,699
	Principal	33,197	50	33,247	33,226
Total		82,928	1,594	84,522	83,857

* Based on Eddington table 4.1, column 5.

** Based on Eddington table 4.1, column 3

Table 4.31. Eddington Baseline Scenario & Corresponding 2010 Base

Source: Eddington DfT supporting paper p.72

We modelled the 2041 base and five scenarios with increased capacities. The increases corresponded roughly to annual increases for 31 years up to 2041 of 90, 200, 400, 600 and 800 lane km:

0 Lane km p.a. – without pricing is the 2041 base scenario

90 Lane km p.a.

200 Lane km p.a.

400 Lane km p.a. – similar to the Eddington "without pricing" scenario

600 Lane km p.a.

800 Lane km p.a.

The 400 Lkmpa and 600 Lkmpa scenarios are *pro rata* increases in capacity by road type and region on the 200 Lkmpa scenario, but in the 800 Lkmpa scenario the extra 200 Lkmpa is applied to East Midlands, East of England, London, South East and South West regions only. The scenarios are marked by diamonds in the graphs in Figures 4.6 to 4.12 below.

Increases in strategic road[120] capacity (measured in lane kilometres) are allocated approximately 60% to motorways and 40% to Trunk A roads with a 30:70 split between conurbations[121] and other areas[122.] However, there are considerable variations between regions and for conurbations. Like Eddington, it is assumed that there would be a programme to increase the capacity of junctions commensurate the increase in link capacity. All scenarios assume no significant change to the non-strategic road network.

For the efficient pricing scenarios, we applied a national charging scheme where the price of using roads is set at a rate that reflects the "marginal cost to society" of the trip[123.] There is a rate per vehicle kilometre for the cost of maintaining the roads and for environmental and safety impacts which vary by vehicle type, road type and the degree of urbanisation; and a rate for congestion depending on traffic conditions, by time of day and day of the week, to reflect the additional delay imposed on other road users and carbon emissions.

Table 32 displays the lengths of the main types of road in the 2041 base and the percentage increase under each scenario.

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[120] I.e. the trunk road network in 2003.

[121] Conurbations comprise London, West Midlands, Greater Manchester, Merseyside, West Yorkshire, South Yorkshire, Tyne & Wear and Glasgow.

[122] This compares with the Eddington Study's ratios of 74:26 motorway:trunk; and 25:75 conurbation:other.

[123] Maximum charges are capped in such a way that no vehicle would ever pay more than four times its total cash outgoings in the uncharged 2041 base.

All regions	2041 Base Lane Km	P90 % increase	P200 % increase	P400 % increase	P600 % increase	P800 % increase
Outer London Motorway	516	6.2	12.4	24.8	37.2	50.8
Conurbations Motorway	3,471	3.8	17.0	33.9	50.5	50.5
Conurbations Trunk	2,876	34.1	39.8	79.5	119.2	126.4
Urban Trunk	5,462	0.9	2.2	4.3	6.1	12.1
Urban Principal	20,836					5.9
Rural Motorway	16,536	9.6	18.8	37.6	56.4	64.6
Rural Trunk	25,223	0.2	5.0	10.0	15.0	19.6
Rural Principal	46,780		0.2	0.3	0.5	4.7
All Lane Kilometres	121,699	2.3	5.2	10.4	15.6	20.9
East England						
Outer London Motorway	0					
Conurbations Motorway	0					
Conurbations Trunk	0					
Urban Trunk	798	0.9	2.2	4.3	6.1	16.6
Urban Principal	2,865					9.9
Rural Motorway	1,603	9.6	18.8	37.6	56.4	71.9
Rural Trunk	2,908	0.2	5.0	10.0	15.0	26.4
Rural Principal	3,750		0.2	0.3	0.5	10.4
All Lane Kilometres	11,925	1.4	3.9	7.9	11.8	22.9
East Midlands						
Outer London Motorway	0					
Conurbations Motorway	0					
Conurbations Trunk	0					
Urban Trunk	1,024	0.9	2.2	4.3	6.1	16.6
Urban Principal	1,984					9.9
Rural Motorway	1,178	9.6	18.8	37.6	56.4	71.9
Rural Trunk	2,727	0.2	5.0	10.0	15.0	26.4
Rural Principal	3,954		0.2	0.3	0.5	10.4
All Lane Kilometres	10,867	1.2	3.6	7.1	10.6	21.6
London						
Outer London Motorway	516	6.2	12.4	24.8	37.2	50.8
Conurbations Motorway	0					
Conurbations Trunk	951	34.1	39.8	79.5	119.2	140.9
Urban Trunk	0					
Urban Principal	0					
Rural Motorway	0					
Rural Trunk	0					
Rural Principal	0					
All Lane Kilometres	1,467	24.3	30.2	60.3	90.4	109.2
North East						
Outer London Motorway						
Conurbations Motorway	46	3.8	17.0	33.9	50.5	50.5
Conurbations Trunk	228	34.1	39.8	79.5	119.2	119.2
Urban Trunk	246	0.9	2.2	4.3	6.1	6.1
Urban Principal	1,223					
Rural Motorway	282	9.6	18.8	37.6	56.4	56.4
Rural Trunk	892	0.2	5.0	10.0	15.0	15.0
Rural Principal	1,284		0.2	0.3	0.5	0.5
All Lane Kilometres	4,200	2.6	4.8	9.7	14.5	14.5
North West						
Outer London Motorway	0					
Conurbations Motorway	1,216	3.8	17.0	33.9	50.5	50.5
Conurbations Trunk	419	34.1	39.8	79.5	119.2	119.2
Urban Trunk	443	0.9	2.2	4.3	6.1	6.1
Urban Principal	2,116					
Rural Motorway	2,406	9.6	18.8	37.6	56.4	56.4
Rural Trunk	1,472	0.2	5.0	10.0	15.0	15.0
Rural Principal	2,626		0.2	0.3	0.5	0.5
All Lane Kilometres	10,699	4.0	8.5	17.0	25.5	25.5
South East						
Outer London Motorway	0					
Conurbations Motorway	0					
Conurbations Trunk	0					
Urban Trunk	873	0.9	2.2	4.3	6.1	16.6
Urban Principal	5,431					9.9
Rural Motorway	3,981	9.6	18.8	37.6	56.4	71.9

Rural Trunk	2,109	0.2	5.0	10.0	15.0	26.4
Rural Principal	5,621		0.2	0.3	0.5	10.4
All Lane Kilometres	18,016	2.2	4.9	9.8	14.7	26.0
South West						
Outer London Motorway	0					
Conurbations Motorway	0					
Conurbations Trunk	0					
Urban Trunk	427	0.9	2.2	4.3	6.1	16.6
Urban Principal	2,176					9.9
Rural Motorway	1,988	9.6	18.8	37.6	56.4	71.9
Rural Trunk	2,574	0.2	5.0	10.0	15.0	26.4
Rural Principal	6,572		0.2	0.3	0.5	10.4
All Lane Kilometres	13,736	1.5	3.8	7.6	11.4	22.4
West Midlands						
Outer London Motorway	0					
Conurbations Motorway	350	3.8	17.0	33.9	50.5	50.5
Conurbations Trunk	241	34.1	39.8	79.5	119.2	119.2
Urban Trunk	471	0.9	2.2	4.3	6.1	6.1
Urban Principal	1,536					
Rural Motorway	1,878	9.6	18.8	37.6	56.4	56.4
Rural Trunk	1,797	0.2	5.0	10.0	15.0	15.0
Rural Principal	3,320		0.2	0.3	0.5	0.5
All Lane Kilometres	9,594	3.0	6.4	12.8	19.2	19.2
Yorks & Humber						
Outer London Motorway	0					
Conurbations Motorway	1,422	3.8	17.0	33.9	50.5	50.5
Conurbations Trunk	773	34.1	39.8	79.5	119.2	119.2
Urban Trunk	150	0.9	2.2	4.3	6.1	6.1
Urban Principal	753					
Rural Motorway	703	9.6	18.8	37.6	56.4	56.4
Rural Trunk	1,380	0.2	5.0	10.0	15.0	15.0
Rural Principal	2,111		0.2	0.3	0.5	0.5
All Lane Kilometres	7,292	5.3	10.4	20.7	31.0	31.0
Scotland						
Outer London Motorway	0					
Conurbations Motorway	437	3.8	17.0	33.9	50.5	50.5
Conurbations Trunk	264	34.1	39.8	79.5	119.2	119.2
Urban Trunk	639	0.9	2.2	4.3	6.1	6.1
Urban Principal	1,453					
Rural Motorway	1,656	9.6	18.8	37.6	56.4	56.4
Rural Trunk	5,933	0.2	5.0	10.0	15.0	15.0
Rural Principal	13,013		0.2	0.3	0.5	0.5
All Lane Kilometres	23,393	1.2	3.5	7.0	10.5	10.5
Wales						
Outer London Motorway	0					
Conurbations Motorway	0					
Conurbations Trunk	0					
Urban Trunk	391	0.9	2.2	4.3	6.1	6.1
Urban Principal	1,299					
Rural Motorway	860	9.6	18.8	37.6	56.4	56.4
Rural Trunk	3,431	0.2	5.0	10.0	15.0	15.0
Rural Principal	4,529		0.2	0.3	0.5	0.5
All Lane Kilometres	10,510	0.9	3.3	6.6	9.9	9.9

Table 4.32. Lane km of road in 2041 base by Region, and percentage increments in the scenarios

The base lane lengths displayed in Table 4.32 do not exactly match those recorded in the DfT's FORGE model as summarised in Table 4.33. This is partly because of some minor differences in the classifications of particular road types, but more importantly, because of assumed numbers of lanes in some situations leading to different overall total lane lengths of lanes. We have the same total of road lengths, Region by Region, as in FORGE. In our modelling, traffic in each block of 20 rows (time periods) is always associated with the FORGE road length for that respective block, so the vehicle km are always associated with the appropriate road km. With the exception of the extra 800 Lkmpa scenario we did not increase urban principal roads. We also put very little into Rural Principal roads. The largest absolute increases in lane kms are in Conurbations Trunk, Rural Motorways and Rural Trunk roads where, in each case we have assigned too much road capacity in the base, thus understating the degree of congestion in these cases. On the other hand we do have increase in Conurbations Motorways where we have about 9% too little road capacity in the base. The logic of our evaluation is to ask "if we made the ABSOLUTE additions shown in Table 4.33 to the base lane kms shown in the first column of Table 4.32, what would be the benefits and costs?". Most of our increments (not all) are to roads where we have overstated the volume of road capacity in the base.

	This study (Lane km)	DfT FORGE (Lane km)	Difference (Lane km)	Percentage difference
London Motorway	516	367	149	41%
Conurbation Motorway	3471	3813	-342	-9%
Conurbation Trunk	2876	1417	1459	103%
London + Conurbation Principal	12539	16465	-3926	-24%
Urban Trunk	5462	3780	1682	44%
Urban Principal	20836	19330	1506	8%
Rural Motorway	16536	14973	1563	10%
Rural Trunk	25223	21641	3582	17%
Rural Principal	46780	50345	-3565	-7%
All	134239	132132	2107	2%

Table 4.33. Differences between base lane lengths used in this model and FORGE (lane km)

We also conducted some experiments with scenarios in which we used an iterative algorithm to take new road capacity away progressively from locations where the net revenues (and therefore with efficient pricing, net benefits) were lower and add it where the net benefits were higher in such a way as to keep a constant total budget for new capacity. Whilst the results were instructive they were so draconian as to be impractical: taken literally they would imply putting practically all the new capacity in a relatively small number of places where congestion is most severe. In principle we could have gone a step further and continued this calculation with progressive increases in the total budget for new capacity to the point where the return at the margin, equalised for all places and road types, fell to a common, appropriate "cut off" value, such as a ratio of benefit to cost of 1.3. This would represent a fully optimised strategic road investment programme (within the limitations of our stylised model). We do not report the detailed results of this exercise in this document however it is a line of investigation worth pursuing in any future work on this topic.

Limitations

In considering our results it is important to bear in mind that we have used the best evidence we can find but many assumptions have been necessary. The aim has been to obtain a feel for the overall orders of magnitude of the implications of policy changes.

Our model has no explicit transport network and makes no attempt to represent origin-to-destination trip patterns. It works in terms of flow rates of passenger kilometres or vehicle kilometres over typical roads at a variety of times and places. Therefore we are not able to distinguish between changes in numbers of trips and changes in average trip length – the historically observed responses to changes in costs and prices (the elasticities) are measures of a combination of both phenomena.

The observed responses of traffic to taxes and charges (the elasticities) represent the long term responses. They implicitly represent people's propensity to change their travel patterns, trip lengths etc., including the propensity to change the densities of land use and the relationships between place of work and place of residence. However, we do not consider the part that active land use policies could play in altering traffic volumes and emissions. The land use patterns assumed are implicit in the TEMPRO trip end profiles.

Our representation of long distance trips is less satisfactory than local, short distance trips. However, relatively short distance, complex trips are overwhelmingly the more important. Our model is particularly limited in its capacity to model road or rail freight trip patterns or trip lengths. The other models that we are aware of also have difficulty with freight because the data are poor and the behaviour is complex.

Exemptions and discounts.

Any practical policy would offer exemptions and discounts. The London Congestion Charging scheme has many exemptions including a 90 per cent discount to residents in the charged area. Clearly this would not make sense for a national road pricing scheme. However we have assumed a cap on charges of four times the 'no efficient pricing' money cost to limit the exposure to charges of those who travel extensively in the most congested conditions.

For the purposes of this exercise we assume that no concessions are given except to public service vehicles. Each vehicle is to be charged per kilometre an amount that represents the congestion delay it imposes on other road users plus an estimate of its environmental damage costs at that time and location. We are therefore implicitly assuming that any concessions the authorities wish to give for reasons of general policy are achieved by means other than concessions on road charges. Whatever concessions are proposed in practice will have direct consequences for our conclusions. They will also have administrative implications and require enforcement.

Comparing the modelling process we used with the Eddington Study

Both the Eddington Study and this one, commissioned by the RAC Foundation address the question of the impacts of efficient pricing and future traffic growth on the need for additional capacity in the strategic road network. Both conclude that efficient pricing would bring benefits and that additional capacity is needed. However, we conclude that more capacity is needed than indicated in the Eddington study. This section explores the principal differences in the modelling process which may have contributed to the variations in the levels of road capacity which are justified.

In summary the main differences are:

- **timescales** – 2041 compared with the Eddington medium term perspective to 2025. Amongst other consequences, we have higher values of time and higher traffic levels but the traffic growth profiles are much the same. There is only a 15 year overlap. Consequently, traffic and congestion have had a chance to grow more and so more road build is justified. Once you add in the fact that the value of time is rising over time (and we are using higher values for non-work trips), this time horizon effect is magnified. More congestion, valued more highly, means a stronger economic case for more road capacity. Our analysis looks at a longer period than did Eddington, which raises the questions of where and when the road build should take place;
- **appraisal methodology** – our B:C ratios are expressed in terms of benefit to society as a whole This particularly affects the low estimate of road building justifiable with efficient pricing, as an increase in capacity leads to less congestion and therefore less charge income;
- we have varied **values of time** to reflect differences in regional earnings, whereas DfT/Eddington has national rates for costs and time for all areas. The effect of flat rates is to underestimate the value for money of extra capacity in southern regions;

- the DfT/Eddington appraisal includes **wider economic benefits** whereas our study does not;
- we have used higher **fuel and environmental costs** than DfT/Eddington and
- the DfT/Eddington additional capacity includes only widening or by-passes on existing strategic roads and does not take account of the potential for entirely **new roads**.

Table 4.34 sets out the differences in more detail. The various parameters and procedures are identified, the differences set out and the probable effects on the results of the forecasting and evaluation are described. The table incorporates comments offered by officials in the DfT whom we consulted.

Despite these differences in perspective and assumptions, on many issues we have come to similar conclusions. The effects of efficient pricing on tax income to Government, public transport, environmental impact and climate change are generally of similar orders of magnitude. However, there remains a substantial difference between the two studies in the estimates of the quantum of additional road capacity that can be justified.

Table 4.34. Differences between RAC Foundation and Eddington approaches

	FEATURE	RAC Foundation	EDDINGTON	PROBABLE IMPLICATIONS
1	Price base	2005	2002	RAC Foundation prices are 9% higher than Eddington[124]. But this probably does not affect BCR
2	Growth rate start year, i.e. base year	2010 for the modelling	2003	Limited
3	Speed/flow relationships.	FORGE/DMRB	FORGE/DMRB	None
4	Values of time £ per hour in 2041 for: • occupants for the six types of car journey • CV and PSV drivers • Bus passengers • Regional modifying factors	WebTAG 3.5.6 for national values Regional variations from RF/OEF income per capita forecasts. Growth in line with RF/OEF real income forecast beyond WebTAG horizon. For non-working VoTs growth is not 0.8 of GDP assumption as WebTAG?	WebTAG Growth is therefore in line HMT Budget 2006 forecast GDP growth	Use of regional values of time in the RAC Foundation study means that higher values of time will be found where congestion is highest (e.g. conurbations and London and the SE). This will result in a stronger justification for additional road capacity in these areas
5	Vkm and car ownership elasticity	TEMPRO & NRTS 1995 – 2005	National Transport Model	Both Eddington and the RAC Foundation study give a 31% increase in vkms 2003-25 indicating the models are similar in the background growth that RP/capacity has to meet.
6	Vehicle operating costs Changes in vehicle efficiency to 2041 for • car, • 3 x CV, • bus	Current WebTAG fuel consumption formulae are assumed. WebTAG 3.5.6 to 2020, extrapolate to 2031 then flat to 2041(see SG note 8 11 06) Car fuel efficiency+14.4% 2005-31, no change 2031-41 Bus 65p/litre +14.4% efficiency	Fuel efficiency +28% (DfT p.27)	RAC Foundation study assumes less improvement in fuel efficiency. This means higher carbon and other emissions - greater benefits from pricing but less from new capacity. Also higher fuel costs will dampen (slightly) the effects of pricing and capacity changes. Identical forecast traffic growth suggests that the complex interaction of different price/quantity assumptions balance out overall.
7	Price per litre of petrol and diesel fuels and fuel tax	Fuel price (inc. tax) +80% 2005-31 (See Arup note 14 11 06 and SG note 8 11 06)	Fuel price +3% Fuel duty no change (DfT p.27)	Higher fuel prices in the RAC Foundation study will tend to dampen road transport demand and the effects of pricing and capacity changes.
8	Hours in the year	Use SG annualisations which are	TUBA annualisations	Minimal

124 Annual index numbers of retail prices 1948-2006 (RPI) (RPIX), http://www.statistics.gov.uk/downloads/theme_economy/RP02.pdf

	[Number of hours in the year for each of 19 times of the week]	similar to TUBA annualisations, but include all days		
9	PCU values [PCU for car, 3 x CV, PSV]	WebTAG	WebTAG	None
10	Freight forecasts	For 2010-31: • NRTF low for artics (+49.6%) • NRTF central for Rigid HGV (+22.5%) • NRTF central for vans (+54.6%) No Change 2031-41	Great Britain Freight Model	RAC Foundation HGV forecasts are thought to be slightly higher than Eddington's. This will increase the estimated benefits from pricing and capacity expansion in the RAC Foundation study.
11	GDP Growth	Not explicit but implicitly 84%	71% between 2003 and 2025.	This will give higher demand in the RAC Foundation study (but see 5).
12	Average vehicle occupancies • occupants of the six types of car journey • CV and PSV drivers • Bus passengers	WebTAG	WebTAG	None
13	Forecast distance travelled per person pa, by Region	By mode as follows: Walk: Tempro Cycle: Tempro Car/Taxi: Based on Tempro (see 5) Bus: TEMPRO + 10% Rail: TEMPRO + 11%	National Transport Model	Probably small
14	Traffic growth by road type	Apportioned as per 1995-2005 change (% of total growth) Motorways ((33.2%) Rural A (31.3%) Urban A (2.3%) Minor (33.2%)	National Transport Model	Probably small
15	Population by Region	TEMPRO	TEMPRO	None
16	Accident costs	WebTAG	WebTAG	None – but both are probably high as accident rates are falling
17	Environmental Costs	WebTAG	WebTAG	None – but both probably high as emission rates are

				falling
18	Carbon Costs	£190/tonne at 2006 prices	£70/tonne at 2000 prices growing at £1 real a year.	RAC Foundation study will have greater carbon benefits from efficient pricing and lower carbon benefits from increased capacity. (RPFS, pg. 94 indicates NTM impacts of doubling carbon costs)
19	Household Income	69% growth between 2003 and 2025	58% growth between 2003 and 2025	This will result in higher demand in the RAC Foundation study. However this is partly offset by assumed higher fuel prices (see 5)
20	Type of model	Demand elasticities, speed/flow relationships by road types and highly disaggregated. Allows for travel time shifts.	Conventional four stage disaggregated model, using FORGE for a simplified road representation.	RAC Foundation study does not allow shifts in demands between road types. This will underestimate benefits from redistribution between parallel routes but underestimate costs of increased congestion of local access roads. Overall effect uncertain but probably small.
21	Road capacity expansion pattern	Follows Eddington Template except final capacity increment is focussed on London and the South East (Note that Eddington does not use region-specific VoT)	Based on B/C analysis of selective individual candidate links	By following the Eddington Template the RAC Foundation study (with regional values of time) has allocated too much capacity away from the congested areas (except in the last increment). This means that a superior allocation is possible in the RAC Foundation study with correspondingly higher benefits than estimated.
22	Forecast year	2041	2025	The later year, with higher incomes, demand and values of time, results in more capacity being justified – but the longer programme timescale means that this should have little effect on the comparative rates.
23	Vehicle Charge Rates	In accordance with PCU rates.	Uniform between vehicle types.	The RAC Foundation method will give higher benefits and revenues on routes with high HGV flows.
24	Price Cap	4xs the price paid in the absence of efficient pricing	80p/kilometrs at 1998 prices (98p @ 2006 prices)	The higher cap in Eddington will mean slightly higher pricing and capacity benefits.
25	Capacity capital costs	£5m - £35m/Lane kilometre[125].	£8.1m in 2002 prices plus £0.9m to £1.25M per lane km landscape costs	Small.
24	Evaluation methodology - 1	The model annualises all costs and benefits for a snapshot year (2041). This is not quite the same as working with an NPV of cash flows	DfT annualises costs and benefits for 2025 and then multiplies them by a factor to represent current NPV.	Depends on time profiles for costs and benefits. DfT method should take account of supply lagging behind demand and give a higher B/C than assuming all occur at one instant. On the other hand the RAC Foundation

[125] Archer & Glaister Tables 17 & 18 plus 25%,

		that, in practice would vary over time		method does not allow for the costs of working capital during construction so also overestimates B/Cs slightly. Relative effect is probably small.
26	Evaluation methodology - 2	Excludes wider economic benefits	Includes wider economic benefits	Eddington study, all other things being equal, would have higher benefits than RAC Foundation.
27	Evaluation methodology - 3	Calculates benefits in relation to cost for the community as a whole.	Takes into account the Social Opportunity Costs of Exchequer Funds.	The Eddington methodology gives lower benefits of additional capacity with efficient pricing as reduced congestion revenues are treated as a cost (to the Exchequer).
28.	Treatment of existing taxation	Duty and VAT on fuel are removed and replaced by costs of externalities associated with fuel consumption.	Fuel duty assumed to stay constant in real terms	Fuel duty and VAT in excess of externalities accrue to government and offset cost of investment in NTM, while in RAC Foundation possible that as investment increases traffic and then lowers MSC prices, increasing cost of investment.

Results

The transition between the 2010 and the 2041 Base

The traffic changes described in this section are essentially the consequences of growing demand for transport, suppressed by the deterrent effect of worsening congestion. As described above and in Annex 1 we have taken the demand growth that would occur if there were no increase in congestion, varying by region based on TEMPRO and other sources, tempered only by an assumption that the pump-price of fuel has grown from £0.80 per litre to £1.55 per litre. But we have "fitted" this growing traffic onto a road network which is assumed to grow modestly in line with the Eddington assumptions up to 2015 and not at all thereafter.

Actual traffic growth on the roads is less than the raw demand growth because of increased journey times as congestion worsens on many roads. This is illustrated in Figures 4.2 and 4.3 which summarise the average changes in traffic and in speeds – but note that the averaging across all times of the week and across the "busy" and "not-busy" directions of flow disguise much more significant speed changes at particular times of the week such as the weekday morning travel to work peak.

Note how in the remote rural areas the traffic is able to grow by almost the full amount of the demand because there is sufficient road capacity and average speeds fall little. But speeds fall a great deal in London, the Midlands, Bristol, the Manchester and West Yorkshire Metropolitan Areas, some other cities and on the major roads joining them. Consequently the demand growth is "choked off". In the worst cases the actual traffic growth is less than a quarter of the underlying demand growth.

Note that in some areas traffic growth is low because increased congestion has suppressed the growth, but in other areas it is relatively low because the underlying demand growth is predicted to be relatively low (in Scotland, for instance).

GB-wide there is a 30% increase in traffic.

Figure 4.2. Moving from 2010 to 2041; Average Traffic Changes

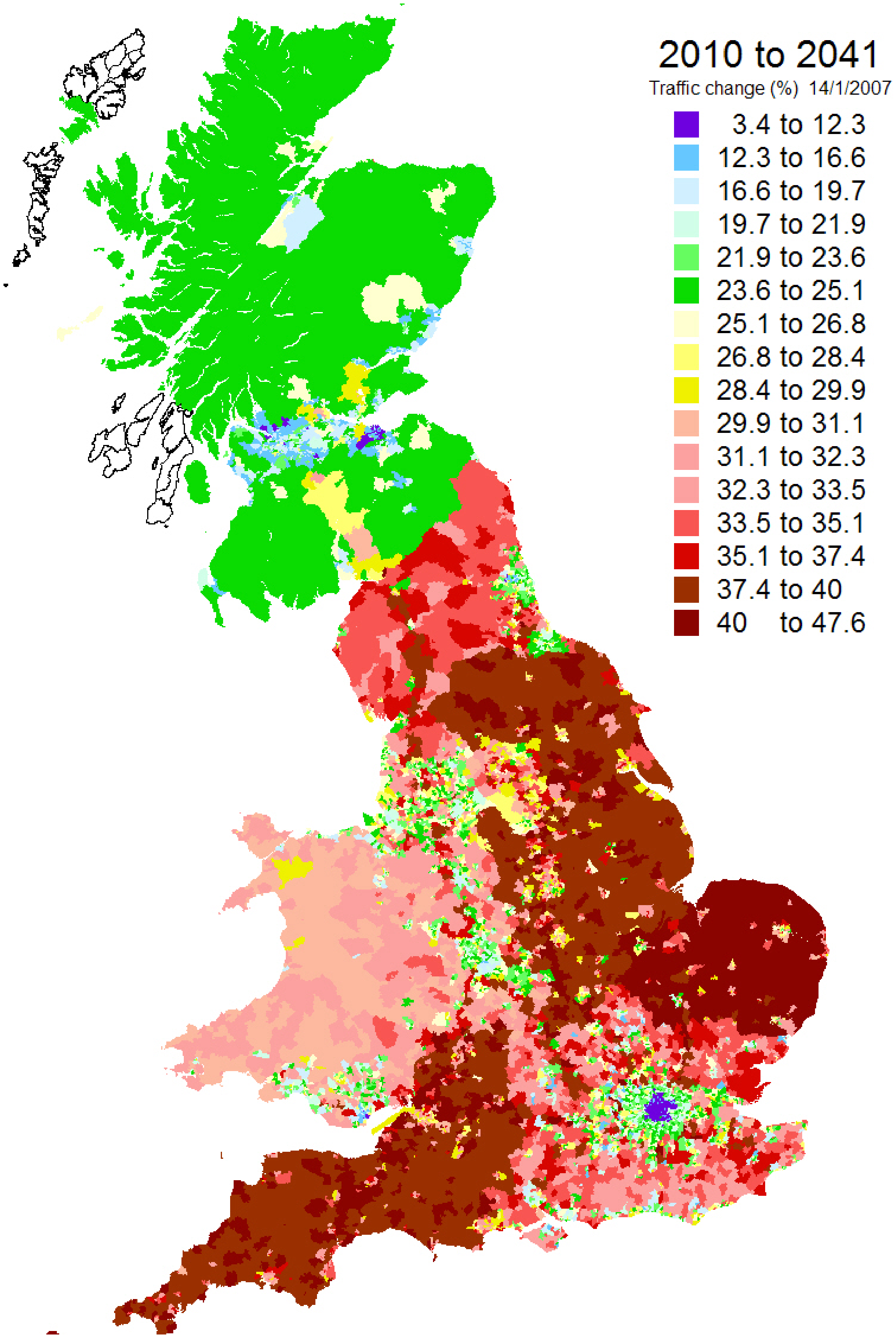
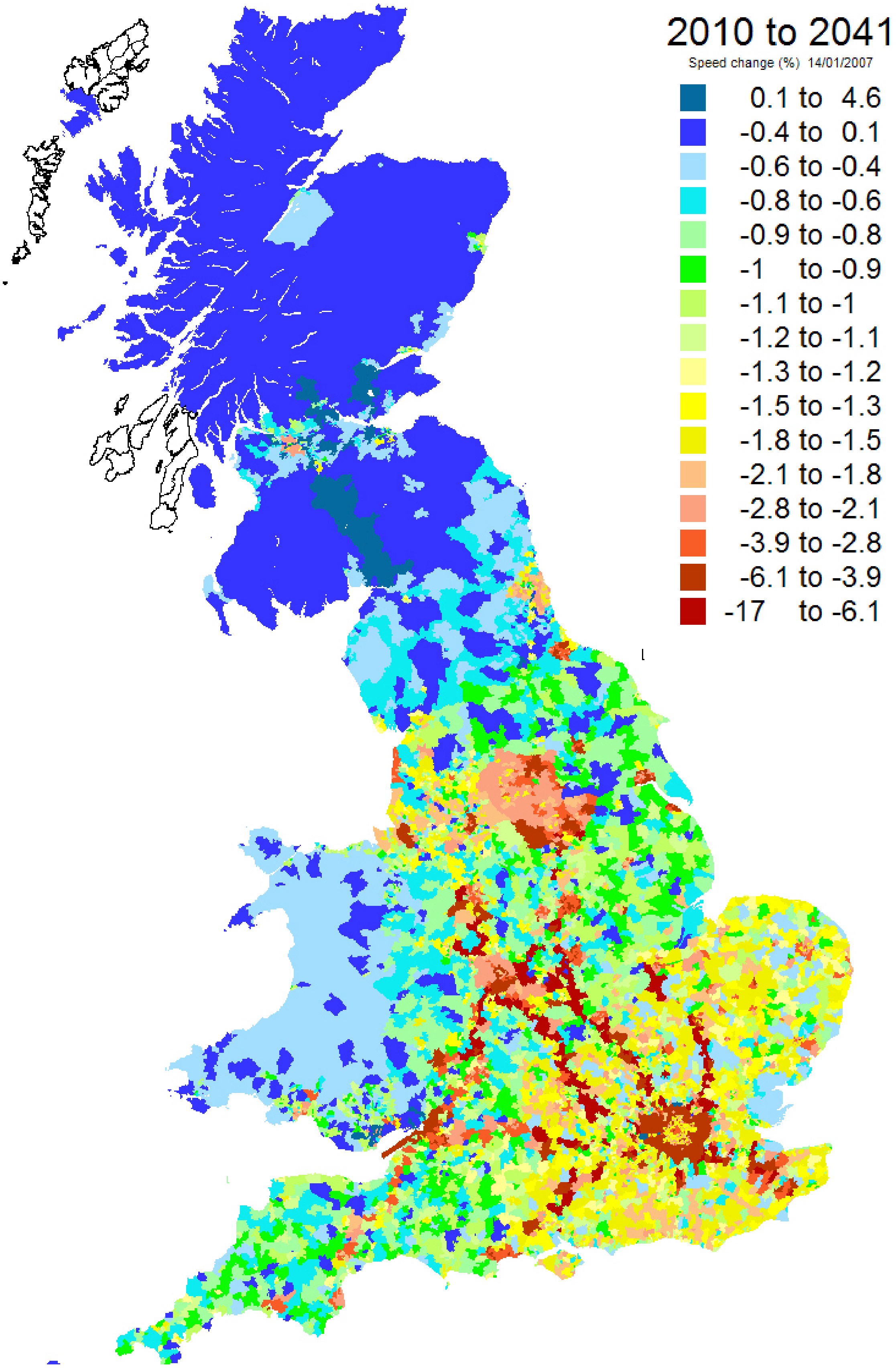


Figure 4.3. Moving from 2010 to 2041; Average Speed Changes



Efficient pricing in 2041

In this scenario we do not expand road capacity beyond the limited extent already assumed in moving from 2010 to 2041. But we introduce "fully efficient" charge (except that a cap on maximum charges of four times the base cost – i.e. that which would have been experienced in the absence of efficient pricing - has been imposed) for the use of the roads. These are per-vehicle kilometre charges that reflect the congestion delay imposed on other vehicles on that road at that time and also incremental road maintenance, noise, air pollution and external accident costs. These charges depend on the vehicle type in proportion to their use of road space (through their passenger car unit PCU equivalence) and because of differences in noise and air pollution characteristics.

Since we are seeking to reflect proper economic costs we remove the present sumptuary tax element in fuel prices (£0.47 + VAT per litre in 2006) and replace it with an explicit carbon tax at £0.14 per litre. We also eliminate the fuel duty concession to public service vehicles. Consequently all vehicle types are assumed to pay roundly £1 per litre, rather than the £0.65 for public service vehicles and £1.55 (in 2041) for all other vehicles. Note that one implication of this is that money costs of road travel will fall in some places since fuel will have become cheaper and the direct road user charges will not have risen sufficiently to offset that reduction.

Overall this policy achieves a 15½ per cent reduction in traffic.

Traffic increases or stays much the same over much of rural Scotland and Wales with little effect on speeds. Traffic is reduced most and speeds improved most in outer London and the other conurbations and large cities. In middle England traffic is reduced slightly less on the high capacity trunk routes between the major cities than in neighbouring areas, though speeds improve slightly more.

Tables 4.35 and 4.36 summarise the economic appraisals of our main scenarios, without and then with efficient pricing. Column (1) displays the estimate of the total benefits experienced by road users, taking into account the value of time and vehicle operating cost savings and after accounting for changes in road user charge payments and fuel duties. In the cases of the efficiently price options it is particularly important to bear in mind that this is the difference between large transport benefits to road users and the disbenefits of having an increase in cash outgoings. This is discussed in detail below, where it is explained that the disbenefits of the latter comprise the actual net "cash out of the pocket" plus deadweight losses caused by levying the charges.

Column (3) it the estimated value of the change in "environmental" costs imposed on others, excluding the saving in carbon costs which is identified in column (3) (positive numbers are benefits).

Columns (4) and (5) record the estimated change in subsidies (revenues net of costs) for the bus and rail industries (positive numbers are reductions and therefore benefits to taxpayers). Since, as noted above, our modelling of public transport cost changes is particularly crude these items are not to be taken too seriously. In any case they are generally not material in magnitude.

Column (6) records the road pricing revenues gross of any costs of collection.

Column (7) is the sum of the preceding columns.

Column (8) is a modification of column (6) to allow for the fact there have been changes in VAT take, fuel duty paid and revenues from the carbon tax. Column (9) is similar to column (7) except that (6) is replaced by (8): it represents the overall benefit to road users and general taxpayers, gross of costs of road price collection and administration and gross of any costs of infrastructure capacity expansion.

The infrastructure costs are noted in column (10). The final column (11) is the ratio of average benefits to costs: not the incremental costs of moving from one capacity increment to the next which are shown in Table 4.38 below.

Speeds and traffic flows

Figure 4.4 shows our estimate of the effects of efficient pricing and capacity increases in the Highways Agency's national inter-urban road network. In each case the scenarios are compared with the 2041 base case. The "with pricing" chart shows that, with no additional lane kilometres, traffic flows are reduced and speeds are increased compared with the base case. The most salient features are:

- Without pricing, the additional capacity has much more effect on motorway speeds than it does on traffic flows or on trunk A road speeds;

- Efficient pricing would reduce overall traffic on motorways by 8% and by 17% on trunk A roads. On the other hand average speeds would increase by 8% and 11% respectively.

It should be borne in mind that the speed and flow effects are averaged over the whole week, and that the effects of both pricing and capacity will be greater at the most congested times and places. Also, the model does not allow for journeys currently on other routes transferring to the upgraded roads, so there will be a tendency for changes in traffic on these roads to be underestimated along with traffic on their feeder roads. Correspondingly traffic on 'relieved' roads will be over-estimated. Insofar that the model does not allow this dimension of optimisation it is likely to tend to underestimate the benefits of the additional capacity – but probably to a limited extent.

Figure 4.5 shows similar charts for all roads in Great Britain, the difference from Figure 4.4 being that the conurbations are not excluded. These simply serve to show that there is a large difference in the effects for single A(T) roads in the conurbations – and hence to warn against the confusion that may be caused by considering an average effect across the conurbations and other areas

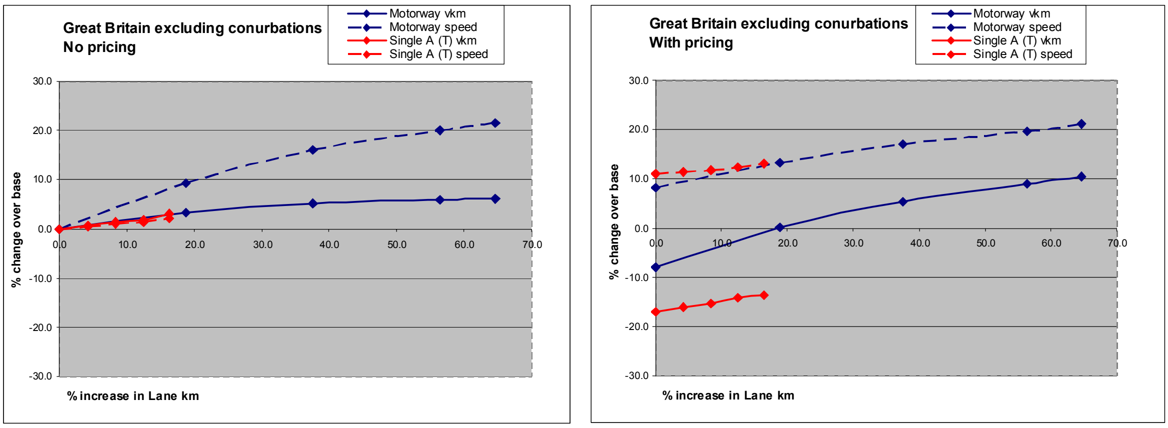
Table 4.35. Summary of financial effects, Capacity increases only, no efficient pricing. (GB, 2041, 2005 prices).

Capacity increase (Lane km pa)	(1) Change in traveller benefit	(2) Saving in environmental costs ex carbon	(3) Saving in carbon costs	(4) Reduction in bus subsidy	(5) Reduction in rail subsidy	(6) Change in tax & charge revenue	(7) Net benefit	(8) Change in revenue after correction for VAT, Duty and carbon tax revenues.	(9) Net benefit after tax correction	(10) Cost of capacity	(11) Benefits/Costs
	£ bn pa	£ bn pa	£ bn pa	£ bn pa	£ bn pa	£ bn pa	£ bn pa	£ bn pa	£ bn pa	£ bn pa	
90	4.92	-0.84	-0.10	0.04	-0.08	0	3.94	0.52	4.46	0.7	6.4
200	7.91	-1.15	-0.18	0.06	-0.1	0	6.52	0.94	7.48	1.48	5.1
400	13.55	-1.98	-0.30	0.12	-0.21	0	11.20	1.57	12.77	2.96	4.3
600	17.55	-2.65	-0.37	0.19	-0.24	0	14.48	1.94	16.42	4.44	3.7
800	22.28	-3.98	-0.64	0.04	-0.33	0	17.37	2.18	19.56	5.61	3.5

Table 4.36. Summary of financial effects, Capacity increases and efficient pricing

Capacity increase (Lane km pa)	Change in traveller benefit	Saving in environmental costs ex carbon	Saving in carbon costs	Reduction in bus subsidy	Reduction in rail subsidy	Change in tax & charge revenue	Net benefit	Change in revenue after correction for VAT, Duty and carbon tax revenues.	Net benefit after tax correction	Cost of capacity	Cost of Collection	Benefit/Costs
	£ bn pa	**£ bn pa**	**£ bn pa**	**£ bn pa**	**£ bn pa**	**£ bn pa**	**£ bn pa**	**£ bn pa**	**£ bn pa**	**£ bn pa**	£ bn pa	
Base capacity	-46.39	16.87	1.21	-2.91	0.22	84.90	53.90	53.33	22.33	n/a	4.5	5.0
90	-39.96	15.73	1.08	-2.66	0.14	83.25	57.58	51.89	26.23	0.70	4.5	5.0
200	-37.40	15.55	1.01	-2.59	0.11	82.85	59.53	51.61	28.29	1.48	4.5	4.7
400	-30.54	14.43	0.86	-2.27	0.05	81.17	63.7	50.19	32.72	2.96	4.5	4.4
600	-25.85	13.57	0.75	-1.89	-0.00	80.34	66.92	49.53	36.12	4.44	4.5	4.0
800	-23.26	12.69	0.7	-2.36	-0.05	81.39	69.12	50.66	38.39	5.61	4.5	3.8

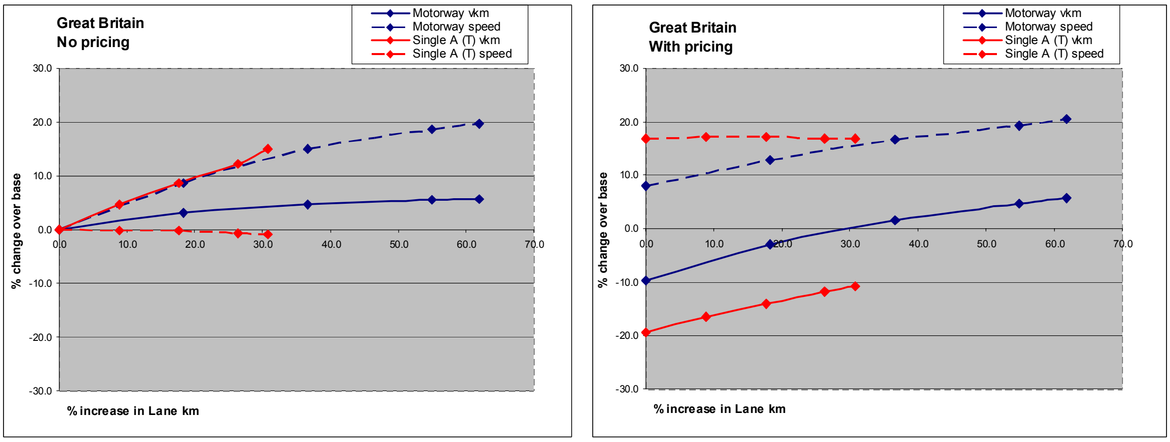
Figure 4.4. The effect of capacity and pricing on the inter urban road network



Notes:

1. In these graphs "Single A(T) roads" also include dual carriageway trunk roads in urban areas.
2. The scenarios tested are marked by diamonds.
3. The percentage increase in capacity on A(T) roads that was tested in the scenarios is much less than the percent increase in motorway capacity because the A(T) network is much more extensive and only 40% of the additional Lane kilometres were added to the A(T) network.
4.

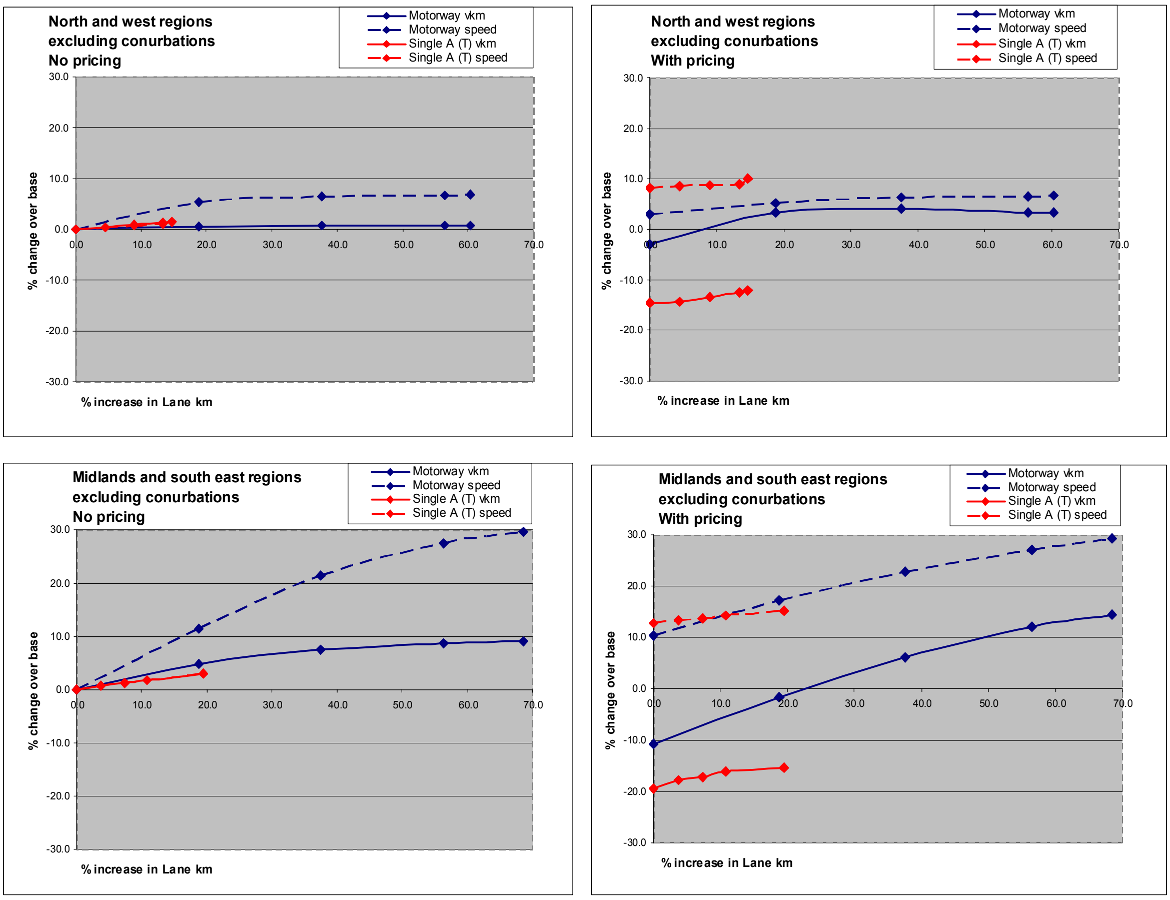
Figure 4.5. The effect of capacity and pricing on the GB trunk road network



The graphs in Figure 4.6 show regional variations. They exclude conurbations and group the regions according to how they respond to pricing and capacity. They thus show the regional differences in the effects of pricing and inter-urban road building.

The northern and western regions[126] are generally characterised by less congested roads and lower forecast traffic growth. Additional capacity has little effect on either average traffic flows or average journey times, although at local level, there will nevertheless be many specific circumstances where the effect of capacity and/or pricing will be substantial.

Figure 4.6. Regional differences in speeds and flows with and without efficient pricing



In the 200 Lane kmpa scenario, journey times on motorways improve without pricing and motorway flows with pricing, though most of this is attributable to the North West and South West regions. It should be noted that the South West is somewhat anomalous because, though the speed and flow graphs are similar to the other regions in this group, it has the highest forecast traffic growth and it also has the greatest seasonal variations in traffic flows; a factor not reflected in the model.

In the midlands and south east regions[127], outside the conurbations population and traffic growth forecasts are highest and the strategic road network is often most congested. Capacity is inadequate to serve the long term growth. Here, a road building programme similar to the 800 Lane kmpa scenario or more will result in considerable increases in both speeds and flows.

Figure 4.7 repeats these charts for the individual Regions, in each case excluding the conurbations, where relevant.

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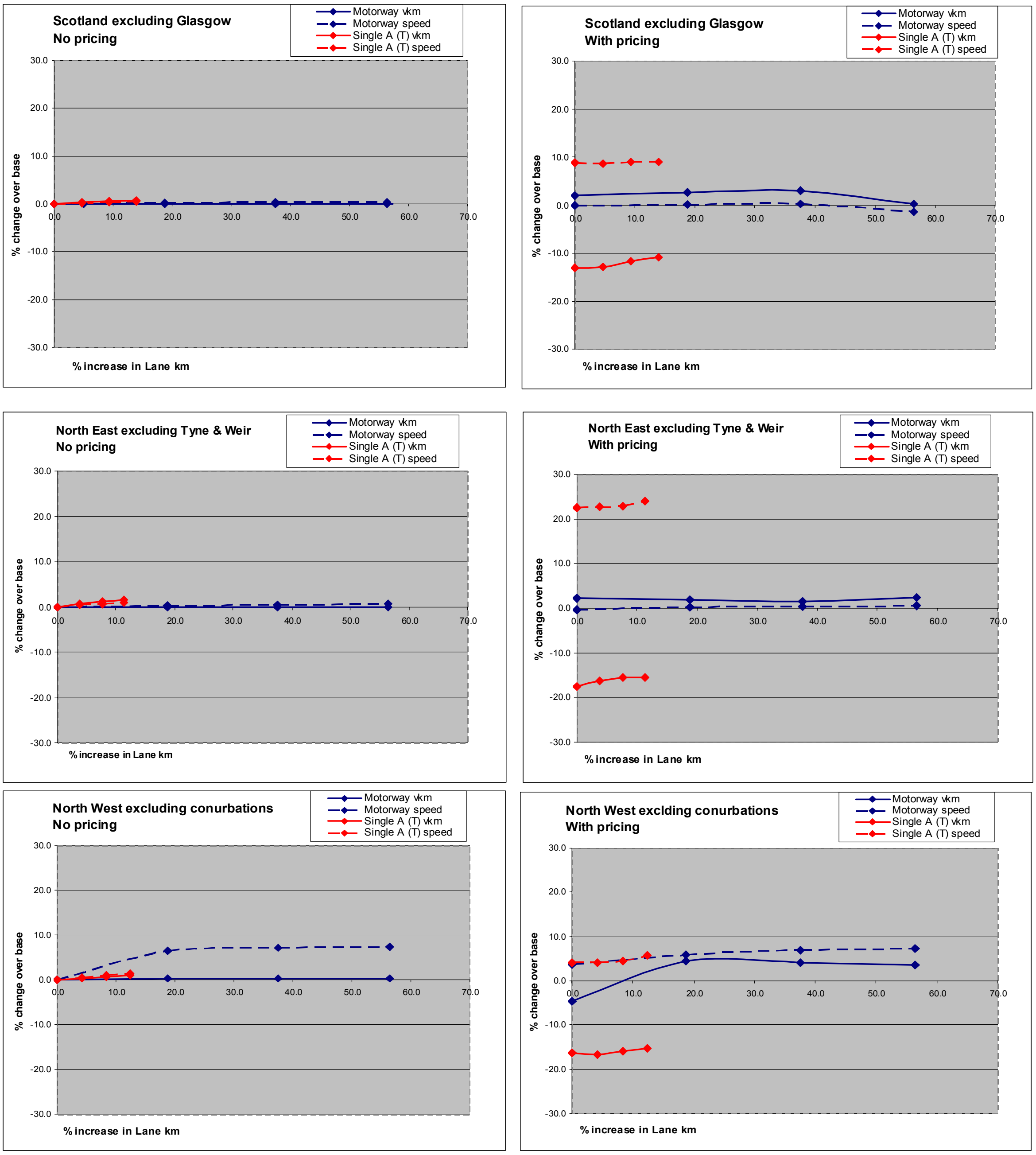
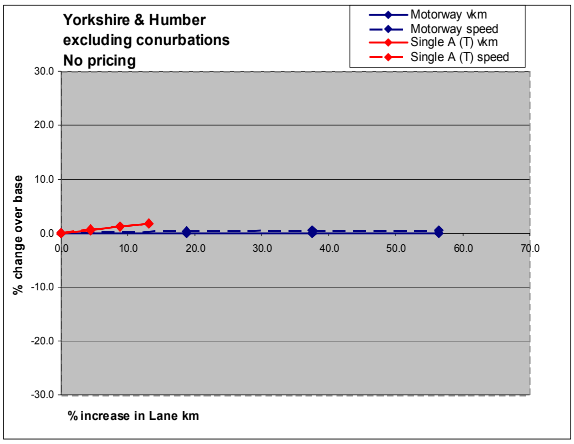
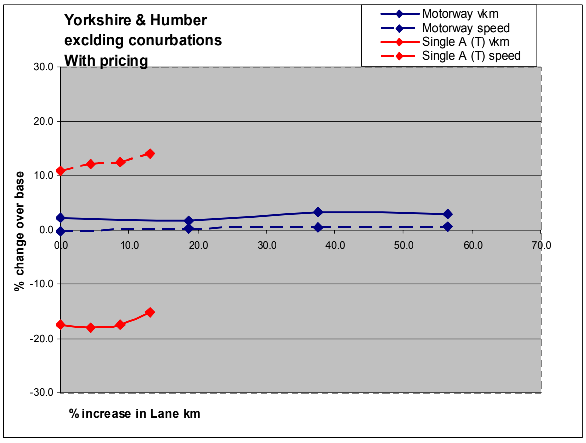
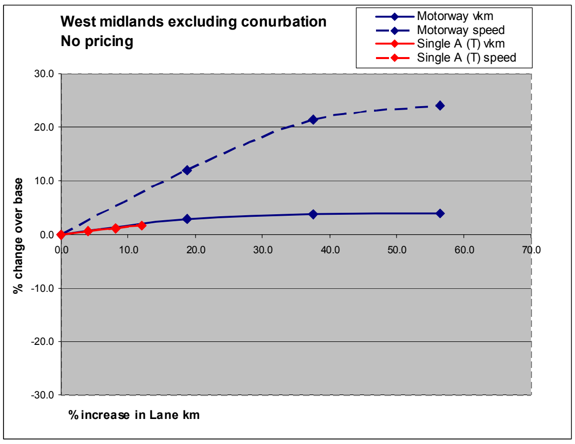
[126] Comprising Scotland, North East, North West, Yorkshire and Humber, Wales and South West.
[127] Comprising East and West Midlands, East of England and South East.

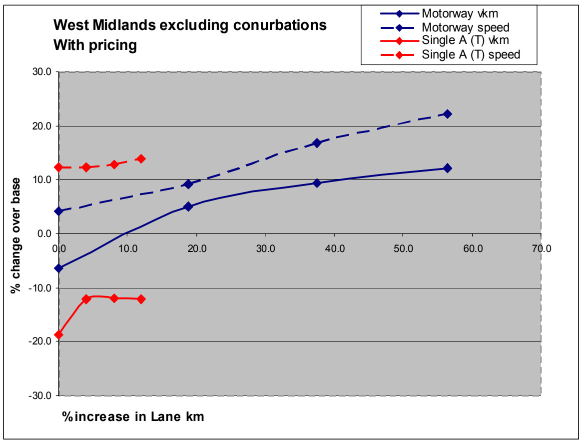
Figure 4.7. Differences in speeds and flows with and without efficient pricing: individual Regions with conurbations excluded

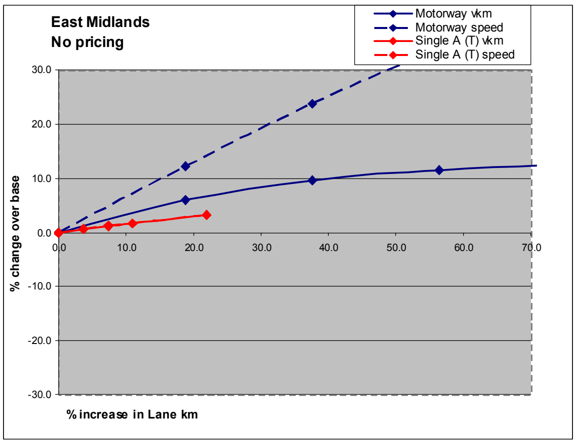


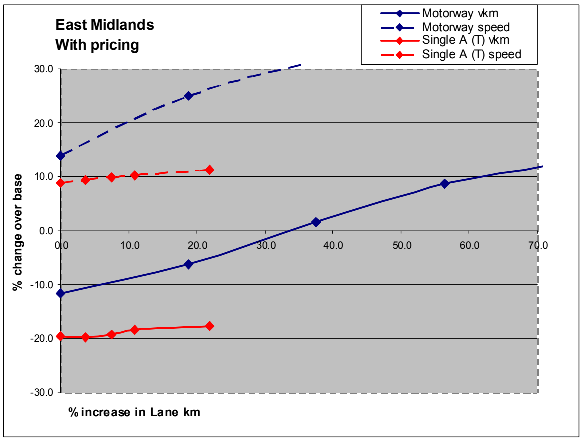

Yorkshire & Humber
excluding conurbations
No pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km

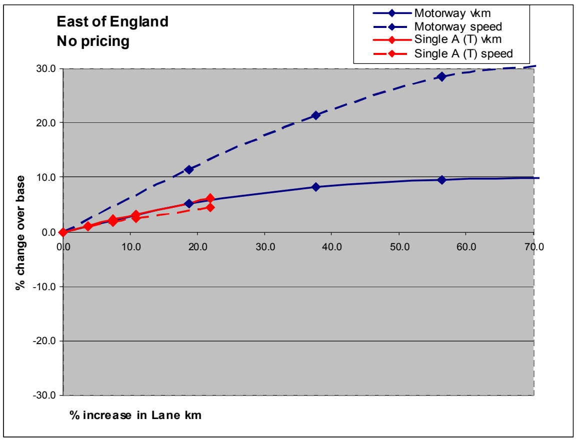

Yorkshire & Humber
excldng conurbations
With pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km

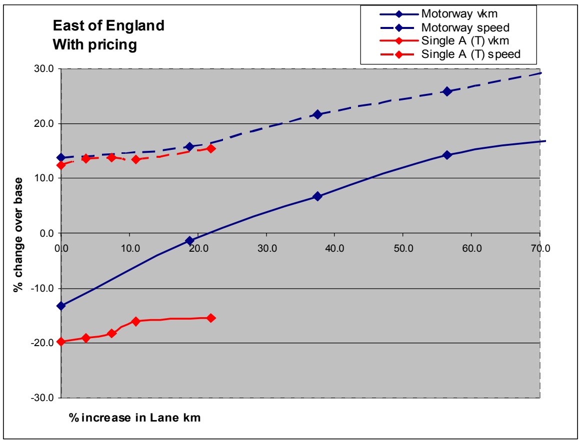

West midlands excluding conurbation
No pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km


West Midlands excluding conurbations
With pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km


East Midlands
No pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km


East Midlands
With pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km


East of England
No pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km


East of England
With pricing
Motorway vkm
Motorway speed
Single A (T) vkm
Single A (T) speed
% change over base
% increase in Lane km

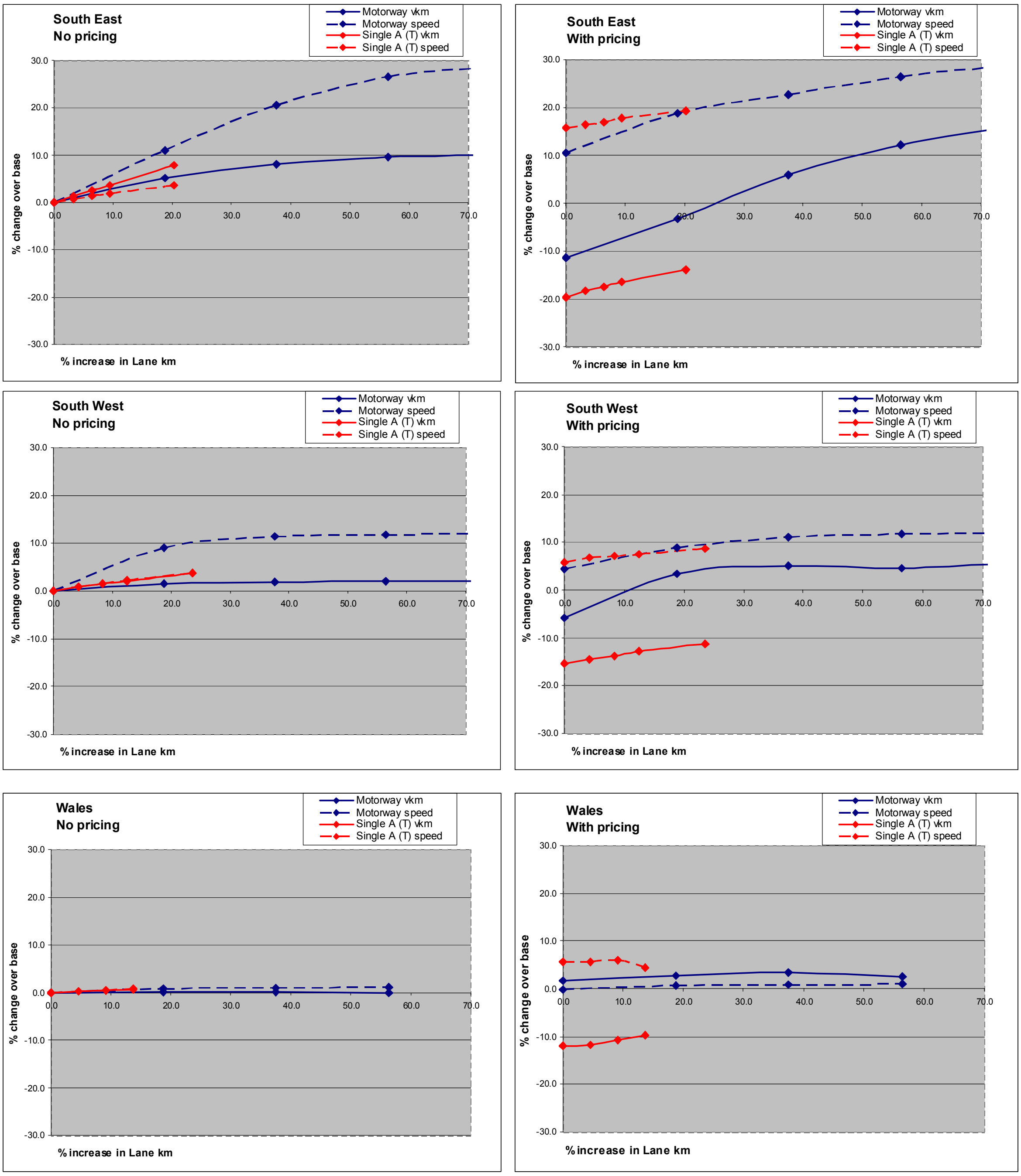
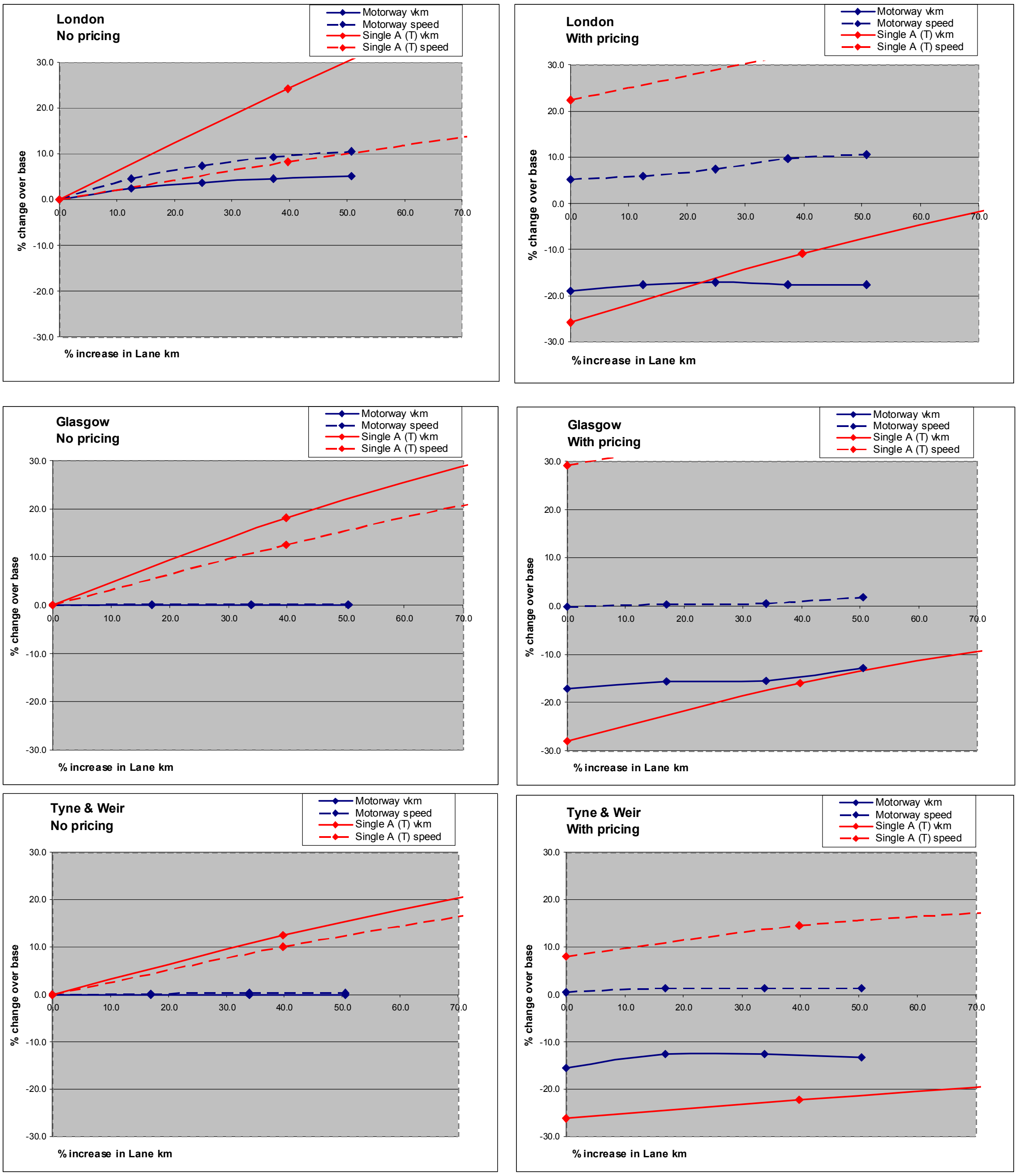
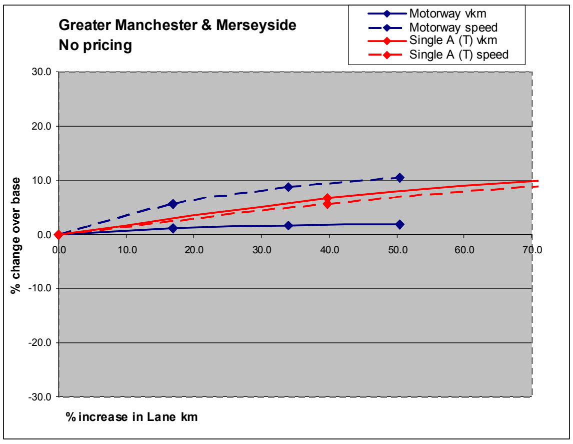


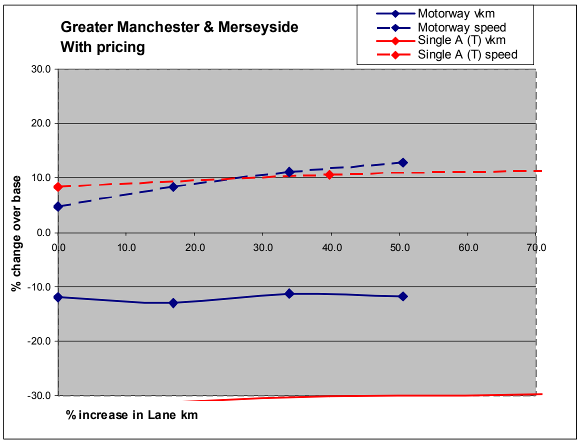
Figure 4.8 shows the corresponding charts for the conurbations on their own. The effect of efficient pricing on traffic and speeds in London and the other conurbations is greater than the pattern in their surrounding regions. This is also true of extra capacity on single A(T) roads and motorways in northern conurbations. motorway. On the A(T) roads the main impact would be on traffic growth due to very high demand in relation to available road space, whilst speed restrictions to some extent limit the effect on journey time reductions. Nevertheless, these findings are conditioned by the fact that in cities there is usually less opportunity and advantage in

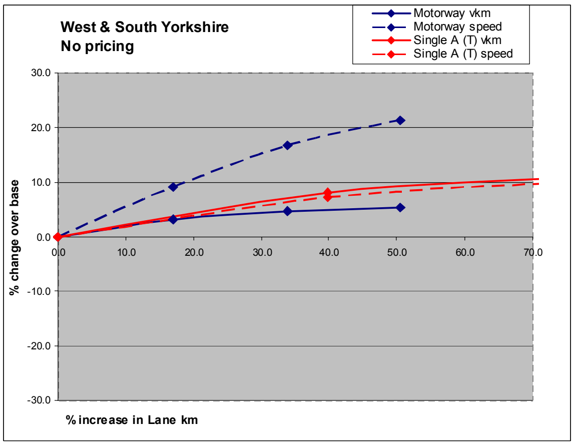
building or widening roads and more scope for public transport, especially in inner areas.

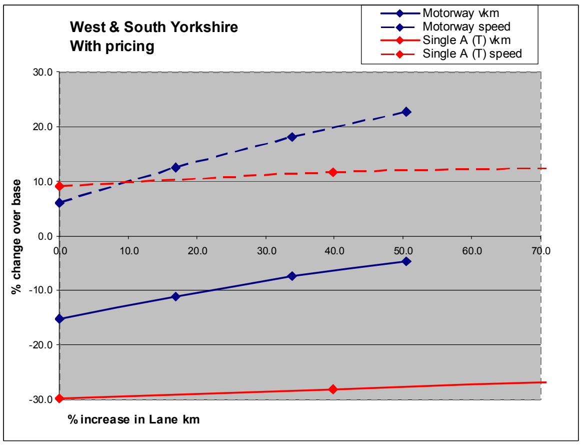
Figure 4.8. Differences in speeds and flows with and without efficient pricing: individual Regions, conurbations only

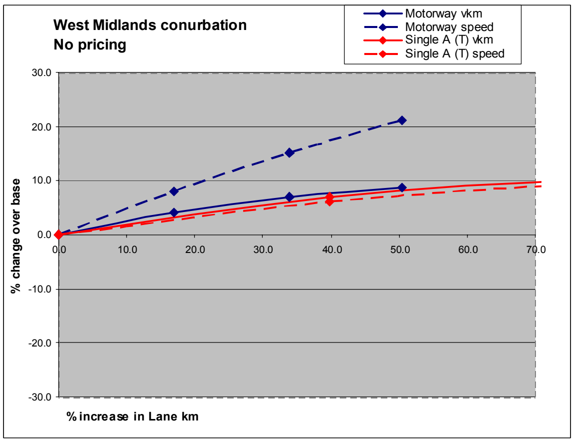


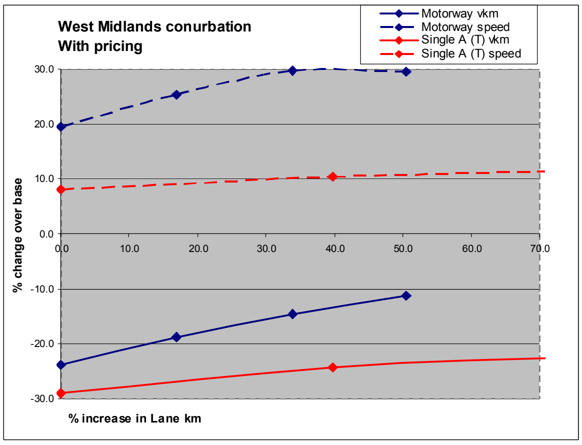












Other effects of efficient pricing

We estimate that there would be a substantial mode shift to buses resulting in a 70% increase in bus passenger travel – reflecting the larger impacts in towns and cities. As the model does not include any changes to the public transport networks these findings should be treated with caution and not taken literally. However there is no doubt that efficient pricing would require significant improvements to urban bus services which would, in part be ‘paid for’ by the reduction in operating costs resulting from less congestion.

The overall effect on land use is very difficult to judge and will vary between cost sensitive and time sensitive activities. There may be some effect on patterns of population and employment. Pricing will reduce the attractiveness of car commuting to or through congested areas, but better bus travel and a more attractive inner urban environment will have the opposite effect. Car dependent employment uses and visitor attractions will be less likely to locate in areas where the charges are highest. In the absence of increases in urban road capacities this may lead to some decentralisation of lower value urban activities.

An assessment was made of how the picture would change if the additional capacity were allocated where the most cost effective congestion relief can be achieved. This resulted in most road capacity expansion in London, the provincial conurbations and the south east. This is consistent with the findings of the Eddington study that the greatest congestion problems are in and around the larger urban areas.

Except to the extent that the final increment of capacity was confined to southern and eastern regions, we have not pursued this line of investigation. Urban transport problems require a fuller and more explicit treatment of parking polices, public transport services and fares and traffic management than was possible in this exercise. However the urban traffic problem is very important and growing; and a comprehensive national transport policy must include policies to deal with these issues. What our study has confirmed is that efficient pricing has a major contribution to make not only on the strategic road network, but also in dealing with the urban traffic problem, albeit at a price of reduced mobility .

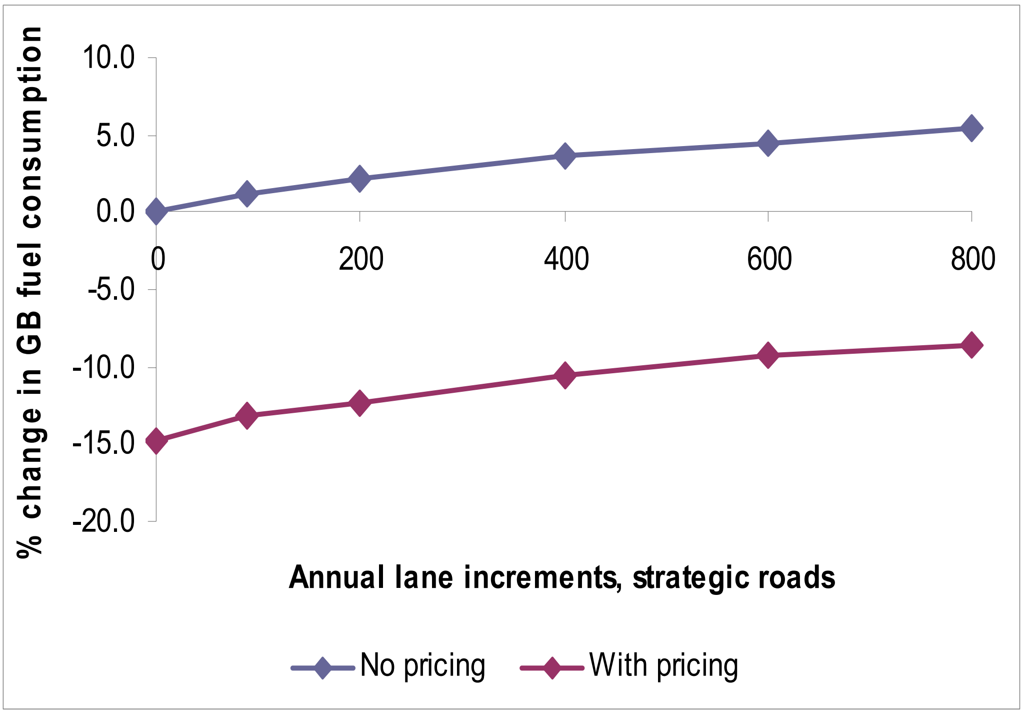
Carbon effects of additional strategic road capacity and efficient pricing

The effect of our scenarios on fuel consumption (and hence CO_2 emissions) in 2041 is shown in Figure 4.9. Without pricing, expanding the main road network by 400 Lkmpa would increase CO_2 emissions by 3.6% and a 600 Lkmpa programme (i.e. six times the annual average starts since 2000) by 4.5%. These figures broadly concur with the Eddington Study which estimated that a strategic road building programme of 350 Lkmpa between 2015 and 2025 together with associated major road and junction improvements would increase 2025 CO_2 emissions from road traffic by only 1%[128]. Efficient pricing without road building would reduce carbon emissions by

[128] Transport demand to 2025 and the economic case for road pricing and investment; DfT; p.38

14.8% and with 600 Lkmpa by 9.2%. In any event, the base level of road transport carbon emissions in 2041 will depend largely on the pace of automotive technological change as demonstrated in the King Report[129].

Figure 4.9. Effect of road building and pricing scenarios on fuel consumption



Charges and income

Table 4.37 shows how the income from efficient pricing is spread geographically in relation to population. The Table shows that 37% of pricing income would accrue from motorways and trunk roads and 32% from non-trunk roads in London and the conurbations.

At the most economically efficient price in 2041(when average incomes will be more than twice as high as today), the average charges (capped) would be around 9p/km at 2041 prices in northern and western regions and 11p/km in midlands and south east regions. It would be higher in conurbations, 40p/km in London and 21p/km elsewhere. The average charge would be much lower on motorways and rural dual carriageway roads than on other roads. In all areas peak charges will usually be much higher than the average. Charges would vary with vehicle type, for example,

[129] HM Treasury 2007 chart 4.2

with an average of 40p/km in London, cars would pay 35p/km, light goods vehicles 60p and HGVs about £1.20.

The charges will generally be for shorter trips in London and the conurbations – in London which currently has 12.9% of the national population, the roads carry only 6.6% of traffic[130]. The income per head of population is nevertheless higher than average in London and the conurbations and it is also significantly lower in northern regions than in southern regions.

Table 4.37. Geographic source of income from efficient pricing (%of total charge income)

	Efficient pricing				
	North & West regions	Midlands and south east regions	London	Other conurbations	Great Britain
Percent of GB population	***30***	***35***	***13***	***21***	***100***
Percent of 2041 traffic (pricing alone)	***35***	***46***	***5***	***14***	***100***
Motorways and rural dual A roads	5	12	4	1	22
Other A roads	11	15	9	11	46
Other roads	8	11	8	4	32
ALL ROADS	**24**	**38**	**22**	**15**	**100**
All Highways Agency roads	8	17	7	6	37
All other roads	16	22	16	9	63

Note: Regional groupings exclude conurbations

Unless pricing in conurbations and other congested urban areas is implemented with a complementary package of additional road capacity, public transport and other measures, it will result in high charges for use of the roads and reduced accessibility for those unwilling or unable to pay for the benefits of improved vehicle speeds.

Costs and benefits

The graphs in Figures 4.4 to 4.8 show that there are substantial gains in mobility as a result of building more road capacity, irrespective of whether efficient pricing in introduced. However, there will not be a compelling case for the investment unless the additional cost can be justified by even greater benefits. The costs and benefits of the scenarios are set out in Table 4.38. All are expressed as the change in each

130 Regional Transport Statistics 2006 tables 4.1 & 9.1.

scenario compared with the 2041 base case. The marginal benefit:cost ratio is the extra benefit of each additional 200 Lkmpa increment of capacity relative to the additional cost. The ratio for the +800 Lkmpa case is higher than that for +600 because the increase in the former is concentrated in those regions where traffic and congestion are greatest.

Table 4.38. Costs and benefits of road building and efficient pricing (£ billion p.a. Great Britain)

	No extra capacity	**+200 Lkm pa**	**+400 Lkm pa**	**+600 Lkm pa**	**+800 Lkm pa**
No pricing					
Gross benefit to society	Base	7.48	12.75	16.42	19.55
Cost of additional capacity	Base	1.48	3.0	4.44	5.61
Average benefit:cost ratio of scenario	Base	5.1	4.3	3.7	3.5
Marginal benefit:cost of additional capacity	-	**5:1**	**3.5:1**	**2.6:1**	**2.7:1**
Efficient pricing					
Gross benefit to society	22.33	28.29	32.72	36.12	38.38
Cost of additional capacity	0	1.48	3.0	4.44	5.61
Cost of charge collection	4.5	4.5	4.5	4.5	4.5
Average benefit:cost ratio of scenario	5.0	4.7	4.4	4.0	3.8
Marginal benefit:cost of additional capacity and collection	**5.0:1**	**4.0:1**	**2.9:1**	**2.4:1**	**1.9:1**

The general picture is that:

- efficient pricing has a high overall benefit:cost ratio to society even if high charging operational costs are assumed;
- at all levels of capacity expansion considered, the marginal benefits of increasing capacity are higher with efficient pricing;
- up to 800Lkmpa of capacity expansion, the marginal benefits of capacity expansion remain above 2:1 without efficient pricing and
- with efficient pricing the 2:1 threshold is crossed towards 800 Lkmpa.

The ratios show that there is a strong economic case for efficient pricing in combination with increasing road capacity. It should be recognised that extra capacity can sometimes be secured without new or widened roads. In some circumstances capacity increases may be provided more cheaply by using motorway hard shoulders, junction improvements, or capacity enhancing traffic management, though in these cases the gains are usually not repeatable and the network's resilience to major incidents may be reduced.

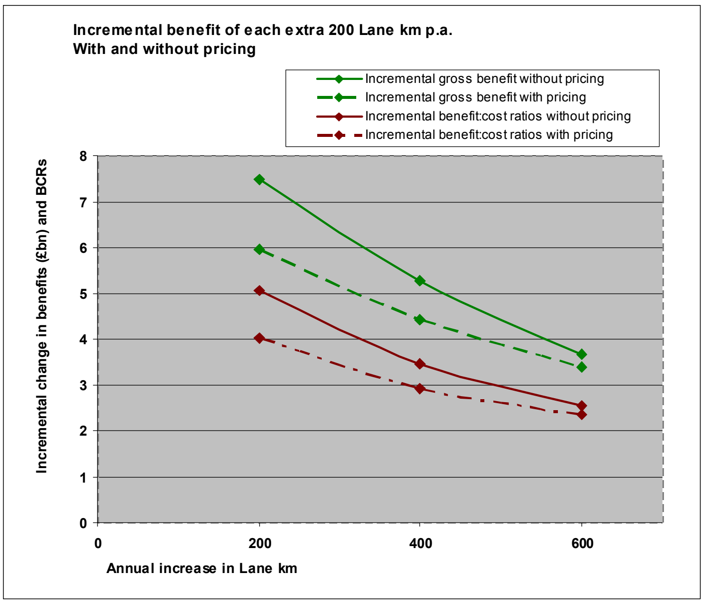
Would efficient pricing reduce the requirement for additional road capacity?

Part of the current interest in road pricing is due to its potential to reduce the need to build extra capacity. Efficient pricing would reduce the requirement because it would both secure a more efficient use of road space and discourage some journeys from being made at all. Fewer vehicles need less road space.

However, if no extra capacity were provided, the charge necessary to regulate congestion would need to continue to increase as population, demand and disposable income all increased. The more severe the price or capacity constraint, the greater would be the loss of mobility and of benefits of this to the economy and to society. The actual reduction would depend on the relationship between capacity and congestion in particular locations and on the responses of individuals to particular levels of charge.

We have estimated the additional benefits resulting from each 200 Lane kmpa increment of capacity in the scenarios that we have tested, comparing with and without efficient pricing[131]. The results are shown in Figure 4.10.

Figure 4.10. The effect of efficient pricing on the benefits of extra capacity



[131] We have not included the 800 Lkmpa scenario as the extra capacity was applied to southern regions only.

The additional benefit resulting from road building would be greater without pricing because there would be more congestion and therefore more to be gained from congestion relief. At 200 Lkmpa, pricing would reduce the benefits resulting from the extra road building by around 20%. This suggests that, applying a given minimum benefit:cost ratio to justify schemes, around 20% less road building would be justified with pricing.

But this level of road building would be considerably below the optimal level to maximise economic and mobility benefits, because capacity would fall far short of the need and desire to travel. At 600 Lkmpa, the extra benefit compared with the 400 Lkmpa scenario would still be more than enough to justify the extra cost (with an average benefit:cost ratio of 2.5:1), but at this level of road building there is less congestion, and the difference in benefits with and without pricing would be reduced. Here pricing would reduce the additional benefit by less than 10%, and the effect on the economic justification for more road capacity would be reduced by a similar amount.

These findings are in contrast to the Eddington Study which estimated that, between 2015 and 2025, 290-325 Lkmpa of additional strategic road capacity in England could be justified without pricing, compared with only 50-85 Lkmpa if efficient pricing is introduced. This equates to an 80% reduction in requirement for road building resulting from an efficient pricing scheme.

However, the benefit:cost ratio used in the Eddington Study assessed benefits and costs to government. In this approach income (and therefore benefit to government) from road pricing would be reduced by building more capacity because the charges for using the road would be reduced as there would be less congestion.

A more appropriate and fairer approach is to assess the benefits and costs to society as a whole, as we have done. A recent report to Congress on the national highway system by the US Department of Transportation, based on the overall effect to society estimated that in the United States efficient pricing would reduce the requirement for road building by a more modest 27.5%[132].

This analysis demonstrates that efficient pricing is not, as it is sometimes presented, simply an alternative to building additional road capacity. There are great benefits to be

[132] US Department of Transport (2006)

gained in more efficient use of the roads by introducing pricing, but more road space will gain even greater benefits, not least because using the roads will be more affordable to people on low incomes. Determining the balance would be a matter for detailed technical assessment of specific circumstances, tempered by political judgement. A key message is the importance of planning road pricing and road construction programmes together to produce the best result for the area concerned.

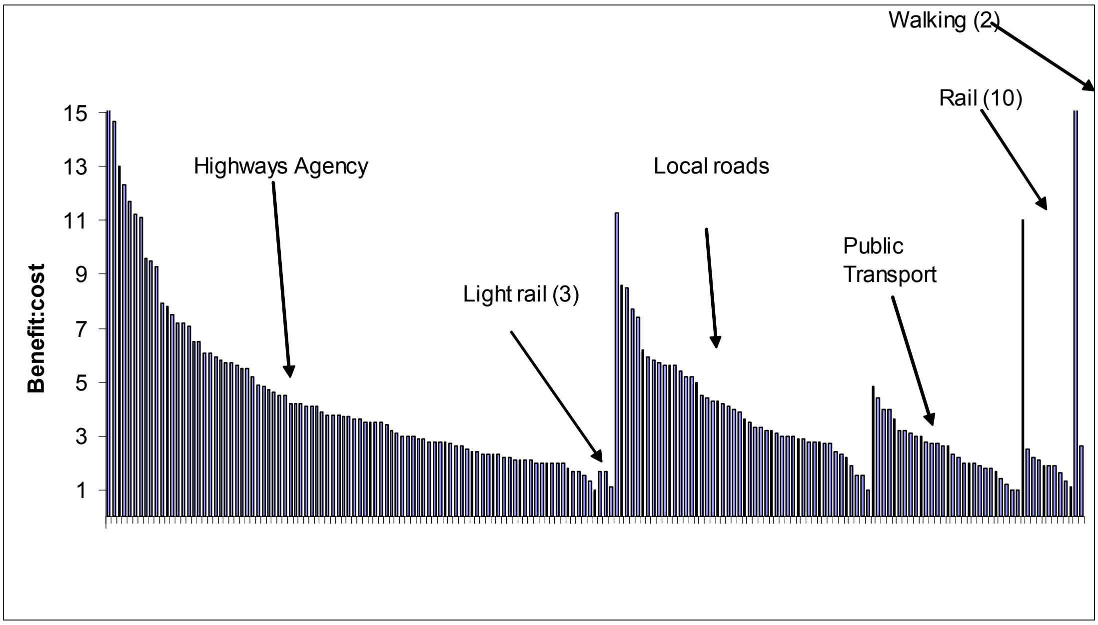
How much additional capacity is justified?

Neither our study nor the Eddington analysis can determine definitively the rate of road building that is justified in economic terms. Both studies were looking at the general case for particular directions of policy, and were not able to look at individual projects. So much will depend on the particular content and circumstances of each individual project. Nevertheless, our analysis does show that without pricing there are large benefits to be gained from additional road building – as indeed does the Eddington "evidence base" of the benefit:cost ratios of past and pipeline schemes (see Figure 4.11), and also the experience of the 1990s. With pricing, there is a strong economic (and social) case for more capacity to serve the growing demand for choice and travel, as well as a source of income to fund the investment.

The fact that the incremental benefit:cost ratio remains high even in the 800 Lkmpa scenario indicates, but does not demonstrate definitively that this level of building would be justified, as these ratios are averages, and each 200 Lkmpa tranche may include some schemes with very high ratios and some others with uneconomic benefit:cost ratios. Much will depend on which projects are chosen, their relationship with other projects, and how the case for them is affected by pricing. This underlines the case for proper long-term transport planning at national, regional and conurbation levels.

So far as can be judged from the regional and conurbation evidence, at least 600 Lkmpa of strategic road building is needed for the period 2010-41 to capture the economic benefits and support growing national prosperity. Our modelling does not include wider benefits to the economy, such as encouraging new business growth that would not otherwise take place, which in some areas could be very significant.

Figure 4.11. Benefit:Cost Ratios for Contemporary Transport Schemes estimated by New Approach To Appraisal



Source: Eddington evidence base, www.DfT.gov.uk

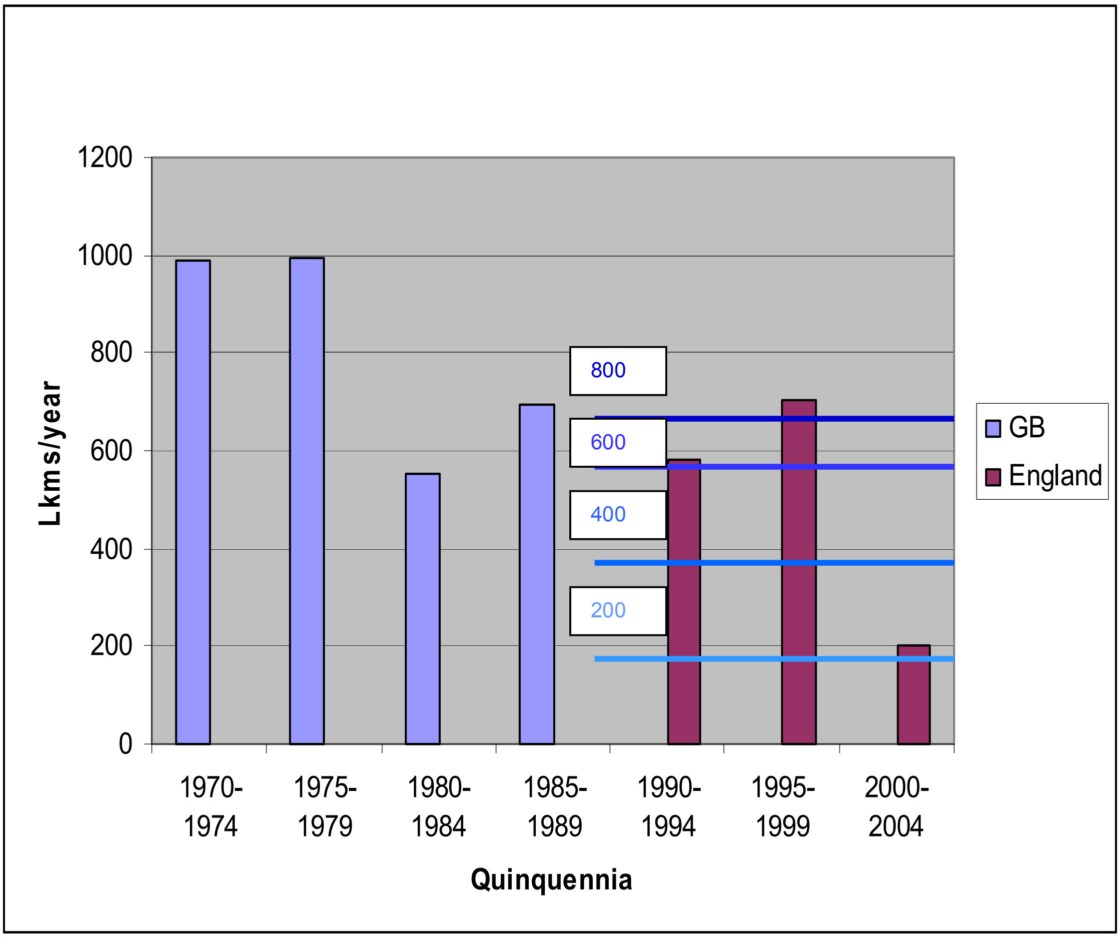


Figure 4.12. Trunk Road Scenarios in Their Historic Context

Source: Authors estimates for GB from TSGB and TSGB 1995 to 2006 for England.

This suggests that projects totalling an average throughout the period of rather more than 600Lkmpa (including junction improvement, public transport or traffic management schemes offering equivalent increases in capacity to road building) should be prepared. This would equate to the annual average rate of road building actually achieved during the 1990s.

The attitude of the motorist

Motorists are concerned about the idea of introducing a national road pricing scheme, not least because it is seen as “just another tax” with unknown consequences for people’s lives. In principle, governments have a wide choice of how to recycle income from efficient pricing—to build more roads, improve public transport, invest in environmental improvements, reduce taxes elsewhere, or increase spending on entirely different social priorities. Each of these choices has different levels of acceptability for the motorist, who has made it clear in opinion polling that their preference is for any revenues to be devoted to transport purposes[133]. The motorist may benefit from any or all of these options, but road pricing will nevertheless be seen as “just another tax” to the extent that the mobility benefits (the value to the motorist of the time saved and the additional distance travelled) are less than the additional charges paid.

In order to identify the transport benefits to road users separately from the disbenefits from taxes and charges a degree of disaggregation of the net benefits displayed in Table 4.36 is required.

As noted above,

Generalised cost = charges + vehicle operating cost + time

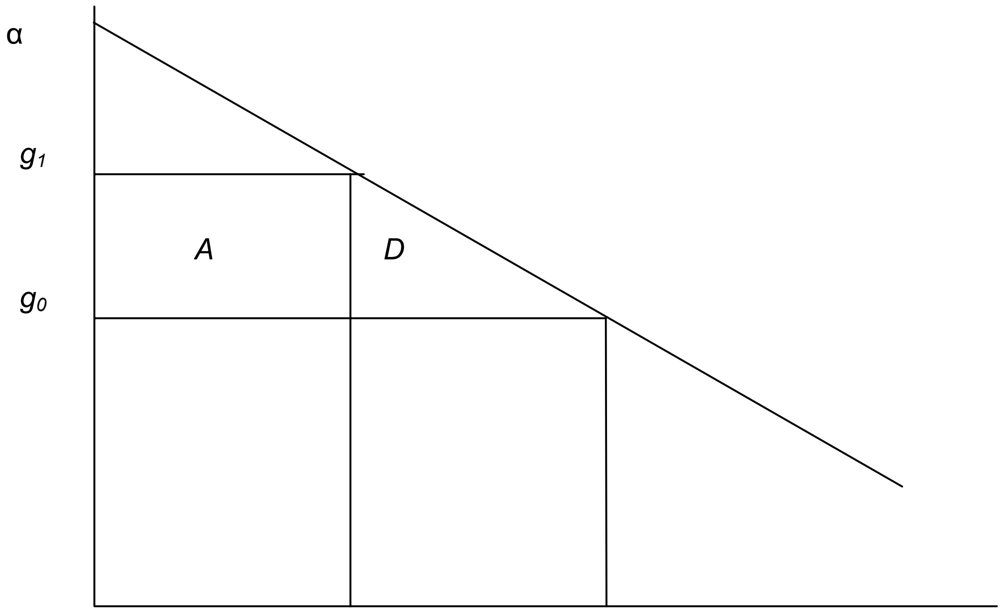
or

$$g = p + voc + t$$

Let g_0 be the generalised cost in the un-priced situation and g_1 be the priced.

The change in user benefit is given by the change in consumer surplus. In the following $f(g)$ represents demand (vkm pa) as a function of generalised cost. α represents an arbitrary, high generalised cost reference point.

$$\int_{g_1}^{\alpha} f(z)\,dz \;-\; \int_{g_0}^{\alpha} f(z)\,dz \;=\; -\int_{g_0}^{g_1} f(z)\,dz$$



In the sketch this is area *–(A + D)* and, using the straight line approximation

$$-(A + D) = -\tfrac{1}{2}(x_0 + x_1)(g_1 - g_0).$$

Rewriting this with the components of GC separated:

$$= -\tfrac{1}{2}(x_0 + x_1)(p_1 - p_0) - \tfrac{1}{2}(x_0 + x_1)\{(voc_1 + t_1) - (voc_0 + t_0)\}$$

We interpret first term here as the welfare cost of raising the charge revenue. In the case of the efficient pricing only scenario where the charge revenue is £84.90 bn (see Table 4.36) this works out at £111.14 bn.

The second term is the benefit of reduced fuel duty (which is the main reason for changes in voc) plus the "transport benefits" (which are the money value of the time savings). In the pricing only scenario these are respectively calculated to be £31.2 bn[134] and £33.2bn as shown in first column and first two rows of Table 4.39.

Table 4.39 recasts the appraisals in Table 4.36 for the cases of efficient pricing with no extra capacity and efficient pricing with 800 Lkmpa, using this disaggregation. It

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[133] RAC Foundation/GfK Poll, 2005

[134] Strictly speaking we should separate out the fiscal effects of the fuel duty reduction and then build up the transport benefits from the duty-free base but we have neglected this consideration.

shows that in 2041 efficient pricing without any extra capacity would cost the traveller 84.9 - 64.75 = £20.2bn per year more than the value of the extra mobility, time saving, safety and public transport benefits – assuming there is no mechanism for recycling the income for the benefit of road users (such as reduced taxes elsewhere or investment in congestion relieving transport projects) The government would gain a net increase in income of about £50bn. At 800 Lkmpa with pricing, the value of the transport benefits to travellers is approximately equal to the additional cost in charges.

Table 4.39. Disaggregation of costs and benefits

Trunk roads all areas	0	800
Road users		
Transport benefits	33.18	50.08
Fuel Duty waived	31.57	30.73
Sub total	64.75	80.81
Welfare costs of road user charge	-111.14	-104.07
Total for road users	**-46.49**	**-23.26**
Exchequer		
Road charges	84.90	81.39
Fuel duty waived	-31.57	-30.73
Public transport subsidies	-2.69	-2.41
Total for Exchequer	**50.64**	**48.25**
General Public		
Environment	16.87	12.69
Carbon	1.21	0.70
Total for general public	**1.21**	**13.39**
Total of net benefits	**22.33**	**38.38**

These figures assume nationwide efficient pricing at marginal economic cost. Selective reduction in charges with a consequent increase in congestion might offer better value for the motorist, and other measures such as waiving Vehicle Excise Duty (say £7bn in 2041), would make the package attractive to motorists at a lower level of road building.

The extent to which the road user is better or worse off, *inter alia*, depends on what he pays in the base case. We could say, as we have done, that he is paying

£1.55/litre without pricing and £1/llitre with pricing. If so, the Exchequer would need to be reimbursed out of the charge revenue for the 55p/litre foregone in tax income.

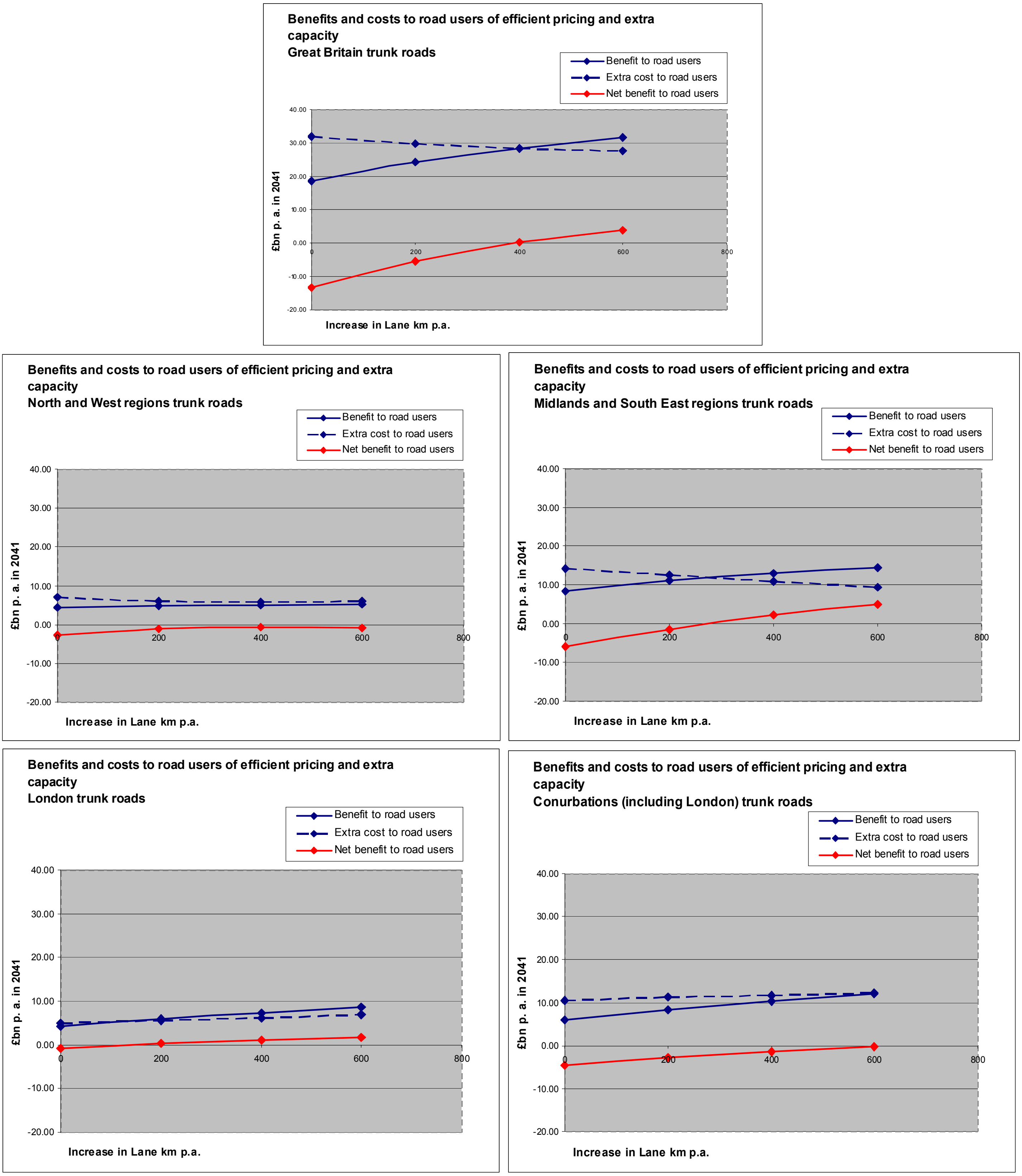
An alternative formulation would be to assume the increase in fuel cost from 80p now to £1/litre in 2041 in all the "with pricing" scenarios includes tax at the same rate as at present (59p/litre) and that this tax includes the 14p carbon tax. The cost of production and royalties would still increase from 21p to 41p per litre. On this basis, there is no need to deduct a tax correction because the tax would be the same as now. In other words, all the road user charges are additional cost to the road user. . This methodology produces the results set out in Table 4.40 and Figure 4.13.

These figures underline the importance of proposals for allocation of the income as part of the road pricing package on public acceptability as well as economic efficiency grounds, including safeguards to reserve a large part of the funds raised for congestion relief and increased accessibility projects. This dimension to the strategy is also necessary to ensure that better transport will be available for more people, including those who would lose from introduction of pricing, and particularly those who are unable to pay the charge and therefore have a diminished choice. Pricing alone addresses congestion at the expense of mobility, whereas additional capacity will reduce congestion at the same time as providing mobility for a larger number of travellers. A good strategy must get this balance right.

Table 4.40. Costs and benefits to trunk road users by regional grouping

Trunk roads All areas	0	200	400	600
Change in traveler benefit	-10.28	-1.23	5.29	9.53
Change in tax & charge revenue	31.81	29.72	28.24	27.71
Gross road user benefits	21.53	28.49	33.53	37.24
Net road user benefits	18.55	24.26	28.38	31.59
Change in revenue after tax correction				
Net benefit to road user	-13.26	-5.46	0.14	3.88
Trunk roads North and west regions (excluding conurbations)	**0**	**200**	**400**	**600**
Change in traveler benefit	-2.04	-0.24	0.18	0.09
Change in tax & charge revenue	7.04	5.97	5.81	5.98
Gross road user benefits	5.00	5.74	6.00	6.07
Net road user benefits	4.31	4.89	5.08	5.15
Change in revenue after tax correction				
Net benefit to road user	-2.73	-1.09	-0.74	-0.83
Trunk roads Midlands and south east regions (excluding conurbations)	**0**	**200**	**400**	**600**
Change in traveler benefit	-4.63	0.37	4.58	7.62
Change in tax & charge revenue	14.26	12.49	10.75	9.40
Gross road user benefits	9.63	12.86	15.33	17.01
Net road user benefits	8.30	10.95	12.98	14.43
Change in revenue after tax correction				
Net benefit to road user	-5.96	-1.54	2.22	5.03
Trunk roads London	**0**	**200**	**400**	**600**
Change in traveler benefit	-0.12	1.37	2.50	3.26
Change in tax & charge revenue	4.97	5.64	6.18	6.91
Gross road user benefits	4.85	7.01	8.68	10.17
Net road user benefits	4.18	5.97	7.35	8.63
Change in revenue after tax correction				
Net benefit to road user	-0.79	0.33	1.16	1.72
Trunk roads all areas	**0**	**200**	**400**	**600**
Change in traveler benefit	-3.61	-1.37	0.53	1.83
Change in tax & charge revenue	10.51	11.25	11.67	12.32
Gross road user benefits	6.89	9.89	12.20	14.15
Net road user benefits	5.94	8.42	10.33	12.00
Change in revenue after tax correction				
Net benefit to road user	-4.57	-2.83	-1.34	-0.32

Figure 4.13. Costs and benefits to users of trunk roads by regional groups



References

A. McKinnon, 2006, Herriot-Watt University, reported at http://www.tnn.co.uk/research/plonearticle.2006-06-22.1653958610

AA, 2007, Fuel Price Reports, http://www.theaa.com/motoring_advice/fuel/index.html [Internet January 2007].

Accent Marketing and Research, Hague Consulting Group and Steer Davies Gleave , 1989, *Inter-city business travel price elasticity research*, Report prepared for British Railways Board.

Accutt M and Dodgson J , 1996, "Cross-elasticities of demand for travel", *Transport Policy*, 2, 271-277.

Algers S., A. Daly, P. Kjellman and S. Widlert , 1995, *Stockholm model system (SIMS): Application*. Paper presented at the 7th World Conference on Transport Research, Sydney.

Archer C. & Glaister S. for the Independent transport Commission, *Investing in Roads: Pricing, Costs and New Capacity*, London, Department of Civil and Environmental Engineering, Imperial College London. http://www.trg.soton.ac.uk/itc/iir_main.pdf.

Arup, Regional Forecasts, OEF, 2005, *Regional Futures, for English Regions Network*, RDA Planning Leads Group, ODPM, DfT

ATOC , 1997, *Passenger demand forecasting handbook*, ATOC: London.

Balcombe, R. et al , 2004, *The demand for public transport: a practical guide*, TRL Report TRL593, Crowthorne.

Bayliss D and Muir Wood A , 2002, *Means to mitigate effects of increasing strategic road capacity in line with demand*, mimeo, 26 November.

Blow L and Crawford I , 1997, *The distributional effects of taxes on private motoring*, Institute of Fiscal Studies, London.

Blum U, Foos G and Guadry M , 1988, "Aggregate time series gasoline demand models: review of the literature and new evidence for West Germany", *Transportation Research A*, 22A, 75-88.

Bristow A and Shires J , 2001, *Quality bus partnerships and market structure: a review of the values of time, elasticities of demand and other parameter values for use in the Quality Bus Partnership Model:* draft report to the DETR.

Bristow A, Hodgson F, Mackie P, Shires J, Preston J, Raje F and Horvald T , 2001, *Achieving best value for public support in the bus industry*, ref. CFITBV1, Institute for Transport Studies.

Brown M., C.-D. Dünkel, F.S. Pekhterev and C. Teo , 1996, *Rail market research in the CIS*, Proceedings of 24th PTRC European Transport Forum; Seminar A; Brunel University.

Burris, M. W., Konduru, K. K. and Swenson, C. R., "Long run changes in driver behaviour due to Variable Tolls", TRB 83rd Annual Meeting, 2004

Civil Aviation Authority, 2006, *UK Airport Statistics 2005*, London, CAA.

Clark S , 1996, “National multi-modal travel forecasts: literature review of aggregate models”, *Working Paper 465, Institute for Transport Studies, University of Leeds*.
Clark S , 1997, “National multi-modal travel forecasts: aggregate elasticities from published Great Britain transport statistics”, *Working Paper 510, Institute for Transport Studies, University of Leeds*.
Coal Authority, 2007, *Summary of Coal Production and Manpower since 1947*, http://www.coal.gov.uk/services/licensingindemnities/index.cfm [Internet January 2007].
Communities and Local Government, 2007, *Homes for the future: more affordable, more sustainable*, HMSO
Dahl C , 1995, “Demand for transportation fuels: a survey of demand elasticities and their components”, *The Journal of Energy Literature*, 1, 3-27.
Daly A.J., G.C. de Jong and K.A. Brohm , 1990, “Vervoerwijzekeuzemodellen met carpooling” Paper presented at Colloquium Vervoersplanologisch Speurwerk; CVS, Delft.
Dargay J & Vythoulkas P , 1999, “Estimation of a dynamic car ownership model: a pseudo-panel approach”, *Journal of Transport Economics & Policy,* 33 (3), 287-301.
Dargay J and Hanly M , 1999, *Bus fare elasticities: report to the Department of Environment, Transport and the Regions*. ESRC Transport Studies Unit, ref. 1999/26, UCL.
Dargay J and Hanly M , 2001, “New evidence on bus fare elasticities for Great Britain”, *Paper presented to the Universities Transport Studies Group Meeting*, Oxford, January, 2001.
Deloitte, 2004, *DfT Road User Charging Feasibility Report on Implementation Feasibility of DfT Road Pricing Policy Scenarios and proposed Business Architecture*, London, DfT.
Department for Communities and Local Government, 2006, *Number of Dwellings on the valuation List at 26 March 2006*, http://www.communities.gov.uk/pub/10/Table104_id1156010.xls [Internet November 2006].
Department for Environment Food and Rural Affairs, 2002, *Digest of Environmental Statistics: New homes built on previously developed land*, London, DEFRA.
Department for Environment Transport and the Regions, 1999, *Focus on Public Transport: Great Britain 1999 Edition*, London, TSO.
Department for Environment Transport and the Regions, 2000, *National Travel Survey: 1997/99 Update*, London, DETR.
Department for Transport Local Government and the Regions, 2001, *A Bulletin of Public Transport Statistics: Great Britain: 2001 Edition* SB (01, 20) London, DTLR.
Department for Transport, 2002, *Transport Statistics Great Britain: 2002 Edition*, London: TSO.
Department for Transport, 2003, *Survey of Foreign Vehicle Activity in Great Britain* SB (03, 29) London, DfT.
Department for Transport, 2004, *Feasibility study of road pricing in the UK*, London, DfT.

Department for Transport, 2004a, *Traffic Speeds on English Trunk Roads 2003*, London, DfT.
Department for Transport, 2004b, *Survey of Privately Owned Vans, Results of Survey October 2002 – September 2003*, London, DfT.
Department for Transport, 2005a, *Traffic Speeds in English Urban Areas 2004* SB (05, 24) London, DfT.
Department for Transport, 2005b, *Public Transport Statistics Bulletin GB: 2005 Edition* SB (05, 31) London, DfT.
Department for Transport, 2005c, *Long Distance Travel: Results from the ONS Omnibus Survey,* http://www.dft.gov.uk/stellent/groups/dft_transstats/documents/page/dft_transstats_039667-03.hcsp#P74_7930 [Internet – January 2007].
Department for Transport, 2005d, *Focus on Personal Travel, London*, TSO.
Department for Transport, 2005e, *Survey of Van Activity (SVA) 2004*, SB (05, 27) London, DfT.
Department for Transport, 2006a *TEMPRO Planning Data Guidance Note*, London, DfT
Department for Transport, 2006a, *Transport Statistics Great Britain: 2006 Edition*, London: TSO.
Department for Transport, 2006b, *Transport Statistics Great Britain: 2006 Edition*, London: TSO.
Department for Transport, 2006b, *Transport Trends 2005 Edition,* London, DfT.
Department for Transport, 2006c, *Public Transport Statistics Bulletin GB: 2006 Edition* SB (06, 29) London, DfT.
Department for Transport, 2006d, *Regional Transport Statistics: 2006 Edition* SB (06, 32) London: DfT.
Department for Transport, 2006e, *National Travel Survey: 2005* SB (06, 30) London: DfT.
Department for Transport, 2006f, *Waterborne Freight in the United Kingdom 2005* SB (06, 33) London: DfT.
Department for Transport, 2006g, *Road Freight Statistics 2005* SB (06, 27) London, DfT.
Department for Transport, 2006h, *Focus on Freight*, London, TSO.
Department for Transport, 2006j, *Road Traffic Statistics: 2005* SB (06, 28) London, TSO.
Department for Transport, 2007, *Transport Analysis Guidance Unit 3.5.6*, DfT, www.webtag.org.uk.
Department of the Environment, Transport and the Regions, 1997, *National Road Traffic Forecasts (Great Britain)*, DETR
Department of Transport, 1975, *Transport Statistics Great Britain 1964-1974*, London, HMSO.
Department of Transport, 1981, *Transport Statistics Great Britain 1970-1980*, London, HMSO.

Department of Transport, 1983a, *Railway Finances: Report of a Committee Chaired by Sir David Serpell KCB CMG OBE*, London, HMSO.
Department of Transport, 1983b, *Transport Statistics Great Britain 1972-1982*, London, HMSO.
Department of Transport, 1984, *Transport Statistics Great Britain 1973-1983*, London, HMSO.
Department of Transport, 1993, *National Travel Survey 1989/91*, London, HMSO.
Department of Transport, 1996, *Transport Statistics Great Britain 1996 Edition*, London, HMSO.
Department of Transport, 1997, *Transport Statistics Great Britain 1976—1986*, London HMSO.
Department of Transport, 2007, *National Travel Survey: 1985/86 Report – Part 1 An Analysis of Personal Travel,* London, HMSO.
DETR , 1997, *Highways economics note 2*, vol. 13, section 2 of the Design Manual for Roads and Bridges.
DETR , 1998, *Transport statistics for London*. DETR: London.
DETR , 1998a, *A New Deal for Trunk Roads in England.* DETR: London
DETR , 1998b, *A New Deal for Trunk Roads in England: understanding the new approach to appraisal.* DETR: London
DETR , 1999, *Transport statistics for metropolitan areas.* DETR: London.
DETR , 2000a, *Modelling using the National Road Traffic Forecasting Framework for Tackling Congestion and Pollution and Transport 2010: The Ten Year Plan: Technical Report*. DETR: London.
DETR , 2000b, Transport *2010: the Ten Year Plan,* DETR: London
DETR , 2000b, *Transport Statistics Great Britain: 2000 Edition*. the Stationary Office: London.
DETR , 2000c, *Air traffic forecasts for the United Kingdom*. DETR: London.
DETR , 2001, *Transport economics note*, DETR: London.
DfT , 2003, *Traffic in Great Britain: Q1 2003 Data*.
DfT , 2004a, *Feasibility study of road pricing in the UK: a report to the Secretary of State for Transport*, DfT, London.
DfT , 2004b, *The future of Transport: a network for 2030: White Paper*, DfT, London.
DfT , 2005, *Transport statistics for Great Britain, 2005*, DfT: London.
DTI , 2000, *Energy projections for the UK*, Energy Paper no. 68, EPTAC Directorate DTI: London.
Economist, 1997, *Pocket Britain in Figures 1997 Edition*, London, Profile Books.
Eddington, Sir Rod, *The Eddington Transport Study*, UK Department for Transport, 2006: http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/

Eltony M , 1993, “Transport gasoline demand in Canada” *Journal of Transport Economics and Policy*, 27, 193 - 208.
European Council of Applied Sciences and Engineering, 2000, *Trends in the location of European industry and its interaction with logistics and transport*, Paris, Euro-CASE.
Evans A , 1992, ‘Road congestion pricing: when is it a good policy’, *Journal of Transport Economics and Policy*, 26, 213-243.
Fairhurst M & Edwards D , 1996, “Bus travel trends in the UK, *Transport Reviews*, 16, 2,, 157-167.
Glaister S, 2001, “The economic assessment of local transport subsidies in large cities”, in Grayling T (ed.) *Any more fares? delivering better bus services*, IPPR: London.
Glaister, S, 2002,, “UK Transport Policy 1997-2001”, *Oxford Review of Economic Policy*, Vol. 18 No.2, Summer 2002.
Glaister S and Graham D , 2001, “Motorists and petrol price changes”, The Utilities Journal, January 2001.
Glaister S and Graham D J , 2003, *Transport pricing and investment in England: technical report*, Imperial College London: London.
Glaister S and Graham DJ , 2000,. The effect of fuel prices on motorists, Automobile Association, ISBN 0 7495 2537 1.
Glaister S and Graham DJ , 2004, *Pricing our roads: vision and reality*. Institute of Economic Affairs: London.
Glaister S and Graham DJ , 2005, ‘An evaluation of national road user charging in England’ *Transportation Research A: Policy and Practice*, 39, 632-650
Glaister S and Graham DJ , 2006, ‘Proper Pricing for Transport Infrastructure and the Case of Urban Road Congestion’, *Urban Studies*.
Glaister S. and Graham, D. J , 2006,. “National Road Pricing: Is it fair and Practical?”, Social Market Foundation:
http://www.smf.co.uk/index.php?name=UpDownload&req=viewdownloaddetails&lid=191/
Goodwin P , 1992, “A review of new demand elasticities with special reference to short and long run effects of price changes” *Journal of Transport Economics and Policy*, 26, 155-163.
Graham D and Glaister S , 2002a, “The demand for automobile fuel: a survey of elasticities”, *Journal of Transport Economics and Policy*, 36, 1-26.
Graham DJ and Glaister S , 2006, ‘Spatial implications of transport pricing’, *Journal of Transport Economics & Policy*.
Grayling T and Glaister S , 2000, *A new fares contract for London*. IPPR: London.
Gunn HF, 1987, *Level-of-service elasticities from NSES*; HCG, The Hague.
Hague Consulting Group , 1990, *The Netherlands’ “Value of Time” Study: Final Report*;

Hague Consulting Group , 1991a, *Elasticiteiten volgens het Landelijk Model*; HCG, The Hague.
Hague Consulting Group , 1991b, *De effecten van Rekening Rijden volgens het Landelijk Model - Rapport B*; HCG, The Hague.
Hague Consulting Group , 1992, *Lange afstands zakelijk verkeer in het Landelijk Model*; HCG, The Hague.
Hague Consulting Group , 1996, *Rapport de validation, Rapport final préparé pour le compte de Syndicat des Transport Parisiens*; HCG, Paris.
Hague Consulting Group , 1997, *ILCM, Integrale Luchthaven Competitie Model*; Los
Hensher D, Milthorpe F and Smith N, 1990, "The demand for vehicle use in the urban household sector: theory and empirical evidence", *Journal of Transport Economics and Policy*, 24, 2, 119-137.
HM Treasury, *The King Review of low carbon cars, Part 1: the potential for CO_2 reduction*, HMSO, London, October 2007.
House of Commons Transport Committee, *Jam tomorrow?: the multimodal study investment plans*, Third Report of Session 2002-03, HC38, March 2003.
http://www.statistics.gov.uk/STATBASE/expodata/files/9750074771.csv
Independent Transport Commission, 2004, *Suburban Future, Southampton*, ITC.
INRETS , 1997, *MATISSE, Test de la version du 15/05/97, Document technique*; INRETS, Paris.
Jager J.M. , 1985, *De invloed van brandstofprijzen op het autopark en de (auto) mobiliteit*; paper presented at Colloquium Vervoersplanologisch Speurwerk; CVS, Delft.
Johansson O and Schipper L , 1997, "Measuring the long run fuel demand of cars: separate estimations of vehicle stock, mean fuel intensity, and mean annual driving distance", *Journal of Transport Economics and Policy*, 31, 277-292.
Jong G de and Gunn H , 2001, "Recent evidence on car cost and time elasticities of travel demand in Europe", *Journal of Transport Economics and Policy*, 35, 137-160.
Keuchel S. , 1994,*Wirkungsanalyse von Maßnahmen zur Beeinflußung des Verkehrmittelwahlverhaltens; Eine empirische Untersuchung des Berufsverkehrs der Stadt Münster*; Universität Münster
Maddison D, Johansson O, Pearce D , 1996, *Blueprint 5: the true costs of road transport.* Earthscan: London.
Ministry of Transport/British Railways Board, 1963, *Reshaping of British Railways*, London, HMSO
Monopolies and Mergers Commission , 1994, *Report on the Midland Main line-National Express Group Merger.*
MVA Consultancy , 1987, *LDTM travel demand elasticities*; MVA, London.

MVA Consultants, Institute for Transport Studies University of Leeds, and Transport Studies Unit University of Oxford , 1987, *The value of travel time savings*, Policy Journals: Newbery.
National Statistics, 2000, *National Travel Survey: 1997/99 Update*, London, ONS.
National Statistics, 2005, *Social Trends No. 35 – 2006 Edition*, London, palgrave macmillan.
National Statistics, 2006a, *GAD National population projections 2004-based*, London, Palgrave Macmillan
National Statistics, 2006a, *Gross Domestic Product chained volume measure table ABMI*, http://www.statistics.gov.uk/CCI/nscl.asp?ID=5910 [Internet November 2006].
National Statistics, 2006b, *UK Population Grows to more than 60m*, [Internet January 2007] http://www.statistics.gov.uk/CCI/nugget.asp?ID=6
National Statistics, 2006c, *Social Trends No. 36 – 2006 Edition*, London, palgrave macmillan.
National Statistics, 2006d, *Employment and Earnings Estimates* (BCAJ + DYZN), http://www.statistics.gov.uk/statbase/TSDSeries1.asp [Internet January 2007].
National Statistics, 2006e, *Family Spending: A Report on the 2005-2006 Family Expenditure Survey*, London, palgrave macmillan.
National Statistics, 2006f, *Population Trends Summer 2006 N0 124*, London, palgrave macmillan.
National Statistics, 2006g, *Trade in Goods and Services*, http://www.statistics.gov.uk/statbase/TSDSeries1.asp [Internet January 2007].
National Statistics, 2006h, Internet Access, http://www.statistics.gov.uk/CCI/nugget.asp?ID=8&Pos=1&ColRank=1&Rank=176 [Internet January 2007].
National Statistics, 2006i, *Value of Internet sales rises 5% in 2005,* London, ONS News Release.
National Statistics, 2006j, *Gross Domestic Product by Gross Values Added,* http://www.statistics.gov.uk/StatBase/tsdataset.asp?vlnk=3282&More=N&All=Y [Internet January 2007].
National Statistics, 2006k, *2005 e-commerce survey of business: Information and Communications Technologies adoption and usage*, http://www.statistics.gov.uk/statbase/product.asp?vlnk=6645 [Internet – January 2007].
National Statistics, 2007a, *Retail Price Index 1946 – 2006*,
National Statistics, 2007b, *2006-based national population projections: underlying long-term assumptions.*
NERA, AEA Technology, TRL , 1999, *Report on the study into lorry track and environmental costs*. NERA: London.
Newbery D , 1998, *Fair payment from road-users: a review of the evidence on social and environmental costs*, AA Policy Paper. The Automobile Association: Basingstoke.

Newbery D , 2002, *Road user and congestion charges, mimeo*, University of Cambridge, August.
ODPM , 2004, *The English indices of deprivation*, 2004, ODPM: London.
Office of Communications, 2006, *The Communications Market 2006*, London, OfCom.
Office of the Rail Regulator, 2006, *National Rail Trends Yearbook 2005/06,* London ORR.
ONS , 2001a, *Regional Trends*. ONS: London.
ONS , 2001b, *Family Spending*. ONS: London.
Oscar Faber and NERA , 2002,, *Paying for road use: technical report*, Commission for Integrated Transport.
Peirson J and Vickerman R , 1997, "Environmental effects of transport: a model of optimal pricing and investment for the UK", *International Journal of Environment and Pollution*, 17(3), 343-356.
Phillip's, 2006, *Navigator Britain*, London. Phillip's.
Poterba JM , 1991, 'Is the gasoline tax regressive?', in Bradford D (ed) *Tax policy and the economy 5*, MIT Press, Cambridge MA.
Potter, S., 1997, *Vital Travel Statistics*, London, Landor Publishing.
Preston J , 1998, *Public transport elasticities: time for a rethink*?, *Paper presented to the Universities Transport Studies Group Conference*, Dublin, January, 1998.
Preston J , 2000, "Big and small is beautiful: the emerging organisation of the Pan-European bus industry", in Meersman H, Van de Voorde E and Winkleman W (eds.), *Selected Proceedings of the 8th World Conference on Transport Research*, Transport Policy, 4. Pergamon: Oxford.
Preston J and Mackie P , 1990, *Assessing the economics and finances of concessionary fares schemes*, PTRC Summer Annual Meeting, September 1990.
Proost S and Van Dender K , 1999, *TRENEN II STRAN: final report for publication*. Centre for Economic Studies: Katholieke Universiteit, Leuven.
Puller S and Greening L , 1999, "Household adjustment to gasoline price change: an analysis using 9 years of US survey data", *Energy Economics*, 21, 37-52.
Report for Dienst Verkeerskunde, Rijkswaterstaat; HCG, The Hague.
Richardson H and Bae CH , 1998, "The equity impacts of road congestion charging", in Button K and Verheof A *Road pricing, traffic congestion, and the environment: issues of efficiency and social feasibility*, Edward Elgar, Cheltenham.
ROCOL , 2000, *Road user charging options for London: report of a working party*, Government Office for London: London.
Romilly P, Song H and Liu X , 1998, "Modelling and forecasting car ownership in Britain: a co-integration and general to specific approach", *Journal of Transport Economics and Policy*, 32 , 2,, 165-185.

Rouwendal J , 1996, “An economic analysis of fuel use per kilometre by private cars”, *Journal of Transport Economics and Policy*, 30, 3-14.
Roy R (ed.), 2000, *Revenues from efficient pricing: evidence from the member states: final report study*. For UIC, CER and the European Commission. UIC: Paris.
Sansom T, Nash CA, Mackie PJ, Shires J , 2001, *Surface transport costs and charges: final report*. For the Department of Transport Environment and the Regions, Institute for Transport
Sansom T, Still B, Nash C , 1999, *Cross channel case study*. Pricing European Transport Systems deliverable 9, Institute for Transport Studies, University of Leeds.
Santos G and Rojey L , 2004, “Distributional impacts of road pricing: the truth behind the myth”, *Transportation*, 31, 21-42.
Scottish Executive, 2004, *Scottish index of multiple deprivation 2004, summary technical report*, Scottish Office: Edinburgh.
Selvanathan E.A. and S. Selvanathan , 1994, “The demand for transport and communication in the United Kingdom and Australia” *Transportation Research* 28B , 1,, pp. 1-9.
Small K. A., *Urban Transportation Economics*, Harwood Academic Publishers, 1992.
Small, K. A. “The Scheduling of Consumer Activities: Work Trips”, *The American Economic Review*, Vol. 72, No. 3 (June 1982), 467-479
Starkie D , 2002, “Road networks: efficiency, externalities and consumer choice”, The Beesley Lectures, 2002.
Statistics for Wales, 2005, *The Welsh index of multiple deprivation: summary report*. Stats Wales: Cardiff.
Stern, Sir Nicholas, “The Economics of Climate Change”, 2006: Cambridge. www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm
Sterner T and Dahl C , 1992, “Modelling transport fuel demand”, in T Sterner (ed.) *International Energy economics*, Chapman and Hall, London, 65-79.
Sterner T, Dahl C and Franzén M , 1992, “Gasoline tax policy: carbon emissions and the global environment”, *Journal of Transport Economics and Policy*, 26, 109-119.
Studies, University of Leeds, Leeds, April 2001.
Toner J.P., M. Wardman & G.A. Whelan , 1995, “Competitive interactions in the inter-urban travel market in Great Britain”; Proceedings of 23rd PTRC European Transport Forum, Seminar F, pp. 29-40; University of Warwick.
Trace , 1998a, *Review of Existing Evidence on Time and Cost Elasticities of Travel Demand and on the Value of Travel Time*. TRACE consortium: The Hague.
Transport for London, *Transport 2025*, November 2006: www.tfl.gov.uk/assets/downloads/corporate/T2025-exec-summary-new.pdf
Transport for London. *London Travel Report 2006*, December 2006, London, TfL.

Transport for London, 2002, *Report to the GLA Transport Committee 27th September 2002*, London TfL.
Transport for London, 2006, *Central London Congestion Charging Impacts Monitoring Fourth Annual Report*, London, Mayor of London.
U.S. Department of Transportation et. al., 2007, *2006 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance*: Report to Congress, March.
Waard J. van der , 1990, *Koncept Elasticiteiten Handboek*; Rijkswaterstaat, Dienst verkeerskunde, Rotterdam.
Wardman M, 1997a, "Disaggregate urban mode choice models: a review of the British evidence with special reference to cross elasticities", *Working Paper 505, Institute for Transport Studies, University of Leeds*.
Wardman M, 1997c, "A review of evidence on the value of travel time in Great Britain", *Working Paper 495, Institute for Transport Studies, University of Leeds*.
Wardman M, 1998a, "A review of the British evidence on the valuations of time and service quality", *Working Paper 525, Institute for Transport Studies, University of Leeds*.
Wardman M, 1998b, "The value of travel time: a review of the British Evidence" *Journal of Transport Economics and Policy*, 32 (3), 285-316.
Wardman M, 2000, "Using stated preference data to analyse bus preferences", *Working Paper 555, Institute for Transport Studies, University of Leeds*.
Wardman M, 2001, "A review of the British evidence on time and service quality valuations", *Transportation Research E*, 37E, 2-3, 107-128.
Wardman M, 1997a, "Disaggregate inter-urban mode choice models: A review of British evidence with special reference to cross elasticities"; Working Paper 504; Institute of Transport Studies, University of Leeds.
Wardman M, Toner J and Whelan G, 1997, "Interaction between rail and car in the inter-urban leisure travel market in Great Britain, *Journal of Transport Economics and Policy*, 31, 163-181.
Wardman M., 1997b, "Disaggregate urban mode choice models: A review of British evidence with special reference to cross elasticities"; Working Paper 505; Institute of Transport Studies, University of Leeds.
Whelan G, 1997, "National multi-modal travel forecasts: a review of car ownership forecasting", *Working Paper 489, Institute for Transport Studies, University of Leeds*.
White P, 2000, "Bus tendering in London - a critique", *Paper presented to the workshop "Review of London's Bus Contracting Regime"*.
WS Atkins Planning Consultants & Polak J, 1997, *Bus reliability study - stated preference research: draft final report to the Department of Transport*.

Annex 1 Arup traffic forecasts

1. INTRODUCTION

As part of the RAC Foundation strategic planning study, Arup have undertaken a high level forecasting exercise of total vehicle kilometres by region for the UK, for the period 2006 – 2041. This exercise used a number of strategic variables to calculate forecast vehicle kilometres, including car ownership, fuel price and income. However, it is worth noting that the forecast model does not take into account factors such as network capacity or changing trip distribution patterns. The approach used simple elasticities to calculate vehicle kilometres.

The model outputs forecast vehicle kilometre for each of the government office regions for the period 2005 – 2041. These are presented below, together with an explanation of the model structure and methodology.

2. FORECASTING METHODOLOGY

Three primary drivers were used to forecast vehicle kilometres. These were;

1 Real Income per Household (by region) (Source: Oxford Economic Forecasting Model),
2 Fuel Price (UK) (2000 – 2004 Source: European Energy and Transport Report, World Baseline Scenario, European Union, 2006, and
3 Car Ownership (by region) (Source: TEMPRO V5 database).

Simple elasticities were applied to the forecast growth of each of the above variables in order to develop the forecast in vehicle kilometres. The associated elasticities for each of these variables were:

1 Vehicle Kilometres to Income growth is 0.2 (Source: TEMPRO Guidance Note, Section 4.15).
2 Vehicle Kilometres to Fuel price growth is -0.25 (Source: TEMPRO Guidance Note, Section 4.15).
3 Vehicle Kilometres to Car Ownership growth to is 0.68 (Source: based on data taken from the Department for Transport's National Road Traffic Survey, 1995 to 2005).

2.1 Income

As income rises the propensity to travel increases as travel becomes more affordable. An elasticity taken from the TEMPRO guidance of 0.2 between income growth and vehicle kilometres travelled was assumed. This elasticity in income was applied for each year between 2006 and 2041. Figure A1.1 displays the forecast growth in income per household by region from 2000 to 2041. Growth in Real Personal Household Income per capita was used (based on Oxford Economic Forecasting Model). See Table A1.1 below for year on year growth.

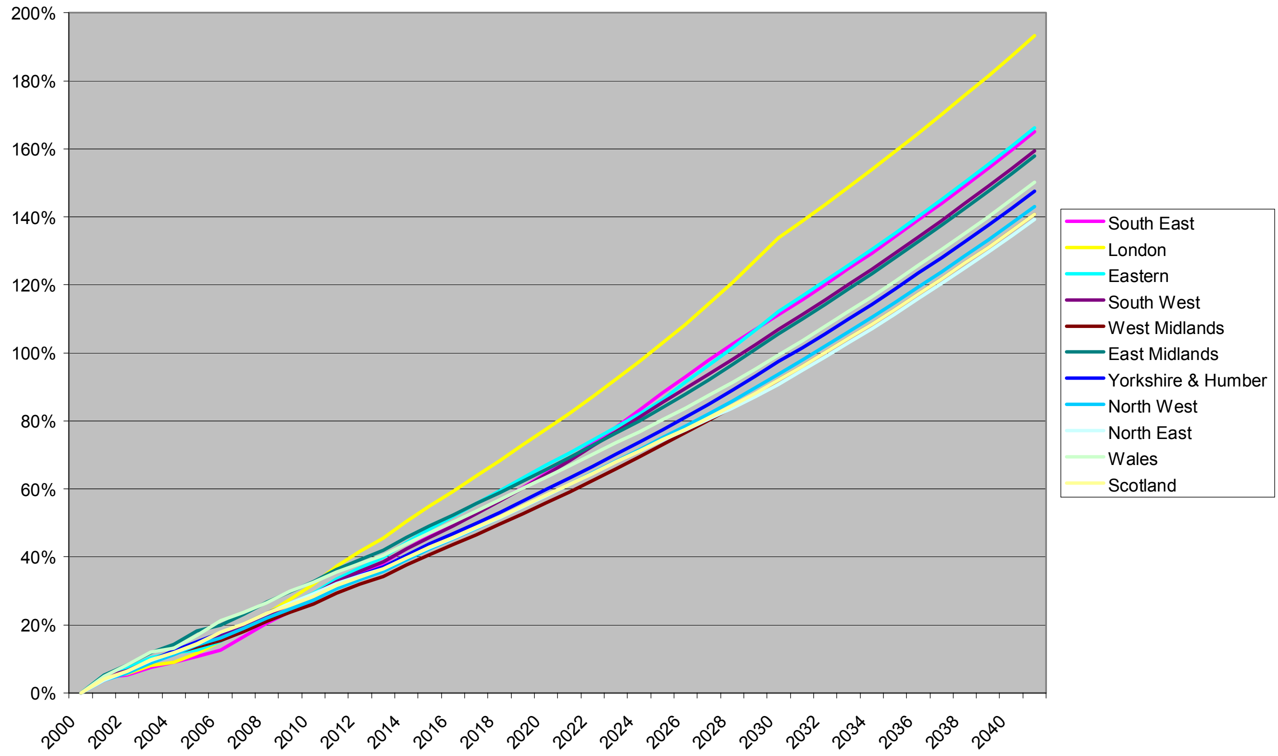


Figure A1.1: Cumulative Growth in Income by Household by Region
Source: Oxford Economic Forecasting Model

2.2 Fuel Price (UK)

Fuel price has a direct effect on the cost of travel. The elasticity assumed between fuel price and vehicle kilometres per car was -0.25 (taken from TEMPRO Guidance Note, Section 4.15) therefore as fuel price increases by 1% vehicle kilometres per car decrease by 0.25%. Growth in fuel price after 2005 was set at 1.6% per annum. Table A1.2 below displays the fuel price growth rates.

2.3 Car Ownership (by region)

As car ownership increases the number of vehicle kilometres also increase. However, the two variables increase at different rates. Using historical car ownership data 1995 to 2005 an elasticity of 0.68 for this relationship was derived. Figure A1.2 below shows the cumulative growth in car ownership, and the year on year growth in car ownership can be found in Table A1.3 below.

Growth rates adjusted to allow for each of the variables described above were developed. These were then applied to the observed vehicle kilometres by region for 2005 taken from TEMPRO V5 database and forecasted forward year on year to 2041.

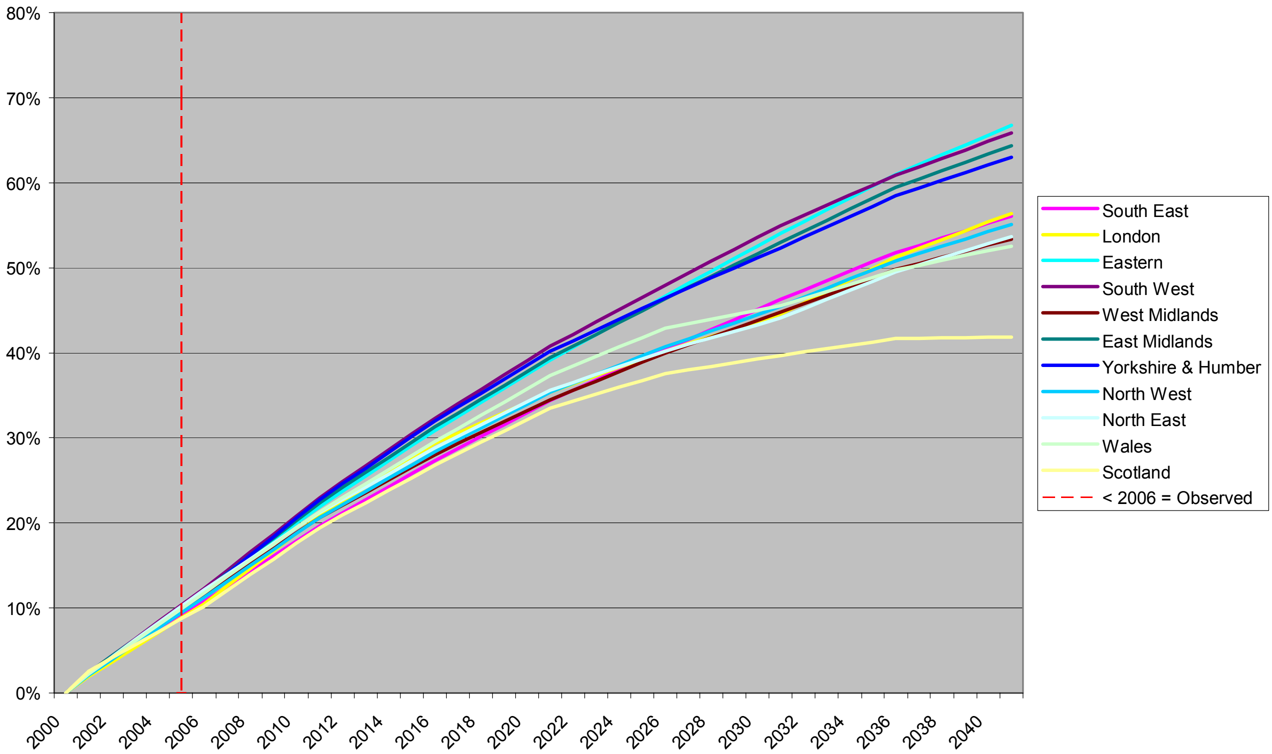


Figure A1.2: Cumulative Growth in Car Ownership
Source**:** TEMPRO V5 database

3. RESULTS

Figure A1.3 displays the increase in vehicle kilometres by government office region from 2000 – 2041, and Figure A1.4 displays vehicle kilometres for all regions. 2000 - 2005 observed data obtained from the DfT's National Road Traffic Survey. Tables A1.4, A1.5 and A1.6 below show vehicle kilometre (in millions), year on year growth rate and the compound annual growth rate respectively.

Figure A1.3: Vehicle Kilometre (millions) Forecast by Region

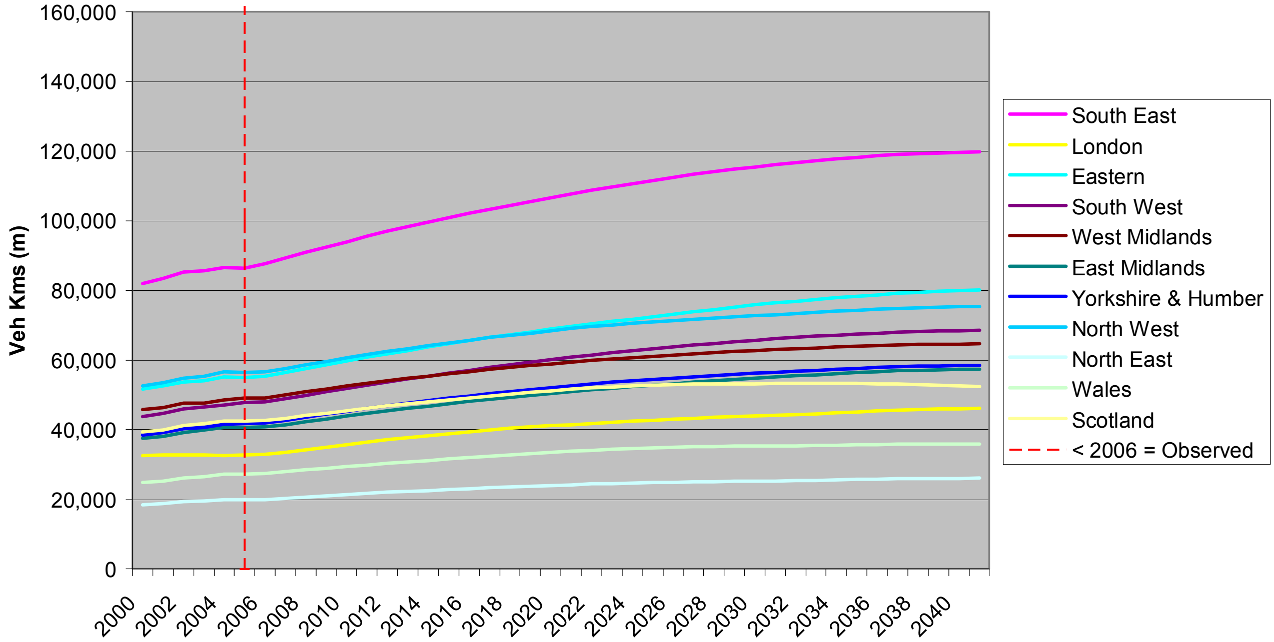


Figure A1.4: Total Region Vehicle Kilometre (millions) Forecast

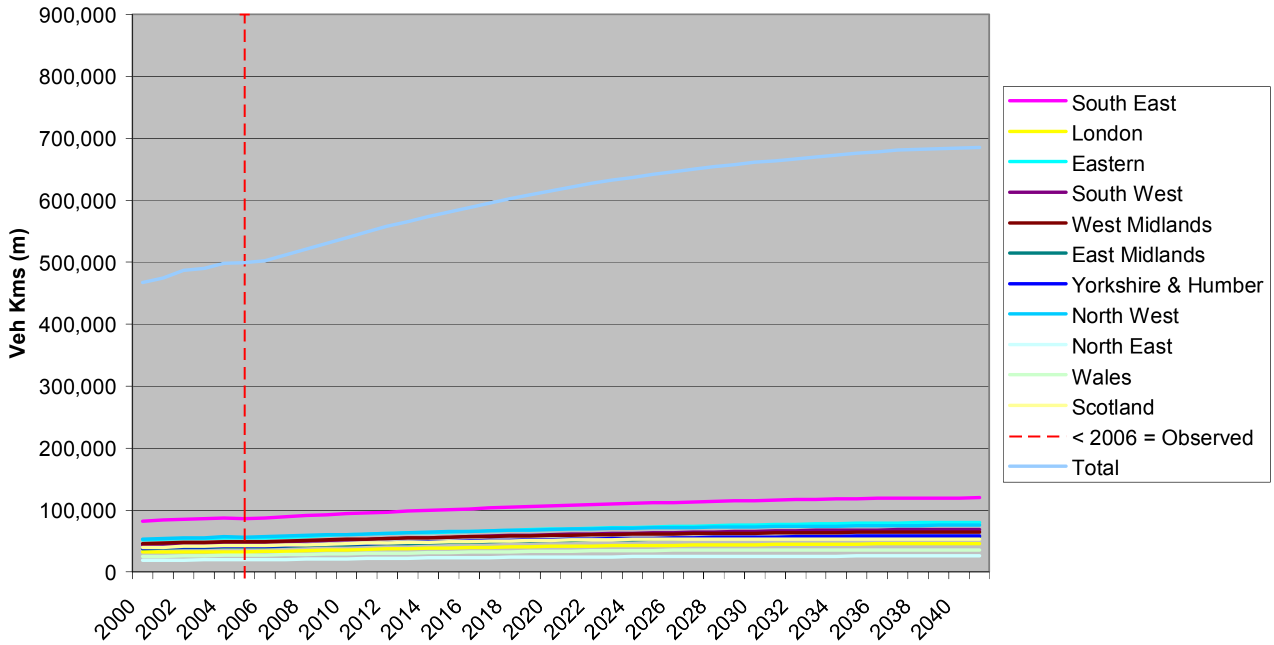


Table A1.1: Year on Year Growth in Household Income

Year	South East	London	Eastern	South West	West Midlands	East Midlands	Yorkshire & Humber	North West	North East	Wales	Scotland	Total
2000	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
2001	**4.51%**	**4.83%**	**5.34%**	**4.66%**	**4.19%**	**5.24%**	**3.81%**	**3.74%**	**3.71%**	**4.85%**	**4.07%**	**4.49%**
2002	**0.80%**	**0.76%**	**1.91%**	**1.82%**	**1.90%**	**2.85%**	**2.40%**	**2.05%**	**2.54%**	**3.25%**	**2.28%**	**1.77%**
2003	**2.11%**	**2.30%**	**2.77%**	**2.77%**	**2.50%**	**3.33%**	**3.15%**	**2.78%**	**3.05%**	**3.45%**	**3.08%**	**2.70%**
2004	**1.27%**	**0.82%**	**1.28%**	**1.71%**	**2.51%**	**2.19%**	**2.56%**	**2.31%**	**2.04%**	**1.09%**	**1.92%**	**1.69%**
2005	**1.57%**	**2.53%**	**0.69%**	**2.67%**	**1.68%**	**3.40%**	**2.22%**	**2.43%**	**2.23%**	**3.25%**	**2.35%**	**2.16%**
2006	1.70%	3.08%	2.40%	2.14%	1.71%	1.39%	2.32%	1.86%	3.03%	3.74%	2.97%	2.31%
2007	3.57%	3.18%	3.17%	2.45%	2.35%	2.73%	2.29%	2.45%	2.11%	1.99%	2.12%	2.75%
2008	3.32%	3.75%	3.36%	2.67%	2.52%	2.95%	2.61%	2.50%	2.47%	2.33%	2.58%	2.96%
2009	2.90%	3.49%	2.66%	2.46%	2.12%	2.41%	2.23%	2.22%	2.57%	2.69%	1.95%	2.61%
2010	2.73%	3.44%	2.61%	2.48%	2.06%	2.30%	2.07%	2.14%	2.15%	1.94%	2.01%	2.49%
2011	3.24%	3.98%	3.08%	2.85%	2.56%	2.70%	2.53%	2.58%	2.36%	2.26%	2.48%	2.95%
2012	2.66%	3.21%	2.49%	2.25%	1.94%	2.09%	1.92%	1.98%	1.69%	1.80%	1.90%	2.33%
2013	2.41%	2.75%	2.32%	2.08%	1.80%	1.95%	1.78%	1.86%	1.63%	1.82%	1.73%	2.13%
2014	2.93%	3.39%	3.02%	2.69%	2.46%	2.63%	2.53%	2.52%	2.33%	2.37%	2.43%	2.78%
2015	2.64%	3.07%	2.79%	2.49%	2.24%	2.39%	2.32%	2.30%	2.14%	2.31%	2.21%	2.53%
2016	2.38%	2.78%	2.53%	2.33%	2.04%	2.17%	2.12%	2.11%	1.98%	2.17%	2.02%	2.32%
2017	2.35%	2.79%	2.48%	2.38%	2.07%	2.15%	2.13%	2.12%	2.03%	2.16%	2.05%	2.32%
2018	2.37%	2.77%	2.42%	2.42%	2.08%	2.13%	2.14%	2.12%	2.07%	2.15%	2.07%	2.32%
2019	2.42%	2.74%	2.35%	2.46%	2.09%	2.11%	2.14%	2.12%	2.08%	2.13%	2.08%	2.32%
2020	2.56%	2.69%	2.28%	2.48%	2.09%	2.09%	2.14%	2.10%	2.08%	2.09%	2.07%	2.32%
2021	2.61%	2.68%	2.24%	2.50%	2.10%	2.09%	2.14%	2.10%	2.08%	2.05%	2.05%	2.32%
2022	2.71%	2.66%	2.19%	2.50%	2.11%	2.09%	2.13%	2.08%	2.04%	2.00%	2.02%	2.32%
2023	2.78%	2.67%	2.18%	2.47%	2.11%	2.10%	2.12%	2.06%	1.99%	1.96%	1.98%	2.33%
2024	2.80%	2.70%	2.19%	2.42%	2.11%	2.12%	2.11%	2.05%	1.93%	1.95%	1.94%	2.33%
2025	2.75%	2.75%	2.25%	2.36%	2.11%	2.16%	2.12%	2.04%	1.88%	1.95%	1.92%	2.33%
2026	2.58%	2.79%	2.84%	2.23%	2.05%	2.14%	2.06%	1.98%	1.79%	1.92%	1.84%	2.33%
2027	2.49%	2.87%	2.56%	2.23%	2.08%	2.23%	2.14%	2.04%	1.75%	2.00%	1.91%	2.33%
2028	2.34%	2.91%	2.57%	2.20%	2.11%	2.27%	2.16%	2.07%	1.82%	2.04%	1.94%	2.33%
2029	2.20%	2.93%	2.62%	2.20%	2.13%	2.30%	2.19%	2.09%	1.87%	2.08%	1.97%	2.32%
2030	2.08%	2.92%	2.67%	2.22%	2.14%	2.30%	2.21%	2.10%	1.91%	2.12%	2.01%	2.32%
2031	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2032	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2033	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2034	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2035	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2036	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2037	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2038	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2039	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2040	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%
2041	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%	2.08%

Source: Based on Oxford Economic Forecasting Model

Table A1.2: Fuel Price Cumulative Growth

Year	Growth Rate
2005	**1.016**
2006	1.032
2007	1.049
2008	1.066
2009	1.083
2010	1.100
2011	1.118
2012	1.135
2013	1.154
2014	1.172
2015	1.191
2016	1.210
2017	1.229
2018	1.249
2019	1.269
2020	1.289
2021	1.310
2022	1.331
2023	1.352
2024	1.374
2025	1.396
2026	1.418
2027	1.441
2028	1.464
2029	1.487
2030	1.511
2031	1.535
2032	1.560
2033	1.585
2034	1.610
2035	1.636
2036	1.662
2037	1.688
2038	1.715
2039	1.743
2040	1.771
2041	1.799

Source: European Energy and Transport Report, World Baseline Scenario, European Union, 2006

Table A1.3: Year on Year Growth in Car Ownership

Year	South East	London	Eastern	South West	West Midlands	East Midlands	Yorkshire & Humber	North West	North East	Wales	Scotland	Total
2000	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
2001	**2.14%**	**1.93%**	**2.21%**	**2.39%**	**2.26%**	**2.44%**	**2.27%**	**2.10%**	**2.25%**	**2.25%**	**2.59%**	**2.23%**
2002	**1.69%**	**1.68%**	**1.91%**	**1.93%**	**1.83%**	**1.86%**	**1.87%**	**1.79%**	**1.93%**	**1.86%**	**1.48%**	**1.79%**
2003	**1.66%**	**1.65%**	**1.88%**	**1.89%**	**1.80%**	**1.83%**	**1.84%**	**1.76%**	**1.89%**	**1.82%**	**1.46%**	**1.76%**
2004	**1.63%**	**1.62%**	**1.84%**	**1.86%**	**1.77%**	**1.80%**	**1.81%**	**1.73%**	**1.86%**	**1.79%**	**1.44%**	**1.73%**
2005	**1.61%**	**1.60%**	**1.81%**	**1.82%**	**1.74%**	**1.77%**	**1.77%**	**1.70%**	**1.82%**	**1.76%**	**1.42%**	**1.70%**
2006	1.58%	1.57%	1.78%	1.79%	1.71%	1.73%	1.74%	1.67%	1.79%	1.73%	1.40%	1.67%
2007	1.60%	1.87%	1.77%	1.90%	1.61%	1.85%	1.94%	1.68%	1.63%	1.71%	1.67%	1.75%
2008	1.58%	1.84%	1.74%	1.87%	1.59%	1.82%	1.91%	1.65%	1.60%	1.68%	1.65%	1.72%
2009	1.55%	1.81%	1.71%	1.83%	1.56%	1.79%	1.87%	1.63%	1.58%	1.65%	1.62%	1.69%
2010	1.53%	1.77%	1.68%	1.80%	1.54%	1.76%	1.84%	1.60%	1.55%	1.63%	1.59%	1.66%
2011	1.51%	1.74%	1.66%	1.77%	1.51%	1.73%	1.80%	1.58%	1.53%	1.60%	1.57%	1.63%
2012	1.29%	1.41%	1.47%	1.53%	1.23%	1.46%	1.51%	1.29%	1.25%	1.36%	1.23%	1.37%
2013	1.27%	1.39%	1.45%	1.51%	1.22%	1.44%	1.49%	1.27%	1.23%	1.34%	1.22%	1.35%
2014	1.25%	1.38%	1.43%	1.48%	1.20%	1.42%	1.47%	1.26%	1.22%	1.33%	1.20%	1.33%
2015	1.24%	1.36%	1.41%	1.46%	1.19%	1.40%	1.44%	1.24%	1.20%	1.31%	1.19%	1.32%
2016	1.22%	1.34%	1.39%	1.44%	1.17%	1.38%	1.42%	1.22%	1.19%	1.29%	1.17%	1.30%
2017	1.11%	0.93%	1.26%	1.27%	1.01%	1.23%	1.24%	1.09%	1.06%	1.19%	1.06%	1.13%
2018	1.10%	0.93%	1.25%	1.26%	1.00%	1.22%	1.22%	1.08%	1.05%	1.18%	1.05%	1.12%
2019	1.09%	0.92%	1.23%	1.24%	0.99%	1.20%	1.21%	1.07%	1.04%	1.17%	1.04%	1.11%
2020	1.08%	0.91%	1.22%	1.23%	0.98%	1.19%	1.20%	1.06%	1.03%	1.15%	1.03%	1.10%
2021	1.06%	0.90%	1.20%	1.21%	0.97%	1.18%	1.18%	1.05%	1.02%	1.14%	1.02%	1.08%
2022	0.89%	0.71%	1.08%	1.03%	0.81%	1.00%	0.90%	0.79%	0.68%	0.82%	0.61%	0.86%
2023	0.88%	0.70%	1.07%	1.02%	0.80%	0.99%	0.89%	0.78%	0.67%	0.81%	0.60%	0.86%
2024	0.88%	0.70%	1.06%	1.01%	0.80%	0.98%	0.88%	0.77%	0.67%	0.81%	0.60%	0.85%
2025	0.87%	0.69%	1.05%	1.00%	0.79%	0.97%	0.87%	0.77%	0.66%	0.80%	0.60%	0.84%
2026	0.86%	0.69%	1.04%	0.99%	0.79%	0.96%	0.87%	0.76%	0.66%	0.80%	0.59%	0.84%
2027	0.84%	0.62%	1.01%	0.95%	0.69%	0.90%	0.81%	0.68%	0.55%	0.36%	0.30%	0.74%
2028	0.83%	0.62%	1.00%	0.94%	0.68%	0.90%	0.80%	0.67%	0.55%	0.36%	0.30%	0.74%
2029	0.82%	0.61%	0.99%	0.93%	0.68%	0.89%	0.79%	0.67%	0.55%	0.36%	0.30%	0.73%
2030	0.82%	0.61%	0.98%	0.92%	0.67%	0.88%	0.79%	0.66%	0.54%	0.36%	0.30%	0.73%
2031	0.81%	0.60%	0.97%	0.91%	0.67%	0.87%	0.78%	0.66%	0.54%	0.36%	0.30%	0.72%
2032	0.75%	0.93%	0.90%	0.76%	0.69%	0.85%	0.80%	0.74%	0.75%	0.58%	0.29%	0.75%
2033	0.75%	0.92%	0.89%	0.76%	0.69%	0.84%	0.79%	0.74%	0.75%	0.58%	0.29%	0.75%
2034	0.74%	0.91%	0.88%	0.75%	0.69%	0.83%	0.79%	0.73%	0.74%	0.57%	0.29%	0.74%
2035	0.74%	0.91%	0.88%	0.75%	0.68%	0.83%	0.78%	0.72%	0.74%	0.57%	0.29%	0.73%
2036	0.73%	0.90%	0.87%	0.74%	0.68%	0.82%	0.77%	0.72%	0.73%	0.57%	0.29%	0.73%
2037	0.57%	0.68%	0.72%	0.61%	0.48%	0.62%	0.57%	0.57%	0.56%	0.38%	0.03%	0.55%
2038	0.56%	0.68%	0.71%	0.61%	0.48%	0.61%	0.57%	0.57%	0.55%	0.38%	0.03%	0.55%
2039	0.56%	0.67%	0.71%	0.61%	0.48%	0.61%	0.57%	0.56%	0.55%	0.38%	0.03%	0.54%
2040	0.56%	0.67%	0.70%	0.60%	0.47%	0.61%	0.56%	0.56%	0.55%	0.38%	0.03%	0.54%
2041	0.55%	0.66%	0.70%	0.60%	0.47%	0.60%	0.56%	0.56%	0.54%	0.38%	0.03%	0.54%

Source: TEMPRO V5 database

Table A1.4: Vehicle Kilometre (millions) Forecast by Region

Year	South East	London	Eastern	South West	West Midlands	East Midlands	Yorkshire & Humber	North West	North East	Wales	Scotland	Total
2000	**82,063**	**32,635**	**51,628**	**43,790**	**45,777**	**37,434**	**38,502**	**52,609**	**18,452**	**24,865**	**39,331**	**467,086**
2001	**83,528**	**32,682**	**52,527**	**44,685**	**46,294**	**38,075**	**39,153**	**53,583**	**18,840**	**25,248**	**39,829**	**474,444**
2002	**85,320**	**32,791**	**53,664**	**45,988**	**47,584**	**39,184**	**40,294**	**54,823**	**19,379**	**26,203**	**41,285**	**486,515**
2003	**85,576**	**32,817**	**54,021**	**46,553**	**47,686**	**39,938**	**40,568**	**55,296**	**19,562**	**26,592**	**41,789**	**490,398**
2004	**86,501**	**32,619**	**55,097**	**47,148**	**48,646**	**40,654**	**41,579**	**56,548**	**19,869**	**27,315**	**42,474**	**498,450**
2005	**86,402**	**32,686**	**55,026**	**47,818**	**49,033**	**40,633**	**41,794**	**56,427**	**19,887**	**27,277**	**42,475**	**499,458**
2006	87,625	32,884	55,282	48,015	49,194	40,741	41,982	56,630	20,005	27,477	42,724	502,559
2007	89,294	33,474	56,389	48,914	50,065	41,503	42,734	57,625	20,366	27,950	43,329	511,643
2008	90,933	34,214	57,535	49,902	50,916	42,345	43,610	58,644	20,714	28,442	44,098	521,353
2009	92,496	34,937	58,601	50,867	51,724	43,141	44,451	59,627	21,064	28,953	44,809	530,669
2010	94,024	35,657	59,657	51,830	52,522	43,924	45,275	60,594	21,396	29,419	45,522	539,820
2011	95,643	36,417	60,767	52,829	53,367	44,739	46,135	61,610	21,735	29,901	46,272	549,415
2012	97,020	37,123	61,805	53,764	54,144	45,498	46,939	62,550	22,043	30,353	46,968	558,208
2013	98,283	37,682	62,718	54,565	54,758	46,132	47,599	63,302	22,289	30,738	47,495	565,561
2014	99,639	38,287	63,714	55,425	55,438	46,823	48,326	64,131	22,564	31,154	48,082	573,583
2015	100,930	38,866	64,677	56,260	56,087	47,488	49,028	64,925	22,828	31,563	48,643	581,296
2016	102,161	39,420	65,602	57,071	56,710	48,128	49,706	65,688	23,082	31,960	49,181	588,710
2017	103,306	39,974	66,515	57,884	57,329	48,761	50,381	66,446	23,336	32,353	49,716	596,000
2018	104,412	40,367	67,339	58,608	57,859	49,324	50,966	67,116	23,562	32,715	50,200	602,468
2019	105,519	40,753	68,147	59,330	58,383	49,880	51,545	67,778	23,785	33,071	50,678	608,870
2020	106,640	41,132	68,937	60,048	58,899	50,426	52,118	68,430	24,006	33,420	51,149	615,205
2021	107,761	41,504	69,712	60,761	59,410	50,965	52,683	69,072	24,223	33,762	51,611	621,464
2022	108,772	41,872	70,473	61,468	59,914	51,498	53,241	69,704	24,435	34,097	52,064	627,536
2023	109,730	42,157	71,145	62,058	60,317	51,940	53,646	70,148	24,561	34,320	52,295	632,317
2024	110,681	42,440	71,809	62,633	60,711	52,376	54,043	70,581	24,681	34,537	52,515	637,007
2025	111,606	42,722	72,471	63,192	61,096	52,808	54,432	71,003	24,795	34,748	52,726	641,598
2026	112,478	43,001	73,206	63,725	61,464	53,230	54,807	71,404	24,900	34,953	52,920	646,089
2027	113,301	43,281	73,891	64,248	61,828	53,653	55,182	71,803	25,000	35,158	53,114	650,459
2028	114,068	43,531	74,552	64,738	62,128	54,047	55,520	72,137	25,074	35,210	53,152	654,155
2029	114,783	43,777	75,209	65,216	62,419	54,434	55,852	72,463	25,146	35,259	53,185	657,742
2030	115,453	44,015	75,860	65,686	62,702	54,812	56,177	72,778	25,216	35,305	53,214	661,217
2031	116,102	44,173	76,409	66,125	62,967	55,156	56,477	73,078	25,290	35,344	53,242	664,364
2032	116,689	44,322	76,944	66,553	63,220	55,490	56,768	73,364	25,360	35,376	53,262	667,349
2033	117,236	44,609	77,420	66,874	63,481	55,804	57,061	73,701	25,479	35,481	53,270	670,417
2034	117,760	44,887	77,879	67,182	63,731	56,107	57,344	74,024	25,594	35,580	53,268	673,354
2035	118,260	45,156	78,322	67,476	63,967	56,398	57,614	74,331	25,703	35,673	53,256	676,157
2036	118,736	45,415	78,748	67,756	64,191	56,677	57,873	74,624	25,807	35,758	53,236	678,821
2037	119,058	45,664	79,157	68,022	64,402	56,945	58,120	74,901	25,905	35,836	53,205	681,216
2038	119,293	45,808	79,435	68,191	64,476	57,087	58,240	75,053	25,954	35,842	53,027	682,408
2039	119,504	45,941	79,695	68,345	64,536	57,218	58,348	75,189	25,998	35,841	52,839	683,454
2040	119,687	46,063	79,936	68,484	64,583	57,335	58,443	75,308	26,036	35,833	52,642	684,349
2041	119,844	46,174	80,158	68,606	64,615	57,439	58,524	75,410	26,068	35,817	52,435	685,090
2005-2041 Growth	39%	41%	46%	43%	32%	41%	40%	34%	31%	31%	23%	37%

Source: 2000 to 2005 - Department for Transport's National Road Traffic Survey

Table A1.5: Vehicle Kilometre Year on Year Growth

Year	South East	London	Eastern	South West	West Midlands	East Midlands	Yorkshire & Humber	North West	North East	Wales	Scotland	Total
2000	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2001	1.79%	0.14%	1.74%	2.04%	1.13%	1.71%	1.69%	1.85%	2.10%	1.54%	1.27%	1.58%
2002	2.15%	0.33%	2.16%	2.92%	2.79%	2.91%	2.91%	2.31%	2.86%	3.78%	3.66%	2.54%
2003	0.30%	0.08%	0.67%	1.23%	0.21%	1.92%	0.68%	0.86%	0.94%	1.48%	1.22%	0.80%
2004	1.08%	-0.60%	1.99%	1.28%	2.01%	1.79%	2.49%	2.26%	1.57%	2.72%	1.64%	1.64%
2005	-0.11%	0.21%	-0.13%	1.42%	0.80%	-0.05%	0.52%	-0.21%	0.09%	-0.14%	0.00%	0.20%
2006	1.42%	0.61%	0.47%	0.41%	0.33%	0.26%	0.45%	0.36%	0.59%	0.73%	0.59%	0.62%
2007	1.90%	1.80%	2.00%	1.87%	1.77%	1.87%	1.79%	1.76%	1.81%	1.72%	1.42%	1.81%
2008	1.84%	2.21%	2.03%	2.02%	1.70%	2.03%	2.05%	1.77%	1.71%	1.76%	1.78%	1.90%
2009	1.72%	2.11%	1.85%	1.93%	1.59%	1.88%	1.93%	1.68%	1.69%	1.80%	1.61%	1.79%
2010	1.65%	2.06%	1.80%	1.89%	1.54%	1.81%	1.85%	1.62%	1.57%	1.61%	1.59%	1.72%
2011	1.72%	2.13%	1.86%	1.93%	1.61%	1.86%	1.90%	1.68%	1.58%	1.64%	1.65%	1.78%
2012	1.44%	1.94%	1.71%	1.77%	1.46%	1.70%	1.74%	1.53%	1.42%	1.51%	1.50%	1.60%
2013	1.30%	1.51%	1.48%	1.49%	1.13%	1.39%	1.41%	1.20%	1.12%	1.27%	1.12%	1.32%
2014	1.38%	1.61%	1.59%	1.58%	1.24%	1.50%	1.53%	1.31%	1.23%	1.35%	1.24%	1.42%
2015	1.30%	1.51%	1.51%	1.51%	1.17%	1.42%	1.45%	1.24%	1.17%	1.31%	1.17%	1.34%
2016	1.22%	1.43%	1.43%	1.44%	1.11%	1.35%	1.38%	1.18%	1.11%	1.26%	1.11%	1.28%
2017	1.12%	1.40%	1.39%	1.42%	1.09%	1.32%	1.36%	1.15%	1.10%	1.23%	1.09%	1.24%
2018	1.07%	0.98%	1.24%	1.25%	0.92%	1.16%	1.16%	1.01%	0.97%	1.12%	0.97%	1.09%
2019	1.06%	0.96%	1.20%	1.23%	0.91%	1.13%	1.14%	0.99%	0.95%	1.09%	0.95%	1.06%
2020	1.06%	0.93%	1.16%	1.21%	0.89%	1.10%	1.11%	0.96%	0.93%	1.06%	0.93%	1.04%
2021	1.05%	0.91%	1.12%	1.19%	0.87%	1.07%	1.08%	0.94%	0.90%	1.02%	0.90%	1.02%
2022	0.94%	0.89%	1.09%	1.16%	0.85%	1.05%	1.06%	0.91%	0.88%	0.99%	0.88%	0.98%
2023	0.88%	0.68%	0.95%	0.96%	0.67%	0.86%	0.76%	0.64%	0.52%	0.65%	0.44%	0.76%
2024	0.87%	0.67%	0.93%	0.93%	0.65%	0.84%	0.74%	0.62%	0.49%	0.63%	0.42%	0.74%
2025	0.84%	0.66%	0.92%	0.89%	0.63%	0.82%	0.72%	0.60%	0.46%	0.61%	0.40%	0.72%
2026	0.78%	0.65%	1.02%	0.84%	0.60%	0.80%	0.69%	0.56%	0.43%	0.59%	0.37%	0.70%
2027	0.73%	0.65%	0.94%	0.82%	0.59%	0.80%	0.68%	0.56%	0.40%	0.59%	0.37%	0.68%
2028	0.68%	0.58%	0.89%	0.76%	0.48%	0.73%	0.61%	0.47%	0.29%	0.15%	0.07%	0.57%
2029	0.63%	0.56%	0.88%	0.74%	0.47%	0.72%	0.60%	0.45%	0.29%	0.14%	0.06%	0.55%
2030	0.58%	0.54%	0.87%	0.72%	0.45%	0.70%	0.58%	0.44%	0.28%	0.13%	0.06%	0.53%
2031	0.56%	0.36%	0.72%	0.67%	0.42%	0.63%	0.54%	0.41%	0.30%	0.11%	0.05%	0.48%
2032	0.51%	0.34%	0.70%	0.65%	0.40%	0.61%	0.51%	0.39%	0.28%	0.09%	0.04%	0.45%
2033	0.47%	0.65%	0.62%	0.48%	0.41%	0.57%	0.52%	0.46%	0.47%	0.30%	0.01%	0.46%
2034	0.45%	0.62%	0.59%	0.46%	0.39%	0.54%	0.49%	0.44%	0.45%	0.28%	0.00%	0.44%
2035	0.42%	0.60%	0.57%	0.44%	0.37%	0.52%	0.47%	0.42%	0.43%	0.26%	-0.02%	0.42%
2036	0.40%	0.57%	0.54%	0.42%	0.35%	0.49%	0.45%	0.39%	0.40%	0.24%	-0.04%	0.39%
2037	0.27%	0.55%	0.52%	0.39%	0.33%	0.47%	0.43%	0.37%	0.38%	0.22%	-0.06%	0.35%
2038	0.20%	0.31%	0.35%	0.25%	0.11%	0.25%	0.21%	0.20%	0.19%	0.02%	-0.34%	0.17%
2039	0.18%	0.29%	0.33%	0.23%	0.09%	0.23%	0.19%	0.18%	0.17%	0.00%	-0.35%	0.15%
2040	0.15%	0.27%	0.30%	0.20%	0.07%	0.20%	0.16%	0.16%	0.15%	-0.02%	-0.37%	0.13%
2041	0.13%	0.24%	0.28%	0.18%	0.05%	0.18%	0.14%	0.14%	0.12%	-0.04%	-0.39%	0.11%

Source: 2000 to 2005 - Department for Transport's National Road Traffic Survey

Table A1.6: Historic and Forecast Vehicle Kilometre Compound Annual Growth Rate

Year	South East	London	Eastern	South West	West Midlands	East Midlands	Yorkshire & Humber	North West	North East	Wales	Scotland	Total
2000-2005	1.04%	0.03%	1.28%	1.78%	1.38%	1.65%	1.65%	1.41%	1.51%	1.87%	1.55%	1.35%
2005-2041	0.91%	0.96%	1.05%	1.01%	0.77%	0.97%	0.94%	0.81%	0.75%	0.76%	0.59%	0.88%

Source: 2000 to 2005 - Department for Transport's National Road Traffic Survey

Annex 2 Highways Agency stress mapping methodology

Note prepared by Scott Wilson Kirkpatrick

INTRODUCTION

The Highways Agency (HA) operates a spreadsheet-based model for examining network stress on a regional and national level. This model is based on a mix of base surveyed data, planned road improvements, planned developments, and DfT issued traffic growth factors. From this it forecasts future traffic levels and their effect for each motorway and trunk road. The model is used as a basis for the 9 Regional Network Reports (RNR) published in 2006 and the National Network Report (NNR) developed in 2007. It is controlled at a regional level by HA Regional Managers and used in Regional Assembly development decisions.

The RAC Foundation have requested that this HA model be used as the basis to examine the effects of incremental increases on the current (2006) national traffic flow levels. The increments to be examined have been stated by the RAC Foundation as 2006 and 2006 plus 10%, 20%, 30%, 40%, and 50%.

At the clients request this technical note is based on increments of the 2006 flows and the network on which it is based assumes completion of all schemes included within the Targeted Programme of Improvements (TPI).

The 2006 flow equivalent to that which would occur if the schemes were in place in 2006 was found, this flow was then incrementally increased and the results plotted.

This technical note explains the process with which the analysis was undertaken and presents the graphical results of the analysis.

NNR MODEL BASIS AND METHODOLOGY

The NNR model is the amalgam of the RNR models. The RNR models are based on HATRIS observed daily flows on 2,484 directional links, of which 2380 (96%) used 2005 flow data, 83 (3%) links used 2004 link data, and only 21 links used flow data surveyed before 2004. Each length of motorway is represented as a separate link between the main junctions. Other trunk roads are divided into lengths defined by the main junctions with other A-roads.

It will forecast network operational stress for any year and growth scenario between 2005 and 2070.

The model does not directly contain specific development or scheme details but just their traffic effects and the year in which they happen. To provide ease of network testing the model is structured in such a way that each development or scheme can be included or excluded at will from the analysis, in addition the model automatically includes only those schemes and developments which would be in place by the examined future year.

Development details within the model are based on Regional Spatial Studies and Local Development Documents. The model contains the traffic flow effects of these developments; as these are part of general traffic growth rather than part of the incremental traffic growth requested these have been, at the instruction of the client, excluded from this analysis

The traffic effects of known road and junction improvements and schemes within the TPI are included within the model and have been included within this analysis.

The NNR model takes the observed flows and applies National Road Traffic Forecasts (NRTF97) vehicle km growth factors to forecast year level. These growth factors were based on central growth where the factors were subdivided by road type.

Any localized development effect where the traffic growth is markedly different from the general traffic growth was included on a link-by-link basis.

Any new roads or improvement contained within the TPI were included in the model. For these schemes the opening year and future year flows were stated.

The model combined base traffic data, normal traffic growth, local development effects, and TPI effects on a link-by-link basis to derive the future year forecast daily traffic flows.

To prevent double counting of development flows only those development related flows not included (or over provided) in the background traffic growth were stated. The growth in total vehicle-km for development and normal growth in the model was constrained to NRTF levels.

The link stress was derived by comparing the forecast link flows to the Congestion Reference Flow (CRF) for each link in the model, the CRF being based on the link type in that forecast year. This is the comparison of the daily traffic flow to the roads daily capacity; capacity being defined as the maximum sustainable traffic flow for the road type.

In the National and Regional Network reports the link stress was then plotted in three colour bands representing 0-90% stress, 90%-100% stress, and 100%+ stress, coloured green, amber, and red respectively. Roads shown red on the map are those that are ‘above or at capacity’. Roads shown green are those that are comfortably below capacity and those shown amber are those that are getting close to capacity.

However, it should be noted that a link which is shown as being below capacity may hide the fact that a junction within that link is at or above capacity, and the stress measurement takes no account of the speed of vehicles. The stress calculations relate only to all-day traffic flows and therefore the effects of peak hour congestion are diluted.

The stress values are based on congestion reference flows (CRF) and have limitations. The CRF is an estimate of the average daily flow which would result in the peak period flow exceeding the sustainable carriageway link capacity. It does not take account of the effect of junctions which can significantly affect congestion and stress. Once traffic flows exceed the CRF, the method overstates the level of link stress, but may disguise specific peak hour problems

RAC FOUNDATION MODEL METHODOLOGY

The RAC Foundation (RACF) model was based on the NNR with changes to the traffic forecasting and network improvement methodology.

The RAC Foundation requested that all TPI Schemes be included but the stress calculations be based on 2006 flow and increments thereof. To enable this, the 2006 with-TPI network and associated flows from the NNR model were required. The NNR model automatically excludes all schemes opening after the forecasting date; therefore a forecast date of 2006 with TPI Scheme inclusion could not be extracted directly.

To derive the data required for the RACF model the NNR model was set up in the following manner:

- TPI schemes are stated in the NNR model with opening and potentially other future year flows. All TPI Schemes within the NNR model are forecast to be open by the year 2026 and were included within the analysis.
- All specifically mentioned developments after 2006 were excluded from the analysis.
- The NNR model forecast year set at 2026.

The output traffic flows were therefore based only on Regionalized NRTF for traffic growth between 2006 and 2026 and the effects of the TPI Schemes.

The RACF model was built from this in the following manner:

- The output 2026 flows and Congestion Reference Flows (CRF) were output, for each link, into a separate RACF model.
- These 2026 with-TPI flows were factored by Regionalized NRTF to derive the equivalent 2006 flows.
- These 2006 flows were increased such that the following flow scenarios were modelled:
  - 2006 base flows
  - 2006 plus 10%,
  - 2006 plus 20%,
  - 2006 plus 30%,
  - 2006 plus 40% and,
  - 2006 plus 50%.
- The base 2006 and increment flows on each link were compared to the link CRF to derive the stress levels.
- These stress levels were plotted using 6 stress bands, as chosen by the RACF's consultants:
  - <90%, green
  - 90%-100%, light blue
  - 100%-110%, blue
  - 110%-130%, purple
  - 130%-150%, orange
  - >150%, red

It should be noted that as the same factor basis was employed to derive the 2026 flows and take them back to 2006 the choice of 2026 rather than any other post TPI opening year (of the last TPI scheme to open) does not affect the results.

TRAFFIC GROWTH
As requested within the brief the traffic has not been factored using any standard growth factors, e.g. NRTF or TEMPRO, but by 10% general increments from its 2006 level to 2006 plus 50%.

CRF BASIS
All CRF values used in the Regional and National Network Reports were based on the illustrative values contained within Annex D of TA46/97 – 'Traffic Flow Ranges for Use in the Assessment of New Rural Road Schemes'.

DATA CAVEAT
This data has been produced using the information contained within the Highways Agency 2006 Regional Network Reports. All the base data for these reports was extracted from the HATRIS database, as per the RNRs all the growth factors have been derived from NRTF 97 (regionalized) central growth. All TPI schemes included in this analysis were included in the RNRs, the data for which has come from many sources. The RNR data was approved by the

HA regional managers and has not been changed or reworked for inclusion within this report. The plots are based directly on the GIS information used within the RNRs.

The stress calculations have been assessed using standard CRF values for each link type. A low stress level may disguise peak hour link and or junction congestion performance. A high stress level may disguise the fact that the CRF would increase if the length of the congested period increased, e.g. a higher flows occurring outside the peak hours. The stress calculations relate only to all-day traffic flows and therefore the effects of peak hour congestion are diluted. However, conventional wisdom suggests that capacity should be measured hourly and hence the stress maps only provide 'broad brush' comparison between what the network looks like now and how it would look at a future date.

The data accuracy contained within the plots is derived directly from HATRIS, the RNRs, and HA approved network forecasts.