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AN INVESTIGATION INTO THE EFFECTS OF VARIOUS TRANSPORT POLICIES ON THE LEVELS OF MOTORISED TRAFFIC IN GREAT BRITAIN IN 2006

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ABSTRACT

An investigation into the effects of various transport policies on the levels of motorised traffic in Great Britain in 2006

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This Working Paper presents the results of tests of various transport policies which could potentially have a major impact on private car travel and hence gain environmental benefits at a national level. The forecasting methodology was to take OPCS population forecasts for year 2006 in 28 age/sex/area type categories, predict the car available percentage of person in each category in 2006, and then predict trip mileage growth (by three mode types) for the 28 categories each subdivided into car available and car non-available. For the latter two predications, NTS data for 1985/6 and 1991/3 were compared and projected forward with various adjustments. The effect of individual transport policies on trip rates for individual cells was determined from results derived from other studies, coupled with a consideration of economic theory. Of the tests considered, only the tripling of fuel prices for private mode transport was able to hold private mode mileage in 2006 at about its 1992 level.

1. INTRODUCTION

The transport sector is a major cause of local, regional and global externalities. Increasing transport volumes on existing infrastructure result in rising noise and local air pollution; whilst new infrastructure involves property demolition and visual intrusion. The transport sector is a significant contributor to the problem of acid rain, and provides the fastest growing source of greenhouse gases in Britain and world wide. As recognition of the extent of the environmental problems caused by growth of road traffic increases, so the search for appropriate policy responses widens. Many cities are still placing most emphasis on improving public transport alternatives to the car, although it is well known that this, by itself, will only have a marginal effect. A number of cities are now proposing to combine this with effective methods of road traffic restraint, including road pricing. In the longer term, increasing attention is being placed on land-use and locational change as a key factor influencing both trip length and mode of travel (including the degree to which trips are made by foot or bicycle).

In this Working Paper, the methodology and results from tests of the effects of various transport policies are reported. These were undertaken as part of a project funded under the UK Economic and Social Research Council "Transport and the Environment" initiative. The project was designed to examine the long term environmental effects both of existing demographic and locational trends, and of alternative strategies in the transport sector. The methodology regarding the demographic projections has been described elsewhere (Siu et al, 1995). The present paper provides a brief description of our project (in Section 2); describes the NTS data we used and how we grouped it (in Section 3); sets out the methodology whereby we derived our year 2006 base forecasts (in Section 4); discusses the method whereby we introduced elasticity information obtained from the literature into our tests and derived consistent elasticities where none were readily available in the literature (in Section 5); summarises our test results (in Section 6); and offers some conclusions (in Section 7). The details of the test results themselves are presented in individual appendices.

Before closing this introduction, we would like to thank again all those who have helped us with this project. In addition to the financial support from ESRC, we received NTS data from the ESRC Data Achieve for just the materials cost. Further NTS data, this time in the form of tabulations, was provided free by the Statistics Directorate of DoT. Much encouragement, together with copies of relevant reports, was received from HETA Division of DoT. We received further encouragement and valuable advice from an advisory committee. Lastly, many of the staff at ITS have read closely what we have written, making many useful suggestions. Pressure of time has meant that we have not been able to take up all the suggestions made to us, from whatever source, but the methodology which we have developed can be used to test a wider range of policies.

2. THE PROJECT

A proposal was made under the ESRC Transport and the Environment Initiative entitled "Reducing the Impact of Transport on the Environment: the Potential of National and Regional Strategies". Briefly, the objectives of the proposal were:

(a) to develop a series of scenarios which predict the likely impacts of transport on the environment in the next 20 years;
(b) to specify a series of individual strategies, and combined, or integrated, strategies to tackle these problems both at a national and a regional level;
(c) to predict the response of transport users to such strategies;
(d) to examine the effectiveness of alternative policies using both national and regional models.

While the project was selected for funding, it was made clear that not all of the above was required and a substantially reduced budget was awarded. Consequently, inter alia, all plans for fresh survey work and the development of urban and regional models were curtailed and it was agreed that we would concentrate on the demographic aspects (reported in Siu et al, 1995), and the construction of a national model calibrated with NTS data to test as large a range of scenarios and strategies as could be managed.

The revised objectives were therefore:

(a) to develop a series of scenarios which will predict the likely impacts of transport on the environment in the next twenty years, based on an understanding of:

- demographic changes
- land use changes and development decisions
- long term changes in the economy
- trends in the use of different modes of transport
- impacts of improvements in vehicle technology;

(b) to specify a series of individual strategies and combined or integrated strategies to tackle these problems both at a national and regional level, including:

- planning strategies
- developments in telecommunications and information technologies
- pricing and investment strategies for transport
- physical and regulatory controls on transport;

(c) to understand and model the response of transport users to such strategies.

Unforseen complications arose with the demographic data, to some extent attributable to our need to split locations by size of settlement, rather than by geographic location. Availability of population forecast data at the level we required forced us to choose 2006 as our forecast year. That year now seems quite close, but it was 20 years after the only data we then had to work with, the 1985/6 NTS (to be discussed in the next section). From a policy viewpoint 2006 is an appropriate horizon for which to develop targets. Targets have already been set for the year 2000 (eg for CO_2 emissions, and accident rates) and it is now timely to consider what motorised traffic levels we should aim for in the middle of the next decade.

It had originally been envisaged that, additionally, the 1989/91 NTS data set would have been available when the project began in January 1993 (in order for us to be able to see, for example, changes in cell trip mileage rates between the two surveys), but this was not the case, and so the 1985/6 NTS was initially used on its own. It was hoped that by sufficient disaggregation, particularly by economic variables such as income, categories could be determined for which trip mileage rates would remain relatively constant over time (after allowing for inflation). However, it eventually became clear that the NTS sample size (25,000 persons) was not sufficiently large for the level of disaggregation that would have been required. Consequently, we renewed our efforts to obtain the 1989/91 NTS data set, but this did not become available till mid 1995, when the project was very nearly over.

Our position was salvaged by Adrian Fisher of the Statistics Directorate of DoT, who provided tabulations to our specifications of the "hybrid" NTS data for 1991-1993. The NTS survey is now a continuing survey but definition changes are being concentrated every three years. Hence the 1989/91 NTS is a proper "round", as is the 1992/94 NTS, but the 1991/93 NTS has some conflicts of definitions since it straddles some changes of definitions brought in at the end of the 1989/91 "round". This particularly affected the income variable, which was in any event grouped, and so hard to compare once inflation had been allowed for. This led us to drop income from our model, instead treating it as part of a general time trend. After considerable investigation and deliberation we arrived at the method of forecasting to be described in Section 4.

While the above work was going on we trawled various sources, including making presentations at conferences, to find a set of transport polices (or strategies) that might form part of our tests. We grouped these together under the following headings:

(A) **Infrastructure**
Highway construction can be carried out at different rates, with consequences for the level of road congestion. Public transport investment, such as Manchester Metrolink, tend to be location specific and so not well suited to our model.

(B) **Management**
Traffic management could be used as a means of traffic growth restraint. We felt that the implications are similar to these of road congestion under (A) above. Policies to favour fuel efficient vehicles would obviously affect the level of pollution from any given level of mileage, but would also lessen the effect of fuel price rises as drivers switch to more fuel efficient vehicles.

(C) **Information**
Real time information could be given to drivers and public transport users, or more general public awareness campaigns could be undertaken. It was not felt that our model would be able to handle this, except as an add-on.

(D) **Pricing**

(D1) **Road Pricing**

Various schemes of road pricing might be introduced by 2006 and have a restraining effect on road traffic growth.

(D2) **Fuel Duty**

The UK government is already committed to raising petrol taxes by 5% p.a. in real terms until the end of the century.

(D3) **Public Transport Fares**

The UK government's policies regarding bus deregulation and rail privatisation carry with them real limitations on what national and local government can do to subsidise the general level of fares, but we should consider what would happen if large reductions in fares were implemented.

(E) **Land Use**

The planning mechanism could be used to concentrate residential development more heavily in existing built up areas, to counteract the drift to more rural areas. We should examine the size of the transport effects involved.

3. THE NTS DATA AND DEFINITIONS OF THE GROUPING WE HAVE USED

3.1 Introduction

The National Travel Surveys (NTS) are a series of household surveys designed to provide a national data bank of personal travel information for Great Britain (DoT, 1993). Surveys were carried out in 1965, 1972/3, 1975/6, 1978/9 and 1985/6. In July 1988 a continuous survey began, at roughly one third of the previous size each year, such that every 3 years a data set of the usual size would be available. The first of these was 1989/91 and the second 1992/4. Some work was also done with the hybrid 1991/93 data set, although this causes some clashes of definitions.

The work reported in this Working Paper utilised the 1985/6 NTS, supplied to us by the ESRC Data Archive, and selected tabulations from the 1991/3 hybrid data set, provided by the Statistics Directorate of the DoT. Some data concerning the surveys is presented in Table 3.1. We carried out extensive work on the 1985/6 data, when it was all we had, and our findings were reported to conferences (eg. Siu et al, 1994; Nash et al, 1995).

Table 3.1: Data concerning the 1985/6 and 1991/3 NTS Surveys

	1985/86	1991/93
Sample		
No. of households	10266	10413
No. of individuals	25785	25173
No. of adults (16+)	20189	19796
No. of journeys	394051	410222
No. of cars	8400	9923
Per person yearly averages		
No. of journeys	1024	1057
No. of journeys over 1 mile	689	750
Miles travelled	5320	6470
Miles travelled by car	4020	5210
Hours travelled	337	361

Source: DOT (1994b)

3.2 The dependent variable

The work reported in this paper solely concerns the dependent variable "trip mileage". We had earlier experimented with numbers of trips, and considered the average length of trips, but did not feel that further consideration of these would add profitably to the work presented here. The NTS surveys gave us, for various groups of individuals, average mileages per week. These were converted into annual averages by multiplying by 52.14. For the 1985/6 survey journey lengths were only available to us in banded form (see Table 3.2). For consistency we also requested this for the 1991/3 tabulations, but in addition we were thoughtfully sent tabulations using the exact mileages. This showed that our method of converting the banded data into actual mileages was inflating the figure by approximately 8.5%. This explained a discrepancy between our figures and figures published in the DoT reports that we had previously noticed. In this report all mileage figures have been deflated so as to conform to DoT published figures.

Table 3.2: Banded distribution of journey lengths and our continuous journey length variable (JLENG), together with 1985/6 and 1991/3 distributions. (NTS Variable J34)

Journey length band (miles)	JLENG (Mid-pt)	1985/86 %	1991/93 %
<1	0.5	11.3	11.1
1-2	1.5	22.5	21.7
2-3	2.5	14.4	14.1
3-5	4.0	17.7	17.8
5-10	7.5	17.3	17.9
10-15	12.5	6.6	6.7
15-25	20.0	5.0	5.2
25-35	30.0	1.8	2.0
35-50	42.5	1.3	1.3
50-100	75.0	1.4	1.4
100-200	150.0	0.5	0.6
>200	260.0	0.2	0.2

Source: DoT (1993), DoT (1994b)

Another adjustment we made was to short walk (ie less then one mile) journeys which were only surveyed on one of the seven days of the survey. In order to correct for this we weighted such journeys by seven when carrying out our analyses. Consequently the journey length distribution for us is <u>not</u> the same as in Table 3.2. We were keen to keep walk and cycle, which together we called "slow" mode, in our analysis, although when it came to the policy tests we could find no reliable elasticity data for these (in particular, cross elasticities) and so we have excluded slow mode from most of our test results tables so as to avoid undermining the veracity of these tables.

Regarding the motorised modes, after earlier investigation, we made a two-way split into public and private. Public mode was defined to be all rail and bus modes, plus taxi and domestic air. Private mode incorporates private cars, plus vans, lorries and motorcycles. Full definitions of the modes are given in Table 3.3.

We split mileage by three journey purposes, referred to in shorthand as Work, Business and Leisure. The Work category will sometimes be referred to as "commuting" and includes trips to/from work, to/from education and "escort education" trips. It does not include travel in the course of work, which forms part of "Business", which covers "briefcase" travel, reps, service engineers, bus and lorry drivers etc. The final category is all other travel, by no means all for "Leisure", but that is the shorthand we have used. Table 3.4 gives the definitions.

Table 3.3: Modes of Transport

Mode	Description	NTS grouping 1991/3 (Variable J36)
Public	Rail, buses (including private hire buses), taxi/minicab, other public transport (including domestic air)	04, 12-20
Private	Car (drivers and passengers), motorcycles etc., vans, lorries, other private transport	05-11
Slow	Walk and cycle	01-03
NB: The NTS grouping for 1985/6 uses different code numbers, but we understand that there were no major changes in coverage associated with the renumbering.		

Table 3.4: Journey Purpose Definition

Code	Description	NTS Grouping 1991/3 (variable J28)
Work (commuting)	To/from work, education, escort education	01, 04, 19
Business	Travel in course of work	02, 03
Leisure	All other travel	05-18, 20, 21

3.3 The independent variables

3.3.1 Person type

Turning now to the independent variables, we discuss first what might be referred to as "person type". Initially, we decided to work with 10 person types, based on sex, age and working status. Each of these person types was broken down by 3 income bands and whether or not the individual was classified as car-available. This gave 60 categories of individuals, or 57 if we omit the 3 categories of car available children which must, by definition, be empty. This is because we define car-available (CA) individuals as those who have BOTH a driving licence AND daytime access to a vehicle with 3 or 4 wheels. We considered a further subdivision by household structure, but this appeared to add nothing to the explanatory power we already had. This finding presumably arose because we were working at the level of the individual, rather than at the household level (when it would obviously help to know what sort of individuals there were in the household).

When it came to forecasting to 2006, which is the main purpose of this paper, several problems emerged with the 57-way person classification described above. Firstly, we wanted to compare our 1985/6 mileages for each category with data from a later NTS, either to establish constancy over time, or to permit the estimation of the rates of increase/decrease p.a. for each category, which might then be projected forward. Initially, we had been promised the 1989/91 NTS data set, which we could have analysed in the same way as the 1985/6 data set and made any comparisons we wished. The 1989/91 data set did not arrive until the middle of 1995, by which time the project was nearly at an end, and we had by then acquired some 1991/3 NTS tabulations. When the 1989/91 NTS data had not arrived at the time we required it, we sought tabulations from it directly from DoT. However, the data was held in a different form at DoT than at the ESRC Data Archive (which uses SPSS files) and so our commands to produce the tabulations we required were useless. DoT staff did not have the time to understand our very complex requirements and reprogramme them as required, particularly given the scope for mistake and consequent need for checking. We were not in a position to do the reprogramming ourselves since we would have had to learn by trial and error using the DoT's computing equipment, and that was clearly not possible. We had no option but to leave this part of the work till later.

After some further months, the 1989/91 NTS data had still not arrived, but we had heard that a special hybrid 1991/93 NTS data set had been formed by DoT and tabulations supplied to other researchers. Consequently, at the beginning of 1995 we applied again to the DoT, requesting a much simplified set of tabulations, which were kindly supplied within a matter of days.

We clearly had to simplify our request for tabulations as much as possible, and this prompted us to consider how we would forecast our independent variables, so as to obtain the number of individuals falling into each category in 2006. Regarding working status, we could see no way of projecting it, so its only use would have been to test various assumptions concerning its distribution: eg. what would be the effect on mileage in 2006 of the proportion of adults in full time employment falling by 5%? While this would be interesting, we judged that it would not relate to any of the transport policies we wished to test. Consequently, since we were proposing no tests which were thought to vary the distribution of individuals by working status, and because we had no basis for (improving our 2006 base by) assuming a change in that distribution by the year 2006, we accorded working status a low priority, which because of its complex interaction in our 57 categories with age/sex ruled it out of our request. It should be emphasised that long-term forecasts will depend on the particular point in the economic cycle that the economy might find itself in (say) 2006, which will obviously affect the distribution of individuals by working status.

Another complication in obtaining matching 1991/93 data for our 1985/6 data is that our 57 categories included a three-way breakdown by income. The 1991/3 NTS had an income classification that was not even consistent within itself, since it overlapped the 1989-91 and 1992-94, NTS rounds and so incorporated an "end of round" change of banding definition. Furthermore, income was reported in 1991/3 prices and so even if our three way classification could have been reestablished, it would not have been very meaningful. By this we mean that the numbers in the lowest income group will have fallen not just because of real income growth, but because of inflation. This would have been very difficult to correct for. In any event, the DoT data set had not been able to combine the 1991 data with the 1992/3 data in a meaningful way, ie. they know the band was, say, "8", but what this meant in £ would depend on the year that individual was interviewed; and either that was not available, or not available without undue effort. Consequently, we were not able to have our three-way income breakdown included in the 1991/3 tabulations.

In considering where the above difficulties left us, it was clear to us that we needed a complete, but quick, rethink regarding our person types. We decided to work with seven age/sex types, as defined in Table 3.5. We used these in all work reported here.

Table 3.5: Age/Sex Type Definitions

Code	Descriptions	NTS Grouping 1991/3 (Variable I164)
P1500	Children up to 15 years	01-03
M1629	Males, 10 to 29	04-05
M3059	Males, 30 to 59	06
M6000	Males, over 60	07-08
F1629	Females, 16 to 29	09-10
F3059	Females, 30 to 59	11
F6000	Females, over 60	12-13

For each of these seven age/sex types we split between car-available (CA) and car non-available (CO) individuals. To be car-available, an individual had to have BOTH a full driving licence (valid for a car) AND daytime access to a car or other 3 or 4 wheeled vehicle. Table 3.6 sets out the definition formally, using NTS 1989/91 definitions.

Table 3.6: Car-availability definition

Code	Description	NTS Grouping 1989/91
CA	BOTH Full car driving licence AND Daytime access to car	I182 = 01 or 02 or 06 I184 = 01 or 02
CO	EITHER No full car driving licence OR No daytime access to car	I182 = 03 to 05 or 07 to 14 I184 = 03 to 13

Notes:
(i) 1989/91 definitions shown, since variable I184 not listed in the 1991/93 report (DoT, 1994b).
(ii) I184 said to be derived from variables I1, I182, V3 and V5-6, and to be applicable to all persons aged 16 and over. It incorporates `driving licence holding´ which we have repeated directly by reference to I182 - either this is redundant, or we would not otherwise have got what we wanted.
(iii) For both I182 and I184, 5550 individuals, did not answer (DNA). These have been classified as CO.
(iv) "car" means ordinary cars, jeeps, land rovers, light vans, minibuses, dormobiles, motorbikes with sidecars, and invalid cars.

3.3.2 Area type

The next independent variable to be considered is area type. This has been described in detail in Siu et al (1995) and need not be repeated here. Briefly, the division is four-way, and based on a hierachy of urbanisation. London is taken as the first area type. Secondly, all the built up areas of the English Metropolitan Countries and Glasgow are combined and coded CONURB (for conurbations). It must be stressed that not all of the area covered by the counties is included, merely that which is considered "built-up" as defined by OPCS (1994). Such built-up areas are not split, so one centred on a particular Metropolitan County might well extend across the border of that Metropolitan County. Nevertheless, the areas in this category are broadly similar to the common conception of the conurbations of : West Midlands, Greater Manchester, West Yorkshire, Glasgow, Liverpool and Tyneside. There is not a good correlation with administrative areas which may bear these, or other, titles. The third category is all other built-up areas which overall a total population of over 25,000. We have coded these URBAN. All other locations have been coded RURAL, but we should note that any towns of less than 25,000 persons will be included. Table 3.7 gives the definition.

Table 3.7: Area Type Definitions

Code	Description	NTS Grouping (Variable P5)
LONDON	Inner and outer London	01, 02
CONURB	Built up areas in West Midlands, Greater Manchester, West Yorkshire, Glasgow, Liverpool and Tyneside	03-08
URBAN	Other built-up areas of over 25,000 population	09-12
RURAL	All other areas	13, 14

4. PROJECTING FROM 1985/6 AND 1991/3 TO OUR 2006 BASE CASE

4.1 Overview and definitions

This section sets out the method by which we obtained our 2006 base forecast. Other methods were considered and tried. Basically, we first produced forecasts of population in 2006, then we forecast the proportion of car available persons in 2006 using the observed 1985/6 to 1991/3 change with a sigmoid assumption incorporating a saturation level, and lastly we forecast trip mileage rates in 2006 by projecting forward 1985/6 to 1991/3 trip mileage rate growth incorporating some smoothing and adjustments.

To summarise the relevant parts of section 3, for various reasons we were not able to operate at the level of disaggregation originally envisaged. For instance, the 1991/3 NTS did not have a consistent income classification in itself, and so could not be matched with that for 1985/6. Household structure appeared to have little influence, given that we were working at the person, as opposed to household, level. Working status looked important, but we had no projections for this in 2006 and it was greatly complicating our work. Our decision to make use of limited tabulations from the 1991/3 NTS kindly provided by DoT, for which we did not request working status, finally led us to drop that dimension of disaggregation.

The dimensions of disaggregation remaining were as follows:

Sex: "M" or "F", except for children (all "P")

Age:

Up to 15	"1500"
16 to 29	"1629"
30 to 59	"3059"
60+	"6000"

Area type:

LONDON: London (Inner and Outer)
CONURB: Other Conurbations (built up, covering West Midlands, Greater Manchester, West Yorkshire, Glasgow, Liverpool and Tyneside)
URBAN: Other Urban Areas (over 25k population in built up area)
RURAL: Other (includes built up areas of less than 25k population, i.e. small towns)

Car Availability:

CA: Driving licence and daytime access
CO: Either no licence or no daytime access.

A separate report (Siu et al, 1995) sets out how the mid-1989 OPCS (and Scottish and Welsh equivalents) population forecasts for 2006 by age, sex and local area, were converted into 2006 forecasts for our 7 age/sex types by 4 area types, ie 28 cells. The total population for these 28 cells was 58.33M in 2006 compared to 56.12M in 1992, ie a 3.94% increase over the 14 years, equivalent to 0.28% growth p.a.

4.2 Income growth

From the NTS 1991/3 Report (DoT, 1994b), p82, we see that the growth in reported gross weekly household incomes between 1985/6 and 1991/3 was 62%. If we take this time period to be 6.5 years this gives 7.7% pa. Transport Statistics Great Britain, 1994 (DoT, 1994a), p53, gives the following figures for "RPI deflation to 1993 prices".

1985	1.487
1986	1.438
1991	1.054
1992	1.016
1993	1.000

A rough approximation to a deflation factor for our case, then, would be

$$\frac{(1.487 + 1.438)}{2} \cdot \frac{3}{(1.054 + 1.016 + 1.000)}$$

$$= \frac{8.775}{6.140} = 1.429$$

Hence real incomes can be said to have risen between 1985/6 and 1991/3 by a factor of

$$\frac{1.62}{1.429} = 1.13366, \text{ say } 13.4\%$$

or 1.949% pa (near enough 2% pa).

For our central forecasts we will assume GDP growth of 2% p.a. Since our feeling is that 1985/6 was fairly neutral in the economic cycle, it follows that we can take 1991/3 to be also. For convenience we will forecast for a 2006 also neutral in terms of the economic cycle. Consequently, we feel we need make no adjustment for differential economic growth before and after 1992.

4.3 Forecasting car availability in 2006

Our first step was to investigate the effect of holding the car availability proportion in each of the 28 cells at the 1992 value (ie from the 1991/3 NTS). Splitting by CA/CO gives us 56 cells. If the trip mileage rates for these 56 cells were also held at their 1991/3 NTS levels, then the effect of applying 2006 cell populations was to raise trip mileage by 4.39%. This is very largely explained by the 3.94% increase in population. The remainder is due to population growth being relatively higher in the higher trip mileage rate cells (in terms of age/sex and area type).

To forecast the CA/CO split for 2006 we had to take account of economic growth between 1992 and 2006, and also determine the growth path of car availability against income. The 1989 National Road Traffic Forecasts (Great Britain) report (DoT, 1989) states on p36 that there was a working assumption that

> "at saturation, 90% of all adults under retiring age and 50% of those over that age will hold a driving licence"

Since some of our 28 person/area cells are already pressing against these levels, we have taken the NRTF values as merely averages for our saturation CA proportions and taken reasonable assumptions to give the distribution over area and person types. Note that this assumes saturation for not only licence holding but also daytime access to vehicles, suggesting that we might have taken lower values for saturation. The figures we have taken for saturation are shown in Table 4.1. From there it is clear that significantly lower saturation levels would not have made much sense.

Actual CA proportions for 1985/6 and 1991/3 are shown in Table 4.1, together with the assumed level of saturation. The table also shows our projected CA proportions for 2006 and we now turn to describe how these were calculated. The time elapsed between 1985/6 and 1991/3 can be taken to be 6½ years. The time between our 1985/6 base and our 2006 forecast year can be taken to be 20½ years, ie 3.1538 times as long.

The car availability projections for 2006 have been derived as follows. A simple logistic time trend growth path for the proportion who are car available, P, is assumed as follows:

$$P = \frac{S}{1 + be^{-aSt}} \qquad (4.1)$$

where S is the saturation level for P, and is determined to be consistent with NRTF 1989 assumptions (DOT, 1989), t is time and a and b are constants to be estimated. This gives

$$S - P = \frac{Sbe^{-aSt}}{1 + be^{-aSt}}$$

or

$$\frac{P}{S - P} = \frac{S}{Sbe^{-aSt}}$$

or

$$\log_e \left(\frac{P}{S-P} \right) = - \log\,(b) - aSt$$

Let P_1 be observed P at time t_1
Let P_2 be observed P at time t_2

Table 4.1: Forecasts of the proportions of persons having both a driving licence and daytime access to a car (CA) in 2006, by area type and age/sex category

Area Type	Age/Sex	CA/(CO+CA) 1985/6	CA/(CO+CA) 1991/3	Saturation CA/(CO+CA)	CA/(CO+CA) 2006
London	M1629	0.42	0.47	0.86	0.57
	M3059	0.67	0.68	0.90	0.70
	M6000	0.44	0.45	0.50	0.46
	F1629	0.32	0.37	0.86	0.48
	F3059	0.38	0.50	0.90	0.71
	F6000	0.12	0.13	0.30	0.15
Conurb	M1629	0.30	0.46	0.86	0.73
	M3059	0.58	0.66	0.90	0.78
	M6000	0.36	0.44	0.50	0.49
	F1629	0.19	0.30	0.86	0.58
	F3059	0.28	0.41	0.90	0.68
	F6000	0.05	0.11	0.30	0.25
Urban	M1629	0.41	0.52	0.88	0.71
	M3059	0.69	0.76	0.92	0.85
	M6000	0.48	0.57	0.65	0.63
	F1629	0.23	0.43	0.88	0.78
	F3059	0.37	0.54	0.92	0.80
	F6000	0.10	0.17	0.35	0.30
Rural	M1629	0.51	0.59	0.90	0.72
	M3059	0.75	0.83	0.94	0.91
	M6000	0.61	0.64	0.70	0.67
	F1629	0.33	0.45	0.90	0.68
	F3059	0.49	0.64	0.94	0.84
	F6000	0.18	0.26	0.40	0.36

Source: 1985/86 NTS, 1991/93 NTS, our own assumptions, and output from equation (4.5)

$$\log\left(\frac{P_1}{S - P_1}\right) = -\log b - aSt_1$$

$$\log\left(\frac{P_2}{S - P_2}\right) = -\log b - aSt_2$$

$$\log\left(\frac{P_1}{S - P_1}\right) - \log\left(\frac{P_2}{S - P_2}\right) = aS(t_2 - t_1) \qquad (4.2)$$

$$\log\left[\frac{P_1}{P_2}\,\frac{(S-P_2)}{(S-P_1)}\right] = aS(t_2 - t_1)$$

$$\frac{P_1}{P_2}\,\frac{(S - P_2)}{(S - P_1)} = e^{aS(t_2 - t_1)} \qquad (4.3)$$

Let us standardise time such that the time between our 1985/6 data and our 1991/3 data, actually 6½ years, is one time unit on this scale,

ie $t_2 - t_1 = 1$

Then $$a = \frac{1}{S}\log_e\left[\frac{P_1}{P_2}\,\frac{(S - P_2)}{(S - P_1)}\right] \qquad (4.4)$$

To find P_3, the car available proportion for some time in the future, say 2006 when $t_3 - t_1 = (2006.0 - 1985.5)/6.5 = 3.1538$, we use equation (4.2), substituting P_3 for P_2:

$$\log\left(\frac{P_3}{S - P_3}\right) = -aS\,(3.1538) + \log\left(\frac{P_1}{S - P_1}\right)$$

$$= \log\left(\frac{P_1}{S - P_1}\right) - 3.1538\,\log\left[\frac{P_1\,(S - P_2)}{P_2\,(S - P_1)}\right]$$

$$\left(\frac{P_3}{S - P_3}\right) = \left(\frac{P_1}{S - P_1}\right) \left[\frac{P_1 (S - P_2)}{P_2 (S - P_1)}\right]^{-3.1538}$$

$$P_3 = \left(\frac{P_1}{S - P_1}\right) \left[\left(\frac{P_1}{P_2}\right)\left(\frac{S - P_2}{S - P_1}\right)\right]^{-3.1538} (S - P_3)$$

$$P_3 \left\{1 + \left(\frac{P_1}{S - P_1}\right)\left[\left(\frac{P_1}{P_2}\right)\left(\frac{S - P_2}{S - P_1}\right)\right]^{-3.1538}\right\} = S \left(\frac{P_1}{S - P_1}\right)\left[\left(\frac{P_1}{P_2}\right)\left(\frac{S - P_2}{S - P_1}\right)\right]^{-3.1538}$$

$$P_3 = \frac{S\left(\frac{P_1}{S - P_1}\right)\left[\frac{P_1(S - P_2)}{P_2(S - P_1)}\right]^{-3.1538}}{1 + \left(\frac{P_1}{S - P_1}\right)\left[\frac{P_1 (S - P_2)}{P_2 (S - P_1)}\right]^{-3.1538}} \qquad (4.5)$$

P_3 values, i.e. 2006 proportions of persons in the CA group, were calculated from this formula for four area types and six age/sex groups excluding children, and are presented in the final column of Table 4.1.

Compared to using the 1991/3 CA proportions (together with 1991/3 trip mileage rates and 2006 populations), using the forecast 2006 CA proportions increased total trip mileage by 8.4%.

4.4 Forecasting trip mileage in 2006 for each cell

We next turn to forecasting 2006 trip mileage rates for our 56 cells. Had we been able to disaggregate by income and working status, we might have hoped for trip rates to have remained stable over time, but we doubt that our hopes would have been met. In any event, data difficulties prevented a disaggregation by income and working status.

A further difficulty we faced was that our 1991/3 NTS data was not broken down by journey purpose. We are sure that DoT would readily have supplied such a breakdown had we asked, but we had been worried that too great a disaggregation of NTS data would have thrown up misleading comparisons given the limited sample size. We could have overcome this by aggregating, but some such aggregations were anyway available in published NTS reports and it was to those that we turned.

The "Transport Statistics Report" of the 1991/3 NTS (DoT, 1994b) shows the 1985/6 to 1991/3 growth in "miles per person per year", on p6, to have grown by

$$\frac{6473}{5317} = 21.7\%$$

Our own calculations are based on mileage bands, from which we have usually worked with the mid-point, and the equivalent figure is 21%. Within this our own calculations show that trip mileage rates for non-car available persons have risen by 18.5%, whereas trip mileage rates for car available persons have risen (from levels already more than twice as high) by only 7.2%. If we use these growth rates, but holding the CO/CA split constant at 1985/6 values, we get 12.1% growth. The difference between this figure and 21.7% can therefore, loosely, be attributed to the movement of persons from being CO to being CA.

These figures, of 21.0% and 21.7% growth, are shown in Table 4.2 together with the more commonly reported NTS growth figure of 22.5%. This latter figure differs from 21.7% solely due to the exclusion of journeys under one mile. Although it is not what we would have wished, it is for the 22.5% growth that the journey purpose split is presented in the NTS reports, and these figures are presented also in Table 4.2, together with some potentially useful groupings.

Table 4.2: Mileage per person, NTS 1985/6 and 1991/3

		1985/6	1991/3	Ratio
1.	Commuting	1075	1199	1.115
2.	Business	543	676	1.245
3.	Education	147	171	1.163
4.	Escort education	38	64	1.684
5.	Shopping	577	747	1.295
6.	Other escort	309	370	1.197
7.	Other pers. business	315	427	1.355
8.	Visit friends at home	945	1154	1.221
9.	Visit friends elsewhere	200	187	0.935
10.	Entertainment	241	330	1.369
11.	Participate in sport	110	132	1.200
12.	Holiday	336	489	1.455
13.	Day trip	307	373	1.215
14.	Other, including just walk	47	38	0.809
A	All (NTS report excl <1 mile)	5190	6357	1.225
B	All (NTS report incl <1 mile)	5317	6473	1.217
C	All (Our NTS data using JLENG)	5799	7017	1.210
Groupings:				
Commuting, Education, Escort Education		1260	1434	1.138
Business		543	676	1.245
Leisure		3387	4247	1.254
Business and Leisure		3930	4923	1.252
Source: DoT (1993) and DoT (1994b)				
NB: JLENG defined in Table 3.2				

Having seen the increase in trip mileage rates between 1985/6 and 1991/3, we now consider how to project these forward to 2006. Via the good offices of the DoT we were pointed to data patched together from past NTS surveys. We thank them and the researchers who did the patching, but accept responsibility if the findings presented here turn out to be misleading. This data was essentially comparisons of past NTS surveys. We considered the evidence but do not present any of it here.

Initially we thought we had spotted a downward trend in the relationship of mileage growth against income growth, i.e. a declining income elasticity of demand for mileage. However, the 1991/3 figure did not appear to confirm this pattern and there was anyway a great deal of noise in the data for earlier years. Furthermore, car mileage by car non-available persons did not appear to exhibit any such relationships. There was also the possibility that any relationship would, in reality, be lagged. After considering the evidence available, and taking account of all the above points, we decided that we were unable to support the assumption of any downward trend in mileage growth divided by income growth.

After substantial investigation, we decided that we should forecast 1992 to 2006 mileage growth rates from those observed between 1985/6 and 1991/3. Initially we did this crudely, i.e. we said that 1992 to 2006 was 2.1583 times as long a period of time as from 1985/6 to 1991/3 and so took the growth factor between these two surveys, raised it to the power 2.1538, and then multiplied this by the 1991/3 mileage rate. This was done for each of our 56 cells, i.e. 7 age/sex groups by 4 area types by our CA/CO division; broken down by 3 journey purposes and 3 modes.

Consideration of these crude forecasts threw up two problems. Firstly, there was a wide variation in growth rates which did not seem to reflect anything real, and which was felt to be undesirable. Secondly, there was a much higher forecast for public mode than had been anticipated.

The wide variation in growth rates was clearly due to sampling variation, possibly exacerbated by errors in the data. As can be calculated from the figures given in Section 3, the average number of persons in each of our 56 cells is 460 in 1985/6 and 450 in 1991/3, but the spread will be far from even. Each will have made an average 15 journeys in the survey week, but spreading this over 3 journey purposes and 3 main modes gives an average of less than 2 journeys at that level of disaggregation. We would, of course, have liked to consider more journey purposes and modes but we viewed that as pushing the data too far. Even at the level of disaggregation we have chosen, the presence or absence of a particular long distance journey could greatly change the observed mileage rate in 1985/6 or in 1991/3, in either case leading to peculiar growth factors for the period 1985/6 to 1991/3. We felt that this was particularly the case for public transport, where the presence of a long distance rail trip might have a greatly distorting effect.

We recognised that such distortions might be compensated when aggregating over our 56 cells, but felt that this would not be case. This is because the compounding method used to give 1992 to 2006 growth predictions is implicitly weighted by the mileage level already attained. Hence once an erroneously high growth rate has raised mileage to an erroneously high level, it then feeds off itself - giving itself much more weight than erroneously low growth rates and so preventing a proper cancelling out.

The solution we adopted was to run a dummy variable regression on the 56 observed 1985/6 to 1991/3 growth factors. The dummies were the 6 adult age/sex groups, 2 for children CO and CA (of which there are, of course, none), 1 for whether the person was CO or CA, and 4 for the area types, i.e. 13 dummies plus a constant. The effect of the dummy for the empty category of car available children was to explain away the presence of zero for this category in our data set. An alternative would have been to just delete these (empty) cells, but that was not easily possible with the spreadsheet we were using.

The second problem with the crude forecasts was the unexpectedly strong performance of public mode. Some of this was moderated by the regression smoothing discussed above, possibly reflecting an uneven presence of long distance public mode trips in the data for the two years. For those cells where such trips occurred (more) in the 1985/6 data, the small (well below unity) 1985/6 to 1991/3 observed growth factors resulting would have been given little weight. For those cells where they occurred (more) in the 1991/3 data, the large (well above unity) 1985/6 to 1991/3 observed growth factors resulting would have acquired great weight.

However, even after the regression smoothing we felt that there was still a problem. Growth rates for 1985/6 to 1991/3 were particularly high in London. This was thought to be partly due to the effect of Capitalcard and associated measures, which probably represented a one-off effect that would not recur. It was also thought partly due to the enormous increase in Central London employment at this time, which seems unlikely to reoccur to the same extent. Consequently we decided to base the London forecasts on the regression model with the London dummy replaced by that for Conurbations. There had been some growth in public mode mileage in Conurbations, so further public growth in London is predicted, from the high levels already reached in 1991/3, but not at the rates of growth reported between 1985/6 and 1991/3.

Table 4.3 shows the observed 1985/6 to 1991/3 growth rates, by CO and CA, broken down by mode, for our 4 area types and 7 person types. Slow modes are in decline for car non-available persons, but not (on average) for car available persons. Private mode growth is particularly strong for car non-available persons. This will cover some driving outside of the daytime, as well as travel as car passengers. Public mode travel is fairly static, the biggest fall being for children. We should note here that our definition of public transport does include taxis and domestic air, as well as the more obvious buses and trains. Both taxi and domestic air travel have been growing fast, but they still form a small proportion (less than 10%) of public mode as we have defined it.

Table 4.3: Observed 1985/6 - 1991/3 mileage growth factors

Area Type	Age/Sex	CO Car Non-available			CA Car available		
		Public	Private	Slow	Public	Private	Slow
LONDON	P1500	1.35	1.12	0.76	-	-	-
	M1629	1.13	0.74	0.88	1.66	0.79	0.75
	M3059	1.31	1.22	0.71	0.93	1.01	0.97
	M6000	1.56	2.44	1.32	1.83	0.92	0.96
	F1629	1.04	0.82	0.90	0.79	1.01	0.34
	F3059	1.30	0.97	0.85	1.27	0.98	0.95
	F6000	1.32	1.00	1.02	4.23	1.51	1.28
	ALL	1.17	1.05	0.83	1.13	0.97	0.85
CONURB	P1500	1.11	1.79	0.72	-	-	-
	M1629	1.58	1.88	1.22	0.87	0.90	0.91
	M3059	1.16	1.20	0.59	0.81	1.07	0.82
	M6000	0.96	1.38	0.92	0.88	1.11	1.26
	F1629	1.18	1.05	0.93	3.37	1.12	0.55
	F3059	1.35	1.47	0.75	0.85	1.07	1.02
	F6000	1.12	1.66	1.10	0.70	1.02	0.78
	ALL	1.19	1.52	0.81	0.98	1.03	0.88
URBAN	P1500	0.67	1.62	0.76	-	-	-
	M1629	1.29	1.31	0.96	1.25	1.07	0.80
	M3059	1.10	1.46	0.82	1.15	1.06	1.10
	M6000	1.07	1.30	1.13	1.25	1.06	1.07
	F1629	1.04	1.25	0.88	1.06	1.07	0.78
	F3059	0.98	1.20	0.87	0.69	1.15	1.04
	F6000	1.03	1.30	0.85	0.70	1.41	1.30
	ALL	0.95	1.37	0.83	1.01	1.06	0.99
RURAL	P1500	0.67	1.43	0.79	-	-	-
	M1629	1.42	1.37	0.73	0.78	0.96	1.64
	M3059	1.15	1.30	1.06	0.78	1.13	1.51
	M6000	1.00	1.84	0.86	1.31	1.24	0.82
	F1629	1.19	1.16	0.84	0.80	1.11	1.03
	F3059	1.17	1.37	0.95	1.15	1.18	1.05
	F6000	1.29	1.46	1.20	1.09	1.19	0.62
	ALL	1.01	1.35	0.85	0.90	1.11	1.17
ALL	P1500	0.78	1.48	0.76	-	-	-
	M1629	1.33	1.33	0.93	1.11	0.98	0.97
	M3059	1.18	1.30	0.81	0.92	1.09	1.16
	M6000	1.10	1.58	1.03	1.23	1.12	1.00
	F1629	1.12	1.13	0.87	0.99	1.07	0.72
	F3059	1.16	1.24	0.86	0.92	1.13	1.03
	F6000	1.14	1.37	1.00	1.00	1.26	0.93
ALL	ALL	1.04	1.33	0.83	0.98	1.07	1.02

Table 4.4: Regression models used to smooth the 1985/6 to 1991/3 trip mileage growth factors (as shown in Table 4.3)

	Public Mode Model		Private Mode Model	
Dummy variable	Coeffficent	Std. Err.	Coeffficent	Std. Err.
Constant	0.944	0.195	1.314	0.086
P1500 (CA)	-1.039	0.270	-1.062	0.120
P1500 (CO)	-0.114	0.270	0.176	0.120
M1629	0.205	0.215	-0.054	0.095
M3059	0.015	0.215	-0.002	0.095
M6000	0.184	0.215	0.212	0.095
F1629	0.224	0.215	-0.108	0.095
F3059	0.048	0.215	-0.012	0.095
F6000	0.327	0.215	0.131	0.095
LONDON	0.375	0.170	-0.120	0.075
CONURB	0.131	0.170	0.050	0.075
URBAN	-0.049	0.170	0.014	0.075
RURAL	-0.020	0.170	0.045	0.075
CA	0.008	0.115	-0.249	0.051
R^2	0.383		0.761	

Table 4.5: Smoothed 1985/6 - 2006 mileage growth

Area Type	Age/Sex	CO Car non-available			CA Car available		
		Public	Private	Slow	Public	Private	Slow
LONDON	P1500	1.24	2.21	0.51	-	-	-
	M1629	1.92	0.98	0.59	2.85	0.62	0.78
	M3059	1.58	1.79	0.47	1.14	0.89	1.01
	M6000	2.55	5.09	0.89	3.04	1.26	1.00
	F1629	1.82	0.99	0.60	1.40	0.69	0.36
	F3059	1.66	1.38	0.57	1.66	0.85	0.99
	F6000	2.73	1.84	0.68	8.85	1.77	1.33
CONURB	P1500	1.02	4.54	0.48	-	-	-
	M1629	2.68	3.37	0.82	1.50	1.02	0.94
	M3059	1.39	2.34	0.39	0.99	1.35	0.85
	M6000	1.57	3.67	0.62	1.47	2.05	1.31
	F1629	2.07	1.72	0.62	5.98	1.13	0.57
	F3059	1.73	2.82	0.51	1.11	1.32	1.07
	F6000	2.32	3.95	0.74	1.46	1.63	0.81
URBAN	P1500	0.39	3.90	0.51	-	-	-
	M1629	1.59	2.21	0.64	1.56	1.13	0.84
	M3059	0.90	2.67	0.55	0.96	1.25	1.15
	M6000	1.26	3.30	0.76	1.50	1.84	1.11
	F1629	1.33	1.92	0.59	1.37	1.00	0.81
	F3059	0.86	2.16	0.58	0.62	1.32	1.09
	F6000	1.59	2.94	0.57	1.09	2.12	1.35
RURAL	P1500	0.43	3.60	0.53	-	-	-
	M1629	1.85	2.43	0.49	1.03	1.07	1.71
	M3059	1.00	2.51	0.71	0.70	1.41	1.57
	M6000	1.24	4.86	0.58	1.66	2.26	0.85
	F1629	1.60	1.88	0.56	1.09	1.11	1.07
	F3059	1.10	2.60	0.63	1.10	1.44	1.09
	F6000	2.09	3.46	0.80	1.79	1.89	0.65

Table 4.4 shows the regression models we have used. Most of the coefficients are not significantly different from zero but they are the best we have and are suitable for use in a smoothing exercise. As was discussed above, the public mode dummy for London (0.375) was replaced by that for Conurbations (0.131) when smoothing. No similar adjustment was made to the private mode model. We thought it would be unwise to assume that car usage in London would grow at the same rate as Conurbations since road space is so much more crowded in London.

Table 4.5 shows the smoothed figures we used for 1985/6 to 2006 growth. These are formed from two multiplicative parts: first the observed growth from 1985/6 to 1991/3; and second the smoothed growths from 1985/6 to 1991/3 raised to the power 2.1583, representing 14 years as opposed to 6½ years. For public mode these have been adjusted as regards London in the way discussed above. The regression model for private mode was used unaltered. For slow mode a special simplified approach was adopted with 1985/6 to 2006 growth being taken as 67% of the 1985/6 to 1991/3 growth for car non-available persons and 104% for car available persons. This procedure for slow mode effectively projected forward observed growth at an aggregate level. The matter did not seem important enough to us to study at a more disaggregate level.

The effect of including the observed 1985/6 to 1991/3 growth is effectively to base our figures on 1991/3. However, for any rogue 1991/3 cell values, the smoothed regression element will impose a good degree of moderation. Where large entries appear in Table 4.5, e.g. 8.85 for CA F6000 in London, this is mostly due to already observed growth. Table 4.5 is not directly comparable with Table 4.3, since the latter is only for 1985/6 to 1991/3; Table 4.5 is much smoother than Table 4.3 raised to the power 3.1538.

Considering Table 4.5 for a moment, it will be seen that quite a wide variety of growth rates are being proposed. Children everywhere will halve their slow mode mileage, while children in Urban and Rural areas will also halve their public mode mileage. In London all person types (both for CO and CA) increase their public mode mileage, probably as a result of Capitalcard and related initiatives. Some variation in Table 4.5 will still be due to sampling variation, but we will be aggregating sufficiently to make this acceptable.

Private mode mileage is shown to grow much more quickly (about tripling) for CO persons (i.e. not having both a driving licence and daytime access) than for CA persons. It can be seen that considerable private mode mileage growth is implicit in these growth rates. Figures for millions of miles travelled are contained in the Appendix on the Tests, where they appear as 2006 BASE. Test 3 contains some 1992 figures for comparison.

4.5 Summary

We have projected forward to 2006 in three stages:

(i) Obtain population forecasts for 2006 disaggregated by our four area types, and seven age/sex categories.

(ii) Subdivide each of these cells into two, according to whether the person is "car available" or not. In order to forecast the proportion of persons in each cell that will be car available in 2006 we have used observed car availability figures for 1985/6 and

1991/3, together with an NRTF-based saturation level and then assumed a simple signoid path linking them.

(iii) For each of our 56 cells and for three mode types, we have projected observed trip mileage growth in the period 1985/6 to 1991/3 forward to 2006, compounding every 6½ years. Due to sampling variation we have used some smoothing, but taken the 1991/3 figures for mileage to be given. Hence any sampling variation we have used some smoothing, but taken the 1991/3 figures for mileage to be given. Hence any sampling variation affecting the 1991/3 figures will be perpetuated in our forecasts, albeit combined with a smoothed estimate of 1991/3 to 2006 growth. We believe that our aggregation over person types will be sufficient to satisfactorily overcome the effects of the sampling variation just mentioned.

It will be appreciated that it is implicit in the above that all influence or trip mileage by mode have been assumed to continue into the forecast period, except for an adjustment mode to the forecasts of public transport in London. For example, no attempt has been made to adjust for the effects of change in petrol prices between 1985/6 and 1991/3, nor for public transport fare and service changes in that period is built into our 2006 BASE forecasts.

5. ELASTICITIES

5.1 Introduction

The present project has needed to import elasticity values found in a variety of other studies. These elasticities come in a variety of forms, each applicable in particular circumstances. This note will seek to clarify some of the issues involved.

The most convenient summary measure for the effect of one explanatory variable (eg. price) on quantity, for all else held constant, is called elasticity. If price changes have no effect on quantity demanded then we say the elasticity is zero. As the effect of price changes on quantity demanded increases, we say that demand is "inelastic" until the revenue change is zero, when we say elasticity is (minus) unity. Here the price increase, ΔP, has reduced demand by ΔQ, but total revenue has remained the same since the higher price per unit has compensated exactly for the fall in number of units demanded.

ie $$P_0Q_0 = P_1Q_1 = (P_0 + \Delta P)(Q_0 + \Delta Q)$$

$$\Rightarrow \quad P_0\Delta Q + Q_0\Delta P + \Delta Q\Delta P = 0$$

$$\Rightarrow \quad \frac{\Delta Q}{Q_0} + \frac{\Delta P}{P_0} + \frac{\Delta Q\Delta P}{Q_0P_0} = 0$$

This equation shows that equal percentage changes (eg 10% rise in prices causing a 10% fall in Q) will not preserve total revenue. The first two terms will cancel, but that leaves

$$\frac{\Delta Q\Delta P}{Q_0P_0}$$

A 10% rise in prices ($\Delta P = 0.1P_0$) coupled with a 10% fall in quantity demanded ($\Delta Q=-0.1Q_0$) will give a revenue change of

$$\frac{\Delta Q\Delta P}{Q_0P_0} = -0.01$$

ie a 1% fall in revenue. To preserve revenue we always need a larger % price rise than the % quantity fall. This is important for the large price changes considered in our project.

Where price rises cause such large reductions in quantity demanded that revenue falls, we say that demand is elastic. Generally, we expect individual commercial companies to operate at prices where demand is elastic, as otherwise they could increase profits by raising prices and achieving higher revenue from lower sales (and hence costs). For wholly competitive industries, however, demand need not be elastic since any one firm trying to raise its prices might lose much of its sales to its (now lower priced) rivals i.e. the demand for any one firm's output is elastic whereas demand for the industry's output is inelastic. Many industries, including transport, are anyway not fully competitive, and are restrained from raising prices by some form of government intervention.

Given a mathematical form for the demand function, calculus can be used to determine the elasticity for infinitesimally small price changes from any given starting point. These are known as point elasticities, and they can be written as

$$EL(Q\,;P) = \frac{P\partial Q}{Q\partial P} \qquad (5.1)$$

Since demand curves will be downward sloping, $\partial Q/\partial P$ will be negative and so, for sensible values of P and Q, the elasticity will also be negative, although this is sometimes taken as implicit when discussing elasticity values.

5.2 Arc Elasticities

In our policy tests we have considered price changes too large to be approximated by formula (5.1), unless we were to assume that the elasticity were constant over the relevant range. Such assumptions are by no means unusual and have often survived statistical hypothesis testing on data sets, eg Inter City rail ticket sales (Owen and Phillips, 1987). However, an assumption of constant elasticity as prices change has undesirable consequences, contradicting common sense.

For large changes in price, as an alternative to the point elasticity measure, we can define the arc elasticity as

$$EL(Q;P) = \frac{\dfrac{Q_2 - Q_1}{Q_2 + Q_1}}{\dfrac{P_2 - P_1}{P_2 + P_1}} \qquad (5.2)$$

This takes two quantity price combinations (Q_1, P_1), (Q_2, P_2) and takes the base for the elasticity at the linear midpoint

$$\left(\frac{Q_1 + Q_2}{2}, \frac{P_1 + P_2}{2}\right)$$

Denoting the elasticity simply as E, for ease of exposition, we can rearrange this equation for use as a prediction of Q_2 when the starting position (Q_1, P_1) is known, together with E and the new price P_2.

$$\frac{Q_2 - Q_1}{Q_2 + Q_1} = E\left(\frac{P_2 - P_1}{P_2 + P_1}\right)$$

$$(Q_2 - Q_1)\ (P_2 + P_1) = E(P_2 - P_1)\ (Q_2 + Q_1)$$

$$Q_2\ (P_2 + P_1) = Q_1\ (P_2 + P_1) + Q_2\ E(P_2 - P_1) + Q_1\ E(P_2 - P_1)$$

$$Q_2\ (P_2 + P_1 - EP_2 + EP_1) = Q_1\ (P_2 + P_1 + EP_2 - EP_1)$$

$$\frac{Q_2}{Q_1} = \frac{P_2 + P_1 + EP_2 - EP_1}{P_2 + P_1 - EP_2 + EP_1}$$

$$= \frac{\frac{P_2}{P_1} + 1 + E\left(\frac{P_2}{P_1}\right) - E}{\frac{P_2}{P_1} + 1 - E\left(\frac{P_2}{P_1}\right) + E}$$

$$= \frac{\frac{P_2}{P_1}(1 + E) + 1 - E}{\frac{P_2}{P_1}(1 - E) + 1 + E} \qquad (5.3)$$

SPECIAL CASES

(*i*) $E = -1 \Rightarrow \frac{Q_2}{Q_1} = \frac{P_1}{P_2}$ *As required*

(*ii*) *No price change* $P_1 = P_2 \Rightarrow \frac{Q_2}{Q_1} = 1$ *As required*

(*iii*) *Prices double* $P_2 = 2P_1 \Rightarrow \frac{Q_2}{Q_1} = \frac{2 + 2E + 1 - E}{2 - 2E + 1 + E} = \frac{3 + E}{3 - E}$

(*iv*) *Prices double* $E = -1$ $\frac{Q_2}{Q_1} = \frac{2}{4} = \frac{1}{2}$ *As required*

(*v*) *Zero prices,* $P_2 = 0,$ $\frac{Q_2}{Q_1} = \frac{1 - E}{1 + E}$

Worked example

P.T. fares halved, $\frac{P_2}{P_1} = 0.5$

Elasticity for Leisure, E = -0.8
Elasticity for Business/Commuter, E = -0.4

$$\underline{\textit{Leisure}} \quad \frac{Q_2}{Q_1} = \frac{(0.5)(0.2) + 1 + 0.8}{(0.5)(1.8) + 1 - 0.8} = \frac{1.9}{1.1} = 1.73$$

Hence P.T. leisure patronage rises by 73%.

Check, Let $Q_1 = 100$, $P_1 = 100$, then $P_2 = 50$, $Q_2 = 173$

$$E = \frac{173-100}{173+100} \times \frac{100+50}{150+100} = -\frac{73}{273}\frac{150}{50} = -0.8 \qquad \text{AS REQUIRED}$$

Original revenue 10000, New Revenue 8650.

Since demand is inelastic, the increase in quantity demanded is insufficient to outweigh the revenue loss due to the price reduction.

$$\underline{\textit{Business/commute}} \quad \frac{Q_2}{Q_1} = \frac{(0.5)(0.6) + 1 + 0.4}{(0.5)(1.4) + 1 - 0.4} = \frac{1.7}{1.3} = 1.31$$

Hence Business and Commute patronage has risen by only 31%, due to the much lower elasticity value for these journey purposes.

5.3 Relating elasticities to the direction and sizes of price changes to be considered

Consider the case where a halving of price exactly doubles demand so that revenue is maintained and (arc) elasticity is unity.

For example, we may have $P_1 = 100$, $P_2 = 50$, $Q_1 = 100$, $Q_2 = 200$

These values are consistent with the following demand curve, which has constant elasticity.

$$Q = \frac{10000}{P}$$

$$\frac{dQ}{dP} = -\frac{10000}{P^2} = -\frac{Q}{P}$$

$$\textit{Point Elasticity, } EL(Q;P) = \frac{PdQ}{QdP} = -1$$

This point elasticity does not depend on P or Q, and hence is applicable along the whole length of the demand function. A firm finding itself in this position could raise its price endlessly, maintaining a constant revenue but cutting its costs and thereby increasing profits. Although this form of demand function often seems to fit observed data quite well, it is usually thought that as price is increased elasticity will rise, so that beyond some point profits are no longer increased by price rises. Also, the above demand function says demand will be infinite at zero prices, which clearly cannot be the case. All fixed elasticity models have this undesirable property.

An example of another demand function consistent with the above price and quantity information.

$$Q = 300 - 2P$$

$$\frac{dQ}{dP} = -2$$

Point Elasticity $$EL(Q,P) = \frac{P}{Q}\frac{dQ}{dP} = -\frac{2P}{Q}$$

At	(Q, P) = (200, 50)	EL(Q, P) = -½
At	(Q, P) = (150, 75)	EL(Q, P) = -1
At	(Q, P) = (100, 100)	EL(Q, P) = -2

In this case the arc elasticity, being based at (150, 75) gives the desired value of -1 for a price reduction from 100 to 50.

$$EL(Q, P) = \frac{200 - 100}{200 + 100} \times \frac{50 + 100}{50 - 100} = -1$$

Note also that zero fares now only give a demand of 300, sounding rather too conservative. The (point) elasticities can clearly be seen to rise with P, but probably much more strongly than is credible for the situations we will investigate.

Other functions compatible with the given price quantity data can be derived, for example, having any desired degree of sensitivity of elasticities to service levels simply by forming a weighted average of the two forms discussed above. For example, if we were to try the weights 0.75 and 0.25, then:

$$Q = \frac{3}{4}\left(\frac{10000}{P}\right) + \frac{1}{4}(300 - 2P)$$

$$= \frac{7500}{P} + 75 - 0.5P$$

$$\frac{\partial Q}{\partial P} = -\frac{7500}{P^2} - 0.5$$

$$\text{Point Elasticity} = EL(Q, P) = -\frac{7500}{PQ} - \frac{0.5P}{Q}$$

At (Q, P) = (200, 50) EL(Q, P) = -0.875
At (Q, P) = (100, 100) EL(Q, P) = -1.250

Here, doubling price (from 50 to 100) has raised the point elasticity by 43%.

Naturally, when applying such formulae to changes in prices over time, the prices should be at least in real terms (ie adjusting for inflation) but possibly even adjusted for increases in incomes. This demand function is, however, still unrealistic in that zero fares will give infinite demand.

In Fowkes, Sherwood and Nash (1993), it was suggested, for the case of cars only, that elasticities might be factored by

$$0.5\left(\frac{P_2}{P_1} + 1\right) \quad when \quad \frac{P_2}{P_1} > 1.2$$

The, rather weak, backing for this came from the HFA/ACCENT/ITS (1993) work as part of the DoT's London Congestion Charging Study, but it was influenced by some of the ideas expressed above.

With this formula, a doubling of prices would raise elasticities by 50%, not too dissimilarly to the example given above. For want of anything better we adopted the above rule generally (i.e. not just for $P_2 > 1.2\ P_1$). The effect will be as follows. Firstly, greatly reducing public transport fares (possibly to zero) will not produce patronage increases anything like as large as fixed price elasticity assumptions would give. Secondly, the usual low empirical values for car use price elasticities will eventually be overcome as prices are raised - ie traffic will be priced off the roads despite the low point price elasticities currently observed. This is consistent with the HFA/ACCENT/ITS finding.

In 1994 the Department of Transport commissioned research into the likely effects of substantially increased fuel prices on future car ownership and use. The preferred form for the elasticity of private mileage with respect to fuel price was constant, whilst a "linear increase of elasticities according to price also gave a good fit" (Terzis et al., 1995, p.251). In the case of car ownership, the "linear" form was preferred. It is clear from the example given (p.252) that by linear they mean proportional, i.e. a tripling of fuel prices was said to triple the elasticity. Our view is that neither of these two forms is at all sensible for the large changes they were considering. Clearly, if both a constant form and a proportional form were supported by the data then it follows logically that our form must be supported by the data, probably to an even greater degree. This is because our form is halfway between constant and proportional. We are not claiming that our form is exactly right, but that for large changes in prices the constant and proportional forms are horribly wrong.

We will now substitute the factor adopted above, into the demand prediction formula (5.3).

We will use E to refer to the tabulated elasticity values (usually arc elasticities) that we shall later use when considering price changes by various modes. These will then be factored according to the size of the price change involved to give revised elasticities which we shall call F values.

$$F = 0.5E\left(\frac{P_2}{P_1} + 1\right) \tag{5.4}$$

We will now substitute into equation (5.3), taking the E there to be F

$$\frac{Q_2}{Q_1} = \frac{\frac{P_2}{P_1}(1 + F) + 1 - F}{\frac{P_2}{P_1}(1 - F) + 1 + F}$$

$$\frac{Q_2}{Q_1} = \frac{\frac{P_2}{P_1}\left(1 + \frac{E}{2}\frac{P_2}{P_1} + \frac{E}{2}\right) + 1 - \frac{E}{2}\left(\frac{P_2}{P_1}\right) - \frac{E}{2}}{\frac{P_2}{P_1}\left(1 - \frac{E}{2}\frac{P_2}{P_1} - \frac{E}{2}\right) + 1 + \frac{E}{2}\left(\frac{P_2}{P_1}\right) + \frac{E}{2}}$$

$$= \frac{\left(\frac{P_2}{P_1}\right)^2\frac{E}{2} + \frac{P_2}{P_1}\left(1 + \frac{E}{2} - \frac{E}{2}\right) + 1 - \frac{E}{2}}{-\left(\frac{P_2}{P_1}\right)^2\frac{E}{2} + \frac{P_2}{P_1}\left(1 - \frac{E}{2} + \frac{E}{2}\right) + 1 + \frac{E}{2}}$$

$$= \frac{2 - E + \frac{2P_2}{P_1} + E\left(\frac{P_2}{P_1}\right)^2}{2 + E + \frac{2P_2}{P_1} - E\left(\frac{P_2}{P_1}\right)^2}$$

$$= \frac{2\left(\frac{P_2}{P_1} + 1\right) + E\left[\left(\frac{P_2}{P_1}\right)^2 - 1\right]}{2\left(\frac{P_2}{P_1} + 1\right) - E\left[\left(\frac{P_2}{P_1}\right)^2 - 1\right]}$$

$$= \frac{2\left(\frac{P_2}{P_1} + 1\right) + E\left[\left(\frac{P_2}{P_1}\right) - 1\right]\left[\left(\frac{P_2}{P_1}\right) + 1\right]}{2\left(\frac{P_2}{P_1} + 1\right) - E\left[\left(\frac{P_2}{P_1}\right) - 1\right]\left[\left(\frac{P_2}{P_1}\right) + 1\right]}$$

$$\frac{Q_2}{Q_1} = \frac{2 + E\left(\frac{P_2}{P_1} - 1\right)}{2 - E\left(\frac{P_2}{P_1} - 1\right)} \qquad (5.5)$$

SPECIAL CASES

(*i*) $P_1 = P_2$ *no price change*

$$\frac{Q_2}{Q_1} = \frac{2}{2} = 1$$ *As required*

(*ii*) $E = -1$

$$\frac{Q_2}{Q_1} = \frac{3 - \left(\frac{P_2}{P_1}\right)}{1 + \left(\frac{P_2}{P_1}\right)}$$

(iii) E = -1, prices halve, $P_2/P_1 = 0.5$

Demand rises by only 67% (as opposed to the expected 100%).

$$\frac{Q_2}{Q_1} = \frac{3 - 0.5}{1 + 0.5} = \frac{2.5}{1.5} = 1.67$$

(iv) E = -1, prices doubling $\frac{Q_2}{Q_1} = \frac{1}{3} = 0.33$

This shows demand becoming elastic and reducing demand by 67% (rather than the 50% expected).

(v) Price halving, general case

$$\frac{Q_2}{Q_1} = \frac{2 - 0.5E}{2 + 0.5E}$$

e.g for commuting public transport journeys with

E = -0.4, $\frac{Q_2}{Q_1} = \frac{2.2}{1.8} = 1.22$

ie a 22% increase in patronage.

(vi) Prices doubling, general case

$$\frac{Q_2}{Q_1} = \frac{2 + E}{2 - E}$$

eg for commuting public transport journeys with

E = -0.4, $\frac{Q_2}{Q_1} = \frac{1.6}{2.4} = 0.67$

ie a 33% reduction in patronage.

CAUTION. These effects are not reversible. Formula (5.5) must be used once only. In our case we wish to forecast for a given year starting from base 2006 trip mileage rates, and so formula (5.5) is appropriate.

5.4 Cross Elasticities

Changing the price of one commodity affects not only the quantity demanded of that commodity but also the quantity demanded of related commodities, i.e.

$$Q_i = f\,(P_i, P_j, \text{other things})$$

Analogously with the definition of (own) price elasticity of demand in Section 5.1 above, we can define the (point) cross price elasticity of demand for commodity i w.r.t. the price of commodity j as

$$EL(Q_i;P_j) = \frac{P_j}{Q_i}\frac{\partial Q_i}{\partial P_j} \tag{5.6}$$

For competing modes of transport, higher prices on one mode will increase traffic by other modes, so $\partial Q_1/\partial P_j$ will be positive, and so for positive Ps and Qs the cross price elasticities between modes will also be positive.

For small changes in prices the point elasticity formula can be amended by substituting $\partial Q_i = Q_{i2} - Q_{i1}$ and $\partial P_j = P_{j2} - P_{j1}$. For larger changes we again need to use arc elasticities.

$$EL(Q_i,P_j) = \frac{(P_{j2} + P_{j1})\,(Q_{i2} - Q_{i1})}{(Q_{i2} + Q_{i1})\,(P_{j2} - P_{j1})} \tag{5.7}$$

Analogously with section 5.3 above, using the symbol C for $EL(Q_i, P_j)$ we can rearrange the above formula to give the factor of change to the demand of commodity (mode):

$$\frac{Q_{i2}}{Q_{i1}} = \frac{\frac{P_{j2}}{P_{j1}}(1+C) + 1 - C}{\frac{P_{j2}}{P_{j1}}(1-C) + 1 + C} \tag{5.8}$$

Any consequential or retaliatory reaction by the operators of mode i following the price change on mode j would have to be dealt with separately. We will assume that there are no retaliatory reactions.

Once again, it is not sensible to assume that these cross elasticities will remain constant with respect to fares levels. Cross elasticity effects can be thought of as having two components:

(i) mode shift to(from) this mode from(to) the mode having the price increase (decrease)

(ii) an income effect whereby the change in price of the other mode affects disposable incomes and consequently the demand for all commodities, including all other modes of transport.

For simplicity, for our present purpose, we ignore this second component (ii). The argument against ignoring it would run something as follows. Suppose that we greatly raised the costs of car travel on environmental grounds. Travellers committed to travel by car (say for commuting) would find their disposable incomes greatly reduced, and so reduce their expenditure on everything, including leisure rail trips. At the levels of detail we work at we would contend that this second order effect can be neglected when considering how the cross elasticity will change with the level of (here, road) costs. The effect will, of course, still be present in any estimated cross-elasticity values we use.

Returning to (i), i.e. mode shift from large price changes, we can proceed analogously with the argument for own price elasticities. If increasingly large own price rises gradually increase the own price elasticity, then increasing amounts of traffic will be removed from that mode and consequently increased amounts of traffic can be expected to switch modes, so that cross elasticities can be expected to rise with P_2/P_1. Having no better information we again use the formula (5.5) adapted suitably.

$$F = 0.5C\left(\frac{P_{j2}}{P_{j1}} + 1\right) \tag{5.9}$$

Relabelling the C in equation (5.8) as F and substituting, gives expressions similar to those in Section 5.3, which after the manipulation shown there will yield

$$\frac{Q_{i2}}{Q_{i1}} = \frac{2 + C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}{2 - C\left(\frac{P_{j2}}{P_{j1}} - 1\right)} \tag{5.10}$$

5.5 Relationships Between Elasticity Measures

HFA/ACCENT/ITS (1993) contains an excellent Appendix A on relationships between Elasticity Measures, and the exposition need not be repeated here. Rather, some of the key findings will be reported for future reference. Toner (1994) gives an extended expostion of the key results.

The "Ratio of Elasticities" Approach can be used to derive one elasticity from a related one given knowledge of the relationship and typical values for the attributes in question.
For example, if we know the elasticity of quantity demanded with respect to price, EL(Q;P), current levels of price and journey time (P, t) and the value of journey time savings, v, (expressed in consistent units) then

$$EL(Q;t) = \frac{vt}{P}\, EL(Q;P) \tag{5.11}$$

gives the elasticity of quantity demanded with respect to journey time.

We have been unable to find all the elasticity values we needed in the literature, and therefore have had to produce sensible values ourselves. This has been greatly facilitated by understanding the relationships between own price and cross elasticities for two related products, here transport modes.

A common situation will be that we have adequate estimates of the own-price elasticities of, say, two modes, but do not have estimates of the cross elasticities. Assume for the moment that these are the only two modes, and that there are 100 travellers regardless of travel cost. Assume that 88 travel by mode A, with elasticity of -0.2 and 12 travel by mode B.

Consider the effect of raising the price of mode A by 100%. Formula (5.5) gives

$$\frac{Q_{A2}}{Q_{A1}} = \frac{2 - (0.2)\ (2-1)}{2 + (0.2)\ (2-1)} = \frac{1.8}{2.2} = 0.82$$

Since $Q_{A1} = 88$, $Q_{A2} = 72$
Hence $Q_{B2} = 28$

The arc cross elasticity of demand for mode B with respect to the price of mode A is therefore

$$EL(Q_B;\ P_A) = \frac{P_{A1} + P_{A2}}{Q_{B1} + Q_{B2}}\ \frac{Q_{B2} - Q_{B1}}{P_{A2} - P_{A1}} = 3\left(\frac{28 - 12}{28 + 12}\right) = 1.2$$

In general, not all passengers driven off mode A by a price rise for that mode will switch to mode B. Hence the estimate of cross elasticity derived from the above reasoning will be an upper limit. Note, however, that for minority modes, cross elasticities could potentially be quite large.

Under usual assumptions, when the price of mode A increases, the consequent increase in demand for mode B (Q_{B2} - Q_{B1}) can be no larger than the decrease in demand for mode A (i.e. Q_{A1} - Q_{A2})

i.e. $Q_{B2} - Q_{B1} < Q_{A1} - Q_{A2}$

in particular (since price is increasing)

$$\frac{Q_{B2} - Q_{B1}}{P_{A2} - P_{A1}} < \frac{Q_{A1} - Q_{A2}}{P_{A2} - P_{A1}} \qquad (5.12)$$

$$\text{and} \quad \left(\frac{Q_{B2} - Q_{B1}}{P_{A2} - P_{A1}}\right)\left(\frac{P_{A1} + P_{A2}}{Q_{B1} + Q_{B2}}\right) < \left(\frac{Q_{A1} - Q_{A2}}{P_{A2} - P_{A1}}\right)\left(\frac{P_{A1} + P_{A2}}{Q_{B1} + Q_{B2}}\right)$$

$$i.e.\ EL(Q_B;P_A) < \left[- \left(\frac{Q_{A2} - Q_{A1}}{P_{A2} - P_{A1}} \right) \left(\frac{P_{A1} + P_{A2}}{Q_{A1} + Q_{A2}} \right) \left(\frac{Q_{A1} + Q_{A2}}{Q_{B1} + Q_{B2}} \right) \right]$$

$$i.e.\ EL(Q_B;\ P_A) < \left[- EL(Q_A;\ P_A) \left(\frac{Q_{A1} + Q_{A2}}{Q_{B1} + Q_{B2}} \right) \right] \qquad (5.13)$$

For a price decrease, all four differences in equation (5.12) change sign, so the direction of the inequality is unaffected. The result, equation (5.13), says that if we know the own price elasticity of A and the mean relativity of demand shares between the modes, we have an upper limit on the cross price elasticity.

Another useful result, again for uncompensated price elasticities is that (see HFA/ACCENT/ITS, p.A5)

$$EL(Q_i;\ Y) + \sum_{j=1}^{n} EL(Q_i;\ P_j) = 0 \qquad (5.14)$$

where i is included in the j = 1, n; and Y is income.

This formula says that the income elasticity of demand for good i, plus the own price elasticity of demand for good i, plus the sum of all cross price elasticities of demand for good i with respect to prices of all other goods j, must give zero.

Finally, we note that if we wish to disaggregate the transport market, say by journey purpose, then the overall elasticity of demand for a given mode with respect to a given attribute X is the weighted sum of the disaggregate elasticities, using the relative shares of demand as weights (HFA, ACCENT, ITS, p.A6).

5.6 Effect of Income Growth on Elasticities

It has been suggested to us that price elasticities will fall in size over time as incomes rise and money becomes less important vis-a-vis the things it can be used to buy. We know of no empirical evidence on this, but the greatest rate at which we would consider such an effect could plausibly take is at the rate of growth of real incomes. This would imply that person A, having twice the income of person B, but sharing all other characteristics with person B, would have price elasticities half those of person B, all else equal.

In the light of the above, our practice will be to carry out all our tests twice over; once with our best estimate elasticities (denoted N for Normal) and again with these elasticities deflated by the assumed rate of increase in real incomes. Our assumption for the growth of real incomes is 2% p.a., so over 14 years this gives roughly one third real income growth. Consequently our "deflated" price elasticities (denoted by superscript M for Modified) will be 75% of our best estimates (N). This procedure will, in any event, provide a sensitivity test of our elasticity assumptions, which are unavoidably so pivotal to our tests.

The implications for our formulae are as follows.

Firstly, for formula (5.5) we replace both of the E values with 0.75E. On simplifying this gives

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{8 + 3E\left[\frac{P_2}{P_1} - 1\right]}{8 + 3E\left[\frac{P_2}{P_1} - 1\right]} \tag{5.15}$$

Secondly, formula (5.10) similarly becomes

$$\left(\frac{Q_{i2}}{Q_{i1}}\right)^M = \frac{8 + 3C\left[\frac{P_{j2}}{P_{j1}} - 1\right]}{8 - 3C\left[\frac{P_{j2}}{P_{ji}} - 1\right]} \tag{5.16}$$

Hence, our procedure will be to decide on best estimate values for both E and C and then use formulae (5.5) and (5.15) for own price effects and (5.10) and (5.16) for cross price effects.

6. SUMMARY OF THE RESULTS

6.1 Overview

A separate brief note was written on each of the tests we conducted and these are included as an appendix to this paper. Each of the notes on the tests contains figures for the 2006 base case for comparison, usually broken down by journey purpose. All tests assumed that the polices being tested will have negligible effect on the CA/CO split, ie the proportion of persons being car available, in 2006. It must be emphasised, also, that the test results cannot be combined, either in the sense of taking the effects of the different tests to be additive, or in the sense of applying subsets of our effects factors simultaneously. For example, if traffic growth were halted by a tripling of petrol prices (Test 1A), then it would be silly to simultaneously assume that congestion was choking off the proportions of traffic as assumed in Test 5.

Nevertheless, some of our tests will have implications for knock on effects and we have not had time to pursue these in detail. The main case in which this arises is in Tests 1 and 1A, where very large increases in the real cost of motoring are considered. These have the effect of greatly constraining future road use, so that congestion might be supposed to be very much reduced compared to what might otherwise have been expected. If we take our assumption to be that road building will be unaffected by the increase in petrol prices, and remain at its 1985/6 to 1991/3 level (of growth), then journey times will be relatively improved by the policy, causing the overall effects to be less than predicted. However, this is only one possibility. An alternative would be to say that the government would take into account the traffic effects of its own policies when deciding what extra road capacity to provide. This would be the interpretation consistent with our Tests 1 and 1A effects, i.e. road conditions held constant. This argument will be seen to confirm our guidance (above) that our test results should not be taken in combination, Tests 1 and 1A already implicitly assume some of, all, or more than the contraction in road capacity enhancement assumed in Test 5.

Regarding the elasticities we have used, we have searched the literature and consulted widely. Because of our method of relating elasticity to the size of the price change, by formula (5.4), it is actually quite difficult to determine the average elasticities implicit in our work. We would suggest that not too much attention should be paid to the seed elasticities, as they will clearly be non-typical of the elasticities implicit in our work. Nevertheless, the seed elasticities are clearly vitally important for our work, and it may be that readers will feel that a seed elasticity that will give rise to higher elasticities in our work, was anyway too large to begin with. We would like to emphasise here that it has been no part of our project to rework studies of elasticities to derive our own values. We have taken the best available in the literature.

Table 6.1 shows the public transport effects and Table 6.2 shows the private transport effects. We will now discuss each test, in the order they are presented in those tables, which is not the order in which the test are numbered, or are presented in the appendix.

Table 6.1: Summary of tests: public transport mileage (thousand million miles p.a.)

Test No.	See section	Description		LONDON	CONURB	URBAN	RURAL	TOTAL	% Change on 1992
		1992		10.5	8.7	21.4	13.5	54.2	
	6.2	2006 base		14.5	10.4	19.8	13.8	58.5	+7.9%
3	6.3	2006 with adjusted population		14.9	11.1	19.8	13.3	59.0	+8.9%
5	6.4	2006 congested		14.8	11.0	21.2	14.6	61.5	+13.5%
2	6.5	2006 with halved fares	N M	19.8 18.3	15.0 13.7	28.3 25.9	19.4 17.8	82.6 75.6	+52.4% +39.5%
4A	6.6	2006 with road pricing in London		15.3	10.4	19.8	13.8	59.4	+9.6%
4B	6.6	2006 with road pricing in London & other conurbations		15.3	11.3	19.8	13.8	60.3	+11.2%
1	6.7	2006 with doubled petrol prices	N M	15.2 15.0	11.9 11.5	25.1 23.7	17.3 16.4	69.6 66.6	+28.4% +22.9%
1A	6.7	2006 with tripled petrol prices	N M	16.0 15.6	13.7 12.8	32.2 28.4	22.1 19.5	83.9 76.3	+54.8% +40.8%

NB: (i) Area types are defined in Table 3.7
(ii) "N" implies use of "best estimate" elasticities, whilst "M" implies use of elasticities scaled down by the real growth in incomes (see Section 5.6)
(iii) Full details of tests in the appendix.

Table 6.2: Summary of tests: private transport mileage (thousand million miles p.a.)

Test No.	See section	Description		LONDON	CONURB	URBAN	RURAL	TOTAL	% change on 1992
		1992		26.3	33.6	127.1	116.7	303.7	
	6.2	2006 base		32.3	58.0	208.4	201.7	500.5	+64.8%
3	6.3	2006 with adjusted population		33.1	61.7	207.6	195.3	497.7	+63.9%
5	6.4	2006 congested		30.0	52.2	192.6	188.5	463.3	+52.5%
2	6.5	2006 with halved fares	N M	31.0 31.3	56.6 56.9	203.2 204.5	196.7 197.9	487.5 490.6	+60.5% +61.5%
4A	6.6	2006 with road pricing in London		30.1	58.0	208.4	201.7	498.3	+64.1%
4B	6.6	2006 with road pricing in London & the other conurbations		30.1	54.6	208.4	201.7	494.9	+62.9%
1	6.7	2006 with doubled petrol prices	N M	25.9 27.4	42.0 45.5	150.0 162.7	145.5 157.7	363.4 393.3	+19.7% +29.5%
1A	6.7	2006 with tripled petrol prices	N M	20.8 23.3	30.3 35.7	107.7 127.3	104.7 123.6	263.6 310.0	-13.2% +2.1%

NB:
(i) Area types are defined in Table 3.7
(ii) "N" implies use of "best estimate" elasticities, whilst "M" implies use of elasticities scaled down by the real growth in incomes (see Section 5.6)
(iii) Full details of tests in the appendix.

6.2 The 2006 Base

This was derived in section 4. The observed growth in car availability was assumed to decline, but we could not see any way of moderating the increases in mileage per person over time once age/sex, area type and car availability had been allowed for. The effect is a predicted 65% growth in miles travelled by private mode between 1992 and 2006. By comparison, real income growth per head at 2% per annum over these 14 years, would only come to 32%. DoT (1989) report that the cross sectional income elasticity of car kilometres w.r.t. GDP is only 0.9, when calculated from 1985/6 NTS data: That report goes on to say (p21) that:

> "Over the 1960 to 1987 period, the growth in car kilometres, calculated over 4 year intervals, has declined from being 2 times faster than income growth in the 1960's to about 1.2 times faster in the mid - 1980's. This can be reconciled with the cross-section elasticity and a real fuel price elasticity of -0.15 if other influences have resulted in a time trend of 0.8% per annum in car km".

If the factor of 1.2 was still about right, then the 303700 Mmpa of 1992 would be something like 420000 Mmpa by 2006 (as opposed to the 500500 Mmpa we are forecasting). However, it is clear that our base will not come to fruition, due to changes in policies already in place. Most importantly, real petrol prices have been raised by the government's action on fuel duty in order to return UK CO_2 emissions to 1990 levels by 2000. Possibly related to this, the move away from public transport that was apparent in the 1985/6 to 1991/3 period is now abating. Firstly, the shake-out following bus deregulation in 1986 has now stabilised, so it may be that the 1985/6 to 1991/3 included something of a once for all shift from public to private mode - it is still to early to say. Anecdotal evidence suggests that school children now find it more expensive and difficult to attend school by bus (with less free school travel) and parents are giving/arranging more lifts to/from school partly in response to this and to fears regarding safety of children from traffic and attack. Again it may be that 1985/6 to 1991/3 represented a peak period for this switch, which may be much decelerated in the period up to 2006.

Furthermore, between 1985/6 and 1991/3 it was government policy to encourage car use, and provide additional road capacity wherever this could be justified by future flows of (net) time savings, accident savings, operating cost savings and environmental benefits. Since that period the road building programme has been cut on several occasions, and now is substantially reduced from that envisaged in the 1985/6 to 1991/3 period.

If we take all the above points into account, then it seems highly unlikely that, for the conditions actually pertaining in 2006, our model would predict growth in road traffic more than about 1.2 times faster than real income growth. Our 2006 base only reflects what would have happened had the 1985/6 to 1991/3 trends been allowed to continue. They have not. We know that, but we need some well defined and quantifiable base against which we can conduct tests.

For any readers who may be completely unable to accept our 2006 Base as having any practical meaning, then our work on the effect of the various policies still stands. The appendix sets out which elasticities were used and the broad size of the response will be meaningful, even if there is doubt over the meaning of the 2006 Base. We turn now to discuss the tests, in the order they are listed in Tables 6.1 and 6.2.

6.3 Halting the redistribution of population from built-up to rural areas

It is well known that there has for some time been a net migration from built-up, particularly large conurbation, areas to more rural areas. This interests us since it is much harder to provide cost effective public transport to low population density rural areas, and so such areas are characterised by high car ownership and use. Since our project had spent so much effort on the population forecast data, we decided to accept the forecast age/sex split for 2006, but spread it across our four area types in precisely the same way as in 1992.

Any additional population falling within a given age/sex category of a particular area type would then automatically assume all the typical (average) charateritcs of that category in that area type. In particular, they would take on the car availability proportions, and (within car availability bands) the average trip mileage p.a. by each mode, of persons already so classified.

Test 3 shows the detailed results. Persons aged under 16 or 30 to 59, plus females aged 60+, are noticeably fewer in rural areas and noticeably more frequent in the other conurbations (CONURB) once this readjustment has been made. None of the effects is greater than 10% of the 1992 population in that cell, however.

The effect of the adjustment on private mode mileage travelled is relatively minor. Table 6.2 reports a half percent fall in year 2006 private mode mileage. This figure may be lower than otherwise due to our coarse grouping of area types, ie people may move to lower density areas within each of our four area types. However, we have defined our area types by size of settlement, rather then geographic location, so we would not expect to have missed a great deal of the effect. We certainly would not expect the total effect to be greater than a 1% reduction in private mode mileage.

6.4 Allowing congestion to increase much faster than hitherto

Our 2006 Base mileage forecasts have been derived by projecting the growth rates observed between 1985/6 and 1991/3. Since that time there has been a substantial reduction in the government's road building programme. This has the clear consequence that the level of car use per mile of main road will be expected to rise sharply. This will cause substantial additional traffic congestion, which may in turn have an effect on reducing future traffic growth.

In 1994 DoT let a project looking at the effect of increased congestion on traffic growth. For this project the DoT provided some assumed 30 year traffic flow increases by road type, (full details in Test 5 in the appendix). There is an element of "chicken and egg" in the analysis since if the forecast traffic growths (up to 140% growth, in the case of motorways) actually choked off any traffic growth it would undermine the initial assumptions of the study. Nevertheless Christie (1995), of the MVA Consultancy, computed mileage suppression percentage for 1994-2004 which we can readily convert to 1992-2006 and subdivide by area type and journey purpose using the data he presents.

One problem with this procedure is that we have the locations of travellers and not of travel. For example, a person classified as URBAN might regularly drive through rural areas and into a conurbation. Care has been taken to cope with this difficulty in our application of the test both by following Christie's conversion to "origin" area types (which we assume to be soundly based) and by our own considered judgement as to the mix of road types used by persons in each of our area types.

The effect of the traffic growth rates assumed by DoT for this piece of research on road speeds is thought to be sufficient to suppress between 6 and 10% of 2006 mileage. The detail of our workings and assumptions are shown in Test 5 in the appendix. Table 6.2 summarises the effect on private mode travelled: overall it is a reduction of 7.4%.

We interpret the result of Test 5 as saying that a policy of minimal road building, will reduce 2006 road traffic by about 7½% compared to our 2006 base forecast, all else equal.

6.5 Halving public transport fares

It is often said that the costs of motoring impact on the motorist in fixed and variable parts which for any given marginal journey make public transport look expensive. It has therefore been suggested that reductions in public transport fares might, in themselves, attract sufficient drivers out of their cars that, although there would be a loss of profit to the operator's farebox (since the fares elasticity for most forms of public transport is quite low and additional capacity would need to be provided), there might be a sufficient social gain in terms of environmental benefit to offset this loss.

We have chosen to test a very large reduction to public transport fares : a halving. Since we are relating our elasticities to price levels, the already low overall elasticity for public transport is further reduced. Consequently public transport mileage only rises by 41%. The same effect is apparent when we look at the effect on private mode mileage, which only falls by 2½%. Full details are contained in Test 2 in the appendix. There it will be seen that the net effect on the total mileage by public and private transport combined, is an increase of 2%. Hence, such a policy would be likely to have net environmentally damaging effects as it stimulates the use of fossil fuels by public transport operators, with little compensating reduction in private mode mileage.

The same broad picture emerges when replacing our best estimate elasticities (N) with elasticities modified (M) such that they are scaled down by real income growth.

6.6 Road Pricing

The policy of road pricing, or congestion charging as it is sometimes called, is not primarily aimed at reducing private mode travel in total, but merely at particular places. Hence, if a particular town centre was crowded excessively with traffic to the attractors there, it might be thought desirable to charge to enter that city centre in order to reduce traffic in that location. On occasion, however, part of the justification for road pricing has been environmental benefits from reduced car use, and special arrangements made to favour full car loads as opposed to lone drivers. In any event, it is possible that some road pricing schemes may be implemented by 2006 and so we have made an attempt at allowing for these effects in our forecasts. The detail is shown in Test 4 in the appendix.

Firstly, we incorporated the results reported in MVA (1995) relating to a "high" level of road pricing in London. The report was sponsored by DoT while investigating the pros and cons of introducing road pricing into London, and is based on a substantial amount of research by many institutions. In our work, we have accepted roughly the general level of private mode mileage suppression they expected, split this by journey purpose using relativities contained in the report, and assessed the corresponding transfer to public transport that would be likely in consequence. Secondly, we took much the same effects to apply if road pricing were introduced to all the conurbations with prices set to achieve target private mode mileage reductions of the same order. In this latter case, Table 6.2 shows that total GB private mode mileage in 2006 is reduced by about 1%, with neglible increase in the usage of public mode. This does not offer much promise of road pricing forming a leading role in reducing private mode traffic in aggregate.

6.7 Raising petrol prices

The government is already committed to raising fuel duty by 5% in real terms year on year up till the year 2000. Some comments by ministers have not mentioned the end year, leading some to think that the policy might persist thereafter. Since fuel duty is now around 70% of the price of petrol, the real price of petrol is being raised by over 3% year by this policy. Taken with further increases above this commitment, notably at the time of the government's defeat on raising heating fuel VAT, the real price of petrol should have been raised by about one quarter by 2000 and by about one half if the policy were to continue up to 2006. However, the future is not at all clear in this context. On the one hand there is one feeling that only the UK is taking Rio seriously amongst major world economics. On the other hand, some government environmental advisors and notably the Royal Commission on the Environment feel that still greater efforts are required, with a much larger reduction in road traffic.

We have chosen to test two levels of real increase in private mode fuel prices: 100% and 200%. We note that these might be phased in gradually, in the same way that the real petrol rice is being raised year by year, and acknowledge that we are using long-run elasticities. Again we have carried out the calculations on two bases, the first using our best estimate elasticities (N) and the second with modified elasticities (M) reduced by the assumed growth in real increases by 2006. The detail of the tests is reported in the appendix under Test 1 (for the 100% increase) and Test 1A (for the 200% increase).

The findings are dramatic. Even using the modified elasticities and only doubling fuel prices, private mode mileage is reduced by over 21%. Using our best estimate elasticities and tripling fuel prices reduces private mode mileage by 47%. This is 47% of the 2006 base level, which means it is 78% of the 1992 level, more than offsetting the 65% growth over the 1992 level represented by the 2006 Base. All these figures are shown in Table 6.2. The implications for public transport are shown in Table 6.1. It is clear that this is the only policy tested where the policy could be implemented at a conceivable (if potentially unpopular) level and stop the growth of private mode mileage. It should be pointed out that substantial sums of revenue would be raised with which to introduce offsetting measures to make this policy more popular. Since the means for collecting fuel tax are already in place, there should be relatively little leakage of the tax take in administrative costs, and so virtually all the extra revenue should be available for government spending or tax reductions elsewhere.

7. CONCLUSIONS

In this paper we have described the results of a project designed to test the implications of alternative transport policy scenarios for the year 2006. We have described the way in which trends over the period 1985/86 to 1992 were used to project forward mileage rates by person type and location type to 2006, and applied these to population forecasts to obtain 2006 base mileage. This represented a 65% growth in private transport. We then described a series of policy tests regarding population location, levels of road building, public transport fares, electronic road pricing and petrol prices. Of these tests the only one to have a substantial impact on private transport growth was petrol prices, a trebling of which would be needed to prevent further private transport growth over the period 1992 to 2006.

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APPENDIX

DETAILS OF DATA AND POLICY TESTS

TEST 1 DOUBLING FUEL PRICES FOR PRIVATE MODE TRANSPORT

T1.1 Effects: will raise the cost of motoring
=> (1) less motoring (found by using an own-price elasticity)
=> (2) more public mode travel (found by using a cross-price elasticity)

T1.2 Reduction in motoring

Goodwin (1992) summarises the evidence from studies of traffic levels with respect to petrol price in his Table 2, reporting long run values around -0.3. This figure is much less than that for petrol consumption, due to trading down in engine sizes and a general move towards fuel efficiency as fuel prices rise. Since our elasticities will be assumed to rise with prices, and since petrol prices are now historically low, we will take an average somewhat below -0.3. Fowkes et al (1992) took the following range by journey purpose, for London:

Commuting	-0.1
Business	-0.1
Leisure	-0.3

Evidence, quoted by Goodwin, for outside of London suggests higher values, and we will take 50% higher values for other areas.

T1.3 The base elasticities we will use will be

	London	Outside London
Commuting	-0.1	-0.15
Business	-0.1	-0.15
Leisure	-0.3	-0.45

These will be used as E values (seed elasticities) in the following formulae from Section 5 (i.e. formulae (5.5) and (5.15)).

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{2 + E\left[\frac{P_2}{P_1} - 1\right]}{2 - E\left[\frac{P_2}{P_1} - 1\right]} \qquad \left(\frac{Q_2}{Q_1}\right)^M = \frac{8 + 3E\left[\frac{P_2}{P_1} - 1\right]}{8 - 3E\left[\frac{P_2}{P_1} - 1\right]}$$

Where N denotes calculations using our "normal" or "best-estimate" elasticity values and M denotes calculations using our "modified" elasticity values, these being in all cases three-quarters of the "normal" ones, permitting a sensitivity test and possibly allowing for the effect of income growth. Since the elasticities are for traffic relative to fuel price, we can enter 2 for P_2/P_1 since we are doubling fuel prices.

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{2 + E}{2 - E} \qquad \left(\frac{Q_2}{Q_1}\right)^M = \frac{8 + 3E}{8 - 3E}$$

Commuting/Business

London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{1.9}{2.1} = 0.905$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{7.7}{8.3} = 0.928$$

Outside London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{1.85}{2.15} = 0.860$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{7.55}{8.45} = 0.893$$

Leisure

London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{1.7}{2.3} = 0.739$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{7.1}{8.9} = 0.798$$

Outside London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{1.55}{2.45} = 0.633$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{6.65}{9.35} = 0.711$$

T1.4 Increased use of public mode

Data on cross price elasticities is much less plentiful than that for own price elasticities. Goodwin (1992, p161) reports that five results from three studies gave an average cross-elasticity of public transport demand with respect to petrol prices of +0.34, with a range of +0.08 to +0.8. HFA/ITS/ACCENT (1993) present some information broken down by journey purpose, from a sample taken in London (e.g. see p95, Table 6.6). These elasticities are well below +0.34 if small changes in price are involved. Our method will automatically scale them up for large price changes. The following elasticities are derived from that source.

	Cross elasticity w.r.t. Car Costs
Commuting	0.076
Business	0.040
Leisure	0.064

These cross elasticities are with respect to private transport cost, not just the fuel price element. It seems that petrol costs were about half the perceived costs for commuting and about three quarters the perceived costs for other purposes. Hence a given %

change in fuel prices will have an effect on mileage lower than indicated by the above figures. HFA/ITS/ACCENT (1993) report on p44 that London Transport's Scenario Model assumes the following cross elasticities with respect to petrol prices.

	Suburban	Radial
Work	0.05-0.10	0.02-0.05
Non-work	0.06-0.13	0.03-0.05

From both the HFA/ITS/ACCENT and LT sources it appears that cross elasticities of public transport kilometrage to petrol prices are much lower in London than the +0.34 quoted by Goodwin. This is probably sensible since, where public transport is practicable, it already has a high market share in London. In other areas, public transport starts from a much lower market share and so (as was pointed out in Section 5) a small % switch out of car can mean a large % switch into public transport.

Table T1.5 illustrates how different the mix of modes is in London, not just from the national average, but also from the other English Metropolitan counties. For each 1% of mileage switched from private to public mode the mileage to be switched in London is 38.86, Other Mets 43.18 and All GB 54.49. The consequent percentage increase in public mode mileage is then seen to be:

London	38.86/1292 = 3%
Other Mets	43.18/856 = 5%
All GB	54.49/812 = 6.7%

It is therefore reasonable to expect cross elasticities outside London to be over twice those inside London. In this way we can reconcile the different data sources and adopt the cross elasticity values shown in T1.6 below.

T1.5 Average Distance Travelled Per Person Per Year, 1991/3

Miles (% in brackets)	London	Other English Met. Counties	All GB
WALK	246 (4.5)	204 (3.8)	212 (3.3)
PRIVATE	3886 (71.7)	4318 (80.3)	5449 (84.2)
PUBLIC	1292 (23.8)	856 (15.9)	812 (12.5)
ALL MODES	5423	5377	6473

Source: DoT (1995)

T1.6 Following from the above discussion, the following base cross elasticity values are proposed:

	Commuting	Business	Leisure
London	0.04	0.03	0.06
Conurbations	0.10	0.08	0.15
Urban	0.18	0.13	0.27
Rural	0.18	0.13	0.27

T1.7 These values are still well below the figure suggested by Goodwin, and reflect a belief that only a minority of private mileage would switch to public mode. The proportion of trips switching might well be higher, but the replacement public mode trip might be expected to be shorter than the original private mode trip. In any event, the figures above will be increased by the scaling factor we are using to represent non-linearity. For doubled petrol prices, for instance, the above values will be increased by 50% taking their average close to the Goodwin figure.

T1.8 The formula for finding the extent of increased public mode mileage is that derived in Section 5.

$$\left(\frac{Q_{i2}}{Q_{i1}}\right)^N = \frac{2 + C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}{2 - C\left(\frac{P_{j2}}{P_{j1}} - 1\right)} = \frac{2 + C}{2 - C} \qquad for\ P_{j2} = 2P_{j1}$$

$$\left(\frac{Q_{i2}}{Q_{i1}}\right)^M = \frac{8 + 3C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}{8 - 3C\left(\frac{P_{j2}}{P_{j1}} - 1\right)} = \frac{8 + 3C}{8 - 3C} \qquad for\ P_{j2} = 2P_{j1}$$

Example: Commuting in London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{2.04}{1.96} = 1.041 \qquad \left(\frac{Q_2}{Q_1}\right)^M = \frac{8.12}{7.88} = 1.030$$

The remainder are calculated in the same way and given in T1.9

The overall effects of the tests are reported in Tabeles T1.10 and T1.11, which (as for all subsequent tests) show figures for millions of miles p.a. in GB.

T1.9 Public transport change factors resulting from a doubling of petrol prices

Elasticities	Normal			Modified		
	Commuting	Business	Leisure	Commuting	Business	Leisure
London	1.041	1.030	1.062	1.030	1.023	1.046
Conurbations	1.105	1.083	1.162	1.078	1.062	1.119
Urban	1.198	1.139	1.312	1.145	1.102	1.225
Rural	1.198	1.139	1.312	1.145	1.102	1.225

T1.10 2006 base mileage and revised figures (Normal elasticities)

Area	Purpose	Mode	2006 Base	Factor (Test 1N)	2006 New
London	Work	Public	6976	1.041	7262
	Business		934	1.030	961
	Leisure		6583	1.062	6991
London	All		14493		15215
Conurbations	Work		2816	1.105	3111
	Business		384	1.083	416
	Leisure		7239	1.162	8411
Conurbations	All		10439		11939
Urban	Work		6268	1.198	7509
	Business		1022	1.139	1164
	Leisure		12547	1.312	16461
Urban	All		19837		25134
Rural	Work		5142	1.198	6160
	Business		832	1.139	948
	Leisure		7800	1.312	10234
Rural	All		13774		17342
All	All	Public	58542		69630
London	Work	Private	9938	0.905	8994
	Business		2489	0.905	2253
	Leisure		19851	0.739	14670
London	All		32278		25916
Conurbations	Work		17460	0.860	15016
	Business		5661	0.860	4869
	Leisure		34910	0.633	22098
Conurbations	All		58032		41983
Urban	Work		59245	0.860	50951
	Business		20488	0.860	17620
	Leisure		128694	0.633	81463
Urban	All		208427		150034
Rural	Work		59862	0.860	51481
	Business		18665	0.860	16052
	Leisure		123192	0.633	77980
Rural	All		201719		145514
All	All	Private	500456		363447
All	All	Public & Private	558998		433076

T1.11 2006 base mileage and revised figures (Modified elasticities)

Area	Purpose	Mode	2006 Base	Factor (Test 1M)	2006 New
London	Work	Public	6976	1.030	7186
	Business		934	1.023	955
	Leisure		6583	1.046	6886
London	All		14493		15027
Conurbations	Work		2816	1.078	3035
	Business		384	1.062	408
	Leisure		7239	1.119	8100
Conurbations	All		10439		11543
Urban	Work		6268	1.145	7177
	Business		1022	1.102	1126
	Leisure		12547	1.225	15370
Urban	All		19837		23673
Rural	Work		5142	1.145	5887
	Business		832	1.102	917
	Leisure		7800	1.225	9555
Rural	All		13774		16360
All	All	Public	58542		66602
London	Work	Private	9938	0.928	9222
	Business		2489	0.928	2309
	Leisure		19851	0.798	15841
London	All		32278		27373
Conurbations	Work		17460	0.893	15592
	Business		5661	0.893	5056
	Leisure		34910	0.711	24821
Conurbations	All		58032		45469
Urban	Work		59245	0.893	52906
	Business		20488	0.893	18296
	Leisure		128694	0.711	91501
Urban	All		208427		162703
Rural	Work		59862	0.893	53457
	Business		18665	0.893	16668
	Leisure		123192	0.711	87589
Rural	All		201719		157714
All	All	Private	500456		393259
All	All	Public & Private	558998		459862

TEST 1A TRIPLING FUEL PRICES FOR PRIVATE MODE TRANSPORT

The argument follows that of Test 1, except that $\frac{P_2}{P_1} = 3$

1A.1 EFFECT ON PRIVATE MODE

Substitute $P_2 = 3P_1$ into the formula in section T1.3, giving

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{1 + E}{1 - E} \qquad \left(\frac{Q_2}{Q_1}\right)^M = \frac{4 + 3E}{4 - 3E}$$

Commuting/Business

London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{0.9}{1.1} = 0.818$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{3.7}{4.3} = 0.860$$

Outside London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{0.85}{1.15} = 0.739$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{3.55}{4.45} = 0.798$$

Leisure

London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{0.7}{1.3} = 0.538$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{3.1}{4.9} = 0.633$$

Outside London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{0.55}{1.45} = 0.379$$

$$\left(\frac{Q_2}{Q_1}\right)^M = \frac{2.65}{5.35} = 0.495$$

1A.2 EFFECT ON PUBLIC MODE

$$\left(\frac{Q_{i2}}{Q_{i1}}\right)^N = \frac{2 + C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}{2 - C\left(\frac{P_{j2}}{P_{j1}} - 1\right)} = \frac{1 + C}{1 - C} \qquad \textit{for } P_{j2} = 3P_{j1}$$

$$\left(\frac{Q_{i2}}{Q_{i1}}\right)^M = \frac{8 + 3C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}{8 - 3C\left(\frac{P_{j2}}{P_{j1}} - 1\right)} = \frac{4 + 3C}{4 - 3C} \qquad \textit{for } P_{j2} = 3P_{j1}$$

Example: Commuting in London

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{1.04}{0.96} = 1.083 \qquad \left(\frac{Q_2}{Q_1}\right)^M = \frac{4.12}{3.88} = 1.062$$

The remainder are calculated in the same way and given in Table 1A.1

Table 1A.1 Public Transport change factors resulting from a trebling of petrol prices

Elasticities	Normal			Modified		
	Commuting	Business	Leisure	Commuting	Business	Leisure
London	1.083	1.062	1.128	1.062	1.046	1.094
Conurbations	1.222	1.174	1.353	1.162	1.128	1.254
Urban	1.439	1.299	1.740	1.312	1.216	1.508
Rural	1.439	1.299	1.740	1.312	1.216	1.508

Results of the tests are presented in Tables 1A.2 and 1A.3.

Table 1A.2 2006 base mileage and revised figures (Normal elasticities)

Area	Purpose	Mode	2006 Base	Factor (Test 1AN)	2006 New
London	Work Business Leisure	Public	6976 934 6583	1.083 1.062 1.128	7556 992 7425
London	All		14493		15973
Conurbations	Work Business Leisure		2816 384 7239	1.222 1.174 1.353	3441 451 9794
Conurbations	All		10439		13686
Urban	Work Business Leisure		6268 1022 12547	1.439 1.299 1.740	9019 1328 21831
Urban	All		19837		32178
Rural	Work Business Leisure		5142 832 7800	1.439 1.299 1.740	7399 1081 13573
Rural	All		13774		22053
All	All	Public	58542		83889
London	Work Business Leisure	Private	9938 2489 19851	0.818 0.818 0.538	8129 2036 10680
London	All		32278		20845
Conurbations	Work Business Leisure		17460 5661 34910	0.739 0.739 0.379	12903 4184 13231
Conurbations	All		58032		30318
Urban	Work Business Leisure		59245 20488 128694	0.739 0.739 0.379	43782 15141 48775
Urban	All		208427		107698
Rural	Work Business Leisure		59862 18665 123192	0.739 0.739 0.379	44238 13794 46690
Rural	All		201719		104721
All	All	Private	500456		263582
All	All	Public & Private	558998		347471

Table 1A.3 2006 base mileage and revised figures (Modified elasticities)

Area	Purpose	Mode	2006 Base	Factor (Test 1AM)	2006 New
London	Work Business Leisure	Public	6976 934 6583	1.062 1.046 1.094	7409 977 7202
London	All		14493		15587
Conurbations	Work Business Leisure		2816 384 7239	1.162 1.128 1.254	3272 433 9077
Conurbations	All		10439		12783
Urban	Work Business Leisure		6268 1022 12547	1.312 1.216 1.508	8223 1243 18920
Urban	All		19837		28387
Rural	Work Business Leisure		5142 832 7800	1.312 1.216 1.508	6746 1012 11763
Rural	All		13774		19521
All	All	Public	58542		76277
London	Work Business Leisure	Private	9938 2489 19851	0.860 0.860 0.633	8547 2141 12565
London	All		32278		23253
Conurbations	Work Business Leisure		17460 5661 34910	0.798 0.798 0.495	13933 4518 17281
Conurbations	All		58032		35732
Urban	Work Business Leisure		59245 20488 128694	0.798 0.798 0.495	47278 16349 63704
Urban	All		208427		127331
Rural	Work Business Leisure		59862 18665 123192	0.798 0.798 0.495	47770 14895 60980
Rural	All		201719		123644
All	All	Private	500456		309960
All	All	Public & Private	558998		386237

TEST 2 HALVING PUBLIC TRANSPORT FARES

T2.1 Effects

(1) Increased use of Public Mode
(2) Decreased use of Private Mode
(3) Probably some decreased use of Slow Mode

T2.2 The effect of changing public transport fares have been greatly studied and for London the 'Fares Fair' policy gave a real test. Goodwin (1992) again summarises the data, and is not inconsistent with the figures given by Fowkes et al (1993), shown in T2.3 below.

T2.3 Elasticities of bus patronage with respect to fares

Commuting	-0.3
Business	-0.3
Leisure	-0.6

T2.4 Work at TRL broadly supported these figures but increased them by 10% for each car owned. Furthermore, Goodwin made a strong case for using higher elasticities for projections beyond 5 years, as in our case, suggesting an average of -0.65. In view of these two pieces of evidence I use the elasticities shown in T2.5 below.

T2.5 Long run elasticities of bus patronage with respect to fares, by car availability.

	Car Non-Available CO	Car Available CA
Commuting	-0.40	-0.45
Business	-0.40	-0.50
Leisure	-0.80	-0.90

T2.6 Note further that these elasticities will be used as seed elasticities (F) in the formula from Section 5 and so will be somewhat reduced for fare decreases. From Section 5 we have

$$F = 0.5E\left[\frac{P_2}{P_1} + 1\right]$$

so that for halving fares, $P_1 = 2P_2$

F = 0.5E (1.5) = 0.75E

i.e. the arc elasticities that will be implicit in the forecasts for this test will be only 75% of those shown in T2.5 above.

T2.7 The formulae from Section 5 for finding volume changes are:

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{2 + E\left[\frac{P_2}{P_1} - 1\right]}{2 - E\left[\frac{P_2}{P_1} - 1\right]} \qquad \left(\frac{Q_2}{Q_1}\right)^M = \frac{8 + 3E\left[\frac{P_2}{P_1} - 1\right]}{8 - 3E\left[\frac{P_2}{P_1} - 1\right]}$$

where N denotes our 'normal' or 'best' estimates, and M denotes estimates with elasticities scaled down by the rate of growth of real incomes.

For halving fares ($P_1 = 2P_2$)

$$\left(\frac{Q_2}{Q_1}\right)^N = \frac{2 - 0.5E}{2 + 0.5E} = \frac{4 - E}{4 + E} \qquad \left(\frac{Q_2}{Q_1}\right)^M = \frac{8 - 1.5E}{8 + 1.5E} = \frac{16 - 3E}{16 + 3E}$$

T2.8 Predicted Patronage Changes for Public Mode

	E	$(Q_2/Q_1)^N$	$(Q_2/Q_1)^M$
CO			
Work	-0.40	1.222	1.162
Business	-0.40	1.222	1.162
Leisure	-0.80	1.500	1.353
CA			
Work	-0.45	1.254	1.184
Business	-0.50	1.286	1.207
Leisure	-0.90	1.581	1.406

T2.9 Cross price effects

Effects of small public transport fare changes on car traffic are so small as to be swamped by the noise in the data, which is in any event very difficult to obtain (for example O-D information for car travellers usually requires that the car be stopped and the driver interviewed). The 1981 'Fares Fair' policy in London, however, was a large fares reduction (32%) over a very wide area. London Transport estimate that private cars entering Central London fell by 6% between 1980 and 1981. Although lots of other things were going on, principally the economic recession, and 'cars entering Central London' is certainly not 'private mode mileage in London' it does give us a first approximation. A roughly 30% reduction in fares was associated with a 6% reduction in traffic, implying a cross elasticity of 0.2. This seems rather high. Lewis (1978) found a cross elasticity of 0.08. I think this may be suitable for London, where driving conditions are often difficult and where public transport is competitive and holds a good share of total demand.

In other conurbations, urban areas and particularly rural areas, public transport accounts for a much smaller proportion of demand. Hence, even if all those priced onto public transport by the fares reduction had switched from private mode (rather than from slow mode or generation) then there would still be a relatively minor percentage fall in private mode mileage. It is hard to conceive of it being more than one tenth on average. Since
commuting has a much higher public transport mode share, this will probably about cancel out the lower own-price elasticity such that there will probably be little journey purpose difference in the cross elasticities.

Evidence on mode splits for NTS is presented in T2.10 below. T2.11 represents a consolidation of this evidence in proposed cross elasticities.

T2.10 Mode split by area type, NTS 1991/93

	London	Other Conurbations	All area types
PUBLIC	24%	16%	14%
PRIVATE	71%	80%	81%
SLOW	5%	4%	5%

T2.11 Long run cross price elasticities of car mileage with respect to fares, by car availability

Excl London CO	Excl London CA	London CO	London CA
0.05	0.05	0.08	0.08

T2.12 The formulae from Section 5 are

$$\left(\frac{Q_{i2}}{Q_{i1}}\right)^N = \frac{2 + C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}{2 - C\left(\frac{P_{j2}}{P_{j1}} - 1\right)} \qquad \left(\frac{Q_{i2}}{Q_{i1}}\right)^M = \frac{8 + 3C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}{8 - 3C\left(\frac{P_{j2}}{P_{j1}} - 1\right)}$$

For halving fares, $P_{j1} = 2P_{j2}$, and so

$$\left(\frac{Q_{i2}}{Q_{i1}}\right)^N = \frac{2 - 0.5C}{2 + 0.5C} = \frac{4 - C}{4 + C} \qquad \left(\frac{Q_{i2}}{Q_{i1}}\right)^M = \frac{16 - 3C}{16 + 3C}$$

T2.13 Predicted car mileage changes

	C	$(Q_2/Q_1)^N$	$(Q_2/Q_1)^M$
London	0.08	0.961	0.970
Excl London	0.05	0.975	0.981

T2.14 Table T2.15 shows the effect disaggregated by area type, journey purpose and mode. The factors used in the calculations are not shown as these were further disaggregated by our CA/CO split, as described above. Table T2.15 shows the results using both the NORMAL (best estimate) and MODIFIED (reduced by real income growth) elasticities.

Table 2.15: Mileages for 2006 BASE and for 2006 with NORMAL and MODIFIED elasticities

Area	Purpose	Mode	2006 Base	2006 New Normal Elasticities	2006 New Modified Elasticities
London	Work	Public	6976	8618	8171
	Business	Public	934	1183	1114
	Leisure	Public	6583	10023	9004
London	All	Public	14493	19824	18289
Conurb	Work	Public	2816	3466	3289
	Business	Public	384	487	459
	Leisure	Public	7239	11066	9930
Conurb	All	Public	10439	15020	13678
Urban	Work	Public	6268	7765	7356
	Business	Public	1022	1307	1228
	Leisure	Public	12547	19274	17273
Urban	All	Public	19837	28346	25857
Rural	Work	Public	5142	6364	6031
	Business	Public	832	1067	1002
	Leisure	Public	7800	11971	10731
Rural	All	Public	13774	19403	17764
All	All	Public	58542	82593	75588
London	Work	Private	9938	9550	9640
	Business	Private	2489	2392	2414
	Leisure	Private	19851	19076	19255
London	All	Private	32278	31019	31309
Conurb	Work	Private	17460	17024	17129
	Business	Private	5661	5520	5554
	Leisure	Private	34910	34038	34247
Conurb	All	Private	58032	56581	56929
Urban	Work	Private	59245	57764	58120
	Business	Private	20488	19976	20099
	Leisure	Private	128694	125477	126249
Urban	All	Private	208427	203217	204467
Rural	Work	Private	59862	58365	58725
	Business	Private	18665	18199	18311
	Leisure	Private	123192	120112	120851
Rural	All	Private	201719	196676	197886
All	All	Private	500456	487492	490592
All	All	Pub. and Priv.	558998	570085	566180

TEST 3 HALTING THE REDISTRIBUTION OF POPULATION FROM BUILT-UP TO RURAL AREAS

T3.1 Precise Specification

In order to gain sufficient precision to perform calculations, I will state the test more exactly to be as follows:

> "What difference would it make to our 2006 base mileage figures if, for each age/sex group, the total population in 2006 is as predicted in our 2006 base, but these were distributed over area types in the same proportions as in 1992"

T3.2 It immediately follows from the above that we are effectively considering transferring people between area types, without affecting the overall age/sex distribution. It seems reasonable, however, to let the car availability ratios remain unchanged (i.e. at 2006 levels) within area types, so that the population shift will alter the overall proportion of car available persons.

T3.3 For our 7 age/sex groups broken down by 4 area types we already have OPCS population forecasts (as of 1989) for 1992 and 2006. It follows that the proportion falling in each of these 28 categories is known for both years, with sums over age/sex types and sums over area types. What we need to do is to revise the 2006 proportions for the 28 categories while preserving the 1992 proportions by area type and the 2006 proportions by age/sex type.

T3.4 The adjustment made to 2006 populations by age, sex and location were as follows.

Firstly the proportion of population (a_{ij}) falling in each age/sex/location cell in 1992 was calculated from the OPCS projection data, with i denoting location (London, Conurbation, Urban, Rural) and j denoting age/sex (P1500, M1629, M3059, M60+, F1629, F3059, F60+).

Similarly the proportions of population (b_{ij}) falling into each age/sex/location cell in 2006 were calculated.

Sums over i and j will be denoted by dots i.e.

$$\sum_i a_{ij} = a_{\cdot j} \ ; \qquad \sum_i \sum_j b_{ij} = b_{\cdot\cdot} \quad etc$$

Naturally we want $a_{\cdot\cdot} = b_{\cdot\cdot} = 1.000$, i.e. all population accounted for in both periods.

Similarly, the adjusted proportions for 2006 using 1992 location spread, but 2006 age/sex spread, were denoted c_{ij}, and again we require $c_{\cdot\cdot} = 1.000$.

As just stated, we require the sums of each age/sex cell summed over area types in the adjusted 2006 figures to equal those in the base 2006 figures,

$$i.e. \quad c_{\bullet j} = b_{\bullet j} \quad for\ all\ j \qquad (1)$$

Additionally, as also just stated, we require the sums of each location type summed over the age/sex cells for the 2006 adjusted figures to be equal to those in 1992,

$$i.e. \quad c_{i\bullet} = a_{i\bullet} \qquad (2)$$

$$i.e. \quad \sum_j c_{ij} = a_{i\bullet}$$

where the c_{ij} are the b_{ij} values adjusted to meet the earlier requirement (1).

T3.5 Starting with the b_{ij} we might first consider multiplying by

$$\frac{a_{i\bullet}}{b_{i\bullet}}$$

in order to revise the location split back to that applicable in 1992. We cannot call the result c_{ij} because it might not satisfy requirement (1). To ensure it does, we proceed as follows:

$$Proposed\ figure = d_{ij} = b_{ij}\,\frac{a_{i\bullet}}{b_{i\bullet}}$$

$$d_{i\bullet} = \sum_j d_{ij} = \frac{a_{i\bullet}}{b_{i\bullet}} \sum b_{ij} = \frac{a_{i\bullet}}{b_{i\bullet}}\, b_{i\bullet} = a_{i\bullet}$$

$$d_{\bullet j} = \sum_i d_{ij} = \sum_i b_{ij} \left(\frac{a_{i\bullet}}{b_{i\bullet}}\right)$$

This suggests that we multiply each d_{ij} by

$$\frac{b_{\bullet j}}{\sum_i b_{ij} \left(\frac{a_{i\bullet}}{b_{i\bullet}}\right)}$$

Hence we have

$$c_{ij} = \frac{b_{ij}\, b_{\bullet j} \left(\dfrac{a_{i\bullet}}{b_{i\bullet}} \right)}{\sum_i b_{ij} \left(\dfrac{a_{i\bullet}}{b_{i\bullet}} \right)} \qquad (3)$$

Happily, this worked.

T3.6 The calculations are shown in T3.7. The columns give the proportions a, b and c expressed as percentages of the total population of that year. The adjusted 2006 figures are in the final column. The percentage for London, 12%, can be seen to be the same as that in 1992. The percentage of children (P1500) can be seen to be (very nearly) the same as that for 2006 (unadjusted).

T3.7 Population distributions; 1992, 2006 and adjusted 2006

		1992 % (a)	2006 % (b)	ADJ 2006 % (c)
London	P1500	2.445	2.634	2.697
	M1629	1.363	1.169	1.198
	M3019	2.272	2.379	2.437
	M6000	0.953	0.880	0.903
	F1629	1.357	1.134	1.162
	F3059	2.300	2.421	2.480
	F6000	1.310	1.095	1.123
		12.000	11.712	12.000
Conurbation	P1500	3.095	2.973	3.158
	M1629	1.560	1.220	1.296
	M3019	2.773	2.828	3.007
	M6000	1.244	1.229	1.309
	F1629	1.514	1.177	1.252
	F3059	2.722	2.796	2.972
	F6000	1.751	1.564	1.665
		14.660	13.786	14.659
Urban	P1500	8.746	8.852	8.809
	M1629	4.490	3.736	3.718
	M3019	8.216	8.945	8.910
	M6000	3.815	4.164	4.153
	F1629	4.353	3.527	3.513
	F3059	8.305	8.840	8.803
	F6000	5.258	5.292	5.276
		43.183	43.357	43.182
Rural	P1500	6.054	6.358	6.152
	M1629	3.180	2.676	2.589
	M3019	5.778	6.410	6.207
	M6000	2.754	3.045	2.953
	F1629	2.985	2.745	2.658
	F3059	5.715	6.210	6.011
	F6000	3.692	3.702	3.589
		30.158	31.145	30.159
All	P1500	20.340	20.817	20.816
	M1629	10.593	8.801	8.801
	M3019	19.039	20.562	20.561
	M6000	8.766	9.318	9.318
	F1629	10.209	8.583	8.585
	F3059	19.042	20.267	20.266
	F6000	12.011	11.653	11.653
		100.000	100.001	100.000

T3.8 If we take a threshold for changes of 0.1% of total population as worthy of comment, the following are the main effects of the adjustment:

(i)	more children in conurbations	(3.0% → 3.2%)
(ii)	more males 30-59 in conurbations	(2.8% → 3.0%)
(iii)	more females 30-59 in conurbations	(2.8% → 3.0%)
(iv)	more females 60+ in conurbations	(1.6% → 1.7%)
(v)	less children in rural areas	(6.4% → 6.2%)
(vi)	less males 30-59 in rural areas	(6.4% → 6.2%)
(vii)	less females 30-59 in rural areas	(6.2% → 6.0%)
(viii)	less females 60+ in rural areas	(3.7% → 3.6%)

The picture is therefore fairly clear, thirty to sixty year olds have been transferred, by our adjustment, from rural areas to conurbations, along with children and women pensioners. To look at it another way, we can say that the actual movement of such people, between 1992 and 2006, out of conurbations into rural areas has been retarded.

T3.9 Table T3.10 shows the effect of this adjustment on mileage travelled, both in relation to 1992 and our 2006 base run. Effects on private mode transport are relatively minor, whilst for public mode the previously predicted (1992 to 2006 Base) increase in Rural areas is seen to be more than accounted for by the population movement into these areas.

T3.10 Mileages for 1992, 2006 BASE and 2006 with population location distribution controlled to equal that of 1992

Area	Purpose	Mode	1992	2006 Base	2006 with Adj. Pop.
London	Work Business Leisure	Public Public Public		6976 934 6583	7148 957 6747
London	All	Public	10538	14493	14852
Conurb	Work Business Leisure	Public Public Public		2816 384 7239	2994 408 7701
Conurb	All	Public	8744	10439	11103
Urban	Work Business Leisure	Public Public Public		6268 1022 12547	6241 1018 12499
Urban	All	Public	21428	19837	19758
Rural	Work Business Leisure	Public Public Public		5142 832 7800	4978 806 7556
Rural	All	Public	13490	13774	13340
All	All	Public	54204	58542	59054
London	Work Business Leisure	Private Private Private		9938 2489 19851	10181 2550 20338
London	All	Private	26295	32278	33070
Conurb	Work Business Leisure	Private Private Private		17460 5661 34910	18564 6020 37120
Conurb	All	Private	33585	58032	61704
Urban	Work Business Leisure	Private Private Private		59245 20488 128694	58999 20405 128170
Urban	All	Private	127130	208427	207575
Rural	Work Business Leisure	Private Private Private		59862 18665 123192	57957 18074 119290
Rural	All	Private	116737	201719	195322
All	All	Private	303747	500456	497670
All	All	Pub. and Priv.	357950	558998	556724
All	All	Slow	9433	7270	7262
All	All	All	367381	566268	563986

TEST 4 ROAD PRICING IN LONDON AND THE CONURBATIONS

T4A. London only

T4.1 The results of the London Congestion Charging Study (MVA Consultancy, 1995) have now been published. Naturally the effect on car mileage in London is influenced by the geographic structure for the tolling, the time periods for which tolling takes place, and the level of toll charges. The report looked at 'low' and 'high' charge levels. In order to see the national impact it is sensible for us to take the 'high' levels and leave it for others to rescale to them to other interesting values. In this regard, mention should be made that the report works in 1991 prices and adjustments for inflation would need to be made. The 'high' levels involved an £8 all day charge to travel into Central London, with one variant adding a £4 peak period charge to enter Inner London. It is this latter variant that we are imagining is put into place for the current test.

T4.2 Table 7.1 of the Study Report gives reductions in vehicle-kms resulting from this level and structure of charging, broken down by sectors of London. Our lowest level of aggregation is London itself. Having studied the figures carefully, and wishing to work in reasonably round numbers at this stage, we decided to take the effect to be a London-wide reduction for private mode milage of 7% for work, 2% for business and 7% for leisure. These figures equate to an overall reduction of around 6½%. We assume that there will be negligible offsetting increase elsewhere. Note though, that our model relates to travellers rather than travel. Some RURAL inhabitants may drive regularly into London, but we count that as RURAL travel. Hence the effects outside London of road pricing in London might be positive or negative in our model.

T4.3 The above figures for private mode mileage reduction will be applied equally to persons regardless of car availability.

T4.4 There will be consequential effects on public mode usage, and these will be taken to follow the pattern derived in Test 1 in relation to traffic priced off private mode by a doubling of fuel prices.

T4.5 **Calculation of diversion factors for private mode cost rises in London.**

Elasticities	Purpose	2006 Base Private	2006 New Private	Fall	2006 Base Public	2006 New Public	Gain	Diversion Factor
Normal	Work	9938	8994	944	6976	7262	286	0.303
	Business	2489	2253	236	934	961	27	0.114
	Leisure	19851	14670	5181	6583	6991	408	0.079
Modified	Work	9938	9222	716	6974	7186	212	0.296
	Business	2489	2309	180	934	955	21	0.117
	Leisure	19851	15841	4010	6583	6886	303	0.076

Source: Table T1.10 and T1.11 (Halving petrol prices).

T4.6 On the basis of T4.5, diversion factors of 0.3 for work, 0.115 for business and 0.078 for leisure are indicated. However, unpublished data from the London Congestion Charging Study suggests diverson factors averaging 0.50, split equally between bus and rail.

T4.7 There are many reasons why the diversion factors should differ so much. In the case of doubled petrol prices (Test 1), the London effect would affect all car travel in London. The road pricing alternative, however, envisaged bi-directional cordon charging with three cordons and screenlines relating only to Central and Inner London. It can be expected that the journeys affected would have better than average public transport alternatives, thereby giving high diversion factors. Furthermore, the private transport reduction will be the net effect of a main effect suppression of private mode trips, offset to some extent by some move to longer private mode trips due to route or destination switching in order to avoid the tolled area. The diversion factors applicable to the net effect will be greater than those to a petrol price increase. Table T4.8 shows the upgrading of the diversion factors of T4.5 used in our test. These preserve a difference by journey purpose, but average to the value found by the London Congestion Charging Study.

T4.8 **Division Factors for London Road Pricing**

Purpose	Fall in Private mileage	Diversion Factor	Increase in Public mileage
Work	696	0.8	557
Business	50	0.3	15
Leisure	1390	0.2	278
ALL	1738	≈0.48	850

T4.9 The private mode reductions specified in T4.2 above and the public mode increases specified in T4.8, above are incorporated into the results presented in Table 4.10.

T4.10 **2006 base mileage and revised figures**

Area	Purpose	Mode	2006 Base	2006 New London only	2006 New London & Conurbs
London	Work Business Leisure	Public	6976 934 6583	7533 949 6861	7533 949 6861
London	ALL		14493	15343	15343
Conurbations	Work Business Leisure		2816 384 7239	2816 384 7239	3296 407 7606
Conurbations	ALL		10439	10439	11309
Urban	ALL		19837	19837	19837
Rural	ALL		13774	13774	13774
ALL	ALL	Public	58542	59393	60263
London	Work Business Leisure	Private	9938 2489 19851	9242 2439 18461	9242 2439 18461
London	ALL		32278	30142	30142
Conurbations	Work Business Leisure		17460 5661 34910	17460 5661 34910	16587 5548 32466
Conurbations	ALL		58032	58032	54601
Urban	ALL		208427	208427	208427
Rural	ALL		201719	201719	201719
ALL	ALL	Private	500456	498320	494889
ALL	ALL	Public & Private	558998	557713	555152

T4B. London and conurbations

T4.11 We have also considered, in very rough form, the extension of road pricing to the conurbations of West Midlands, Greater Manchester, West Yorkshire, Glasgow, Liverpool and Tyneside. Since public transport is not, relatively, so well placed to handle work trips (as opposed to business or leisure trips) in the conurbations as it is in London. We have assumed that the price is set so as to effect the following reductions in private mode travel:

Work	:	5%
Business	:	2%
Leisure	:	7%

T4.12 Regarding diversion factors, we feel that they will lie somewhere between those found in T4.5 above (from Test 1; doubling petrol prices) and those found in T4.8 above (for London). We have taken the values in T4.13.

T4.13 **Diversion factors for road pricing in the conurbations**

Purpose	Fall in Private mileage	Diversion Factor	Increase in Public mileage
Work	873	0.55	480
Business	113	0.20	23
Leisure	2444	0.15	367
ALL	3430	0.25	870

TEST 5 EFFECT OF ALLOWING CONGESTION TO INCREASE MUCH FASTER THAN HITHERTO

T5.1 Our 2006 base mileage forecasts have been derived by projecting the growth rates observed between 1985/6 and 1991/3. During this period it was government policy to provide additional road space in response to this projected growth wherever this could be justified by travel time savings, operating cost savings or environmental benefits. In calculating these savings and benefits, the NRTF (DOT 1989) traffic forecasts were assumed. Due to there being a shadow price of public funds, not all schemes with positive net present values (NPVs) were undertaken, but there was nevertheless a very substantial road programme directed at relieving congestion on inter-urban routes where the traffic forecasts indicated greatest problems.

T5.2 Due to various pressures, plans for the roads programme have recently been greatly reduced. Following its 'Rio' commitment, the government is keen to curb the rise in car use, and there has been a fall in the public pressure for road building. Government ministers are now said to be talking of the inter-urban road network as largely complete. Even the programme of motorway widening has been substantially cut back, despite there having been no change in the official forecasts of traffic growth. In this context there has been some interest in what would happen if traffic growth were allowed to proceed with little or no extra capacity provided for it. In such circumstances it is to be expected that some of the projected traffic growth will be 'choked-off' by the increased levels of congestion that will be caused. Christie (1995) reports on the outcome of a DOT research project into this topic. Table 1 of that paper, reproduced here as Table T5.3 shows the study assumptions for 30 years traffic flow increases as specified by DOT.

T5.3 **Assumed 30 Year Traffic Flow Increase, 1994 - 2024**

Central London	Nil
Rest of London	30%
Inner parts of other large urban areas	30%
Rest of large urban areas	60%
Small urban areas	100%
Motorways and busy rural dual carriageways	140%
Other rural roads	100%

Source : Christie (1995)

T5.4 It is not being suggested here that either the DOT or ourselves believe that the growths listed in T5.3 will in fact come to pass. However, we need some values for our test and so these appear to give a reasonable place to start. It must be emphasised at the outset that our location data relates to travellers and not to travel. For example, many of our London area type persons will drive regularly outside London.

T5.5 Bearing this last point in mind, and square rooting the growth factors rates shown in T5.3 in order to convert from a 30 year to a 14 year basis (ie. we are taking 1992 -

2006) we found the implied growth rates for our four area types consistent with our 2006 'base plus congestion' forecast, except for the conurbations, where our forecast of private mode mileage was much higher.

T5.6 Table 6 in the Christie paper reports mean percentage journey time increases and percentage mileage suppression by origin area type using 1994 to 2024 assumed traffic flow increases, ie those of T5.3. Since this now refers to origins, which is similar to our traveller area types, and since the 'origin types' used are remarkably similar to our own four area types, we can take them as 1994 to 2024 effects, and roughly calculate 1991/3 to 2006 effects by square rooting and rounding. For example, for London, 14.6% suppression means a factor of 1.146, which square rooted gives 1.075, which rounded down gives 7% suppression. These calculations are set out in Table T5.7, in which the first two columns are reproduced from Christie (1995) and the third column is the calculation just discussed.

As mentioned in T5.5 above, having seen the effect of using these calculations in the case of conurbations, we were not happy. Our NTS data for 1985/6 to 1991/3 shows strong growth in conurbation based private mode mileage. We take the message of Table T5.3 to be that conurbations, relative to urban and rural areas, will become more congested, and can be expected to have smaller increases in traffic flow. Beyond Table T5.3 we might expect some limited road building in urban and rural areas, thereby allowing more traffic growth even than is shown in Table T5.3, whilst there will be little road building in conurbations and so relatively more congestion still. In this light the conurbations might be seen as tending more to the situation as in London. However, while in London congestion was already so bad that there was little private mileage growth in our 1985/6 to 1991/3 data, this is clearly not the case for conurbations. In order to make sense of our data, therefore, we have assumed a suppression rate for conurbations double that which might be derived from Christie. This is shown in the final column of Table T5.7.

T5.7 **Journey Time Increases and Mileage Suppressions by Area Types**

Area Type	Mean % Journey Time increase 1994-2024	Reported % Mileage suppression 1994-2024	Calculated % Mileage suppression 1991/3-2006	Assummed % Mileage suppression 1991/3-2006
LONDON	22.6	14.6	7.0	7.0
CONURB	38.2	10.2	5.0	10.0
URBAN	50.9	15.6	7.5	7.5
RURAL	59.8	13.7	6.5	6.5

Source : Christie (1995) and additional calculations.

T5.8 Before going ahead and using the assumed suppressions in T5.7 we should consider the base, as already contained in our 1985/6 to 1991/3 trend. If congestion had been worsening in that time, some of the above mileage suppression could have been built into our 2006 base forecasts already. However, the position is far from clear and is muddied further by the consideration that the breakdowns are for origin (or domicile) location types. In London, journey times have been fairly static, and this probably goes for most conurbations. In Christie's sample, 70% of drivers said that they perceived journey times to be increasing year on year, but there had by then, 1994, been some gradual recovery from the 1990 recession, so that traffic was picking up again. More drivers would probably have noticed improvements between 1985/6 and 1991/3. On balance, we could not see any reliable way of adjusting the 1991/3 - 2006 figures in T5.7, and so they will be used for our test.

T5.9 Christie also provides a further table, splitting by journey purpose rather than origin. No cross tabulation is given, but it seems better than nothing to use the journey purpose relativities from Christie's Table 5, to disaggregate the calculated 1991/3 - 2006 mileage suppression figures of T5.7. The relativities are taken to be 6.2% for work, 19.1% for business and 15% for leisure. Diversion factors (to public mode) were calculated from the outcome of Test 1. Table 5.10 shows our calculations in detail, and Table 5.11 presents a summary for private mode.

T5.10 **Effects of Congestion in Private and Public Mileage**

Area	Purpose	Mode	2006 Base	Diversion/ Suppression Factors	2006 New
London	Work Business Leisure	Public	6976 934 6583	1.015 1.032 1.020	7081 964 6715
London	All		14493		14759
Conurb	Work Business Leisure		2816 384 7239	1.038 1.088 1.052	2923 418 7615
Conurb	All		10439		10956
Urban	Work Business Leisure		6268 1022 12547	1.052 1.114 1.075	6594 1139 13488
Urban	All		19837		21220
Rural	Work Business Leisure		5142 832 7800	1.045 1.096 1.066	5353 912 8315
Rural	All		13774		14580
All	All	Public	58542		61515
London	Work Business Leisure	Private	9938 2489 19851	0.965 0.894 0.917	9590 2225 18203
London	All		32278	0.930	30018
Conurb	Work Business Leisure		17460 5661 34910	0.950 0.850 0.882	16581 4812 30791
Conurb	All		58032	0.900	52190
Urban	Work Business Leisure		59245 20488 128694	0.963 0.887 0.912	57053 18173 117369
Urban	All		208427	0.925	192595
Rural	Work Business Leisure		59862 18665 123192	0.968 0.902 0.923	57946 16836 113706
Rural	All		201719	0.935	188488
All	All	Private	500456		463291
All	All	Pub & Priv	558998		524806

T5.11 **Private mode traffic growth increase in uncongested and congested conditions**

Area Type	1992 (Mmpa)	2006 Base (Mmpa)	% Increase	2006 Congested (Mmpa)	% Increase
LONDON	26295	32278	22.8	30018	14.2
CONURB	33585	58032	72.8	52190	55.4
URBAN	127130	208427	63.9	192595	51.5
RURAL	116737	201719	72.8	188488	61.5
ALL	303747	500456	64.8	463291	52.5

T5.12 The final column of Table T5.11 can be compared with the assumed flow increases in T5.3, bearing the following points in mind:

(i) Our period (T5.11) is only 14 years long, compared to the 30 years taken in T5.3

(ii) There will still be some enhancement to capacity even if the policies underlying the assumptions in T5.3 go ahead. Hence total private mode growth for persons living in a given area type (eg RURAL) will be greater than the rate of traffic flow increase on particular roads.

(iii) The assumed flow increases in Table 5.3 are not latent demands (in which case they would have related more to our 2006 Base) but achieved demands. For example, if the latent demand for use of small urban roads were to double, some of the traffic would be choked off by the congestion, say 20%. This would leave traffic flow of 80%. But this is not what Table T5.3 is saying. Table T5.3 says that achieved traffic flow growth is 100%, ie after congestion effects have been taken into account. This might require an 125% increase in latent demand, if the rate of choking off were to be (still) 20%. The figure given in Table T5.3 for Central London (Nil) is clearly not a prediction of the increase in latent demand in 30 years time. It is merely saying that there is no more room on the roads. Hence the figures in Table T5.3 are to be compared with the final column of Table T5.11, AFTER the congestion effect adjustment has been made, assuming that both refer to a situation where the road building programme is greatly reduced from that pertaining in the 1985/6 to 1991/3 period.

T5.13 Taking the considerations set out in T5.12 into account, it is our view that our private mode traffic forecasts are quite consistent with the DoT figures presented in T5.3 and used by Christie in his work for DoT, except that we appear to have higher growth in conurbations. The excess is not great, the degree of accuracy attainable with the comparison very rough, and it is not in any case clear which of us is nearer the truth. We have used the above reasoning to justify to ourselves the acceptance of the mileage projections of the method of Chapter 4, although accepting that they are only estimates and could not be taken as the last word.