ESRC Transport Studies Unit, University College London

CHANGING TRAVEL BEHAVIOUR

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INTRODUCTION

TSU

The Transport Studies Unit, established since 1973 at Oxford University, was awarded the status of a designated research centre of the ESRC from 1994 to 2004. The research programme, initially focussed on traffic growth and the development of dynamic methodologies, was launched at a Linacre Lecture in Oxford which attracted much press attention for its comments on induced traffic. The Unit transferred to University College London in January 1996. After a successful mid-term review, the second five year programme focussed on the process of behavioural change and appraisal tools.

ESRC funding and designation came to an end in September 2004 with an exceptionally well-attended final event in London on 'Changing Travel Behaviour', which constituted a suitably unifying theme bringing together a large proportion of the Unit's research projects. Appreciations were given by many of the leading stakeholders in transport policy and research, with an audience of over 400 academics and practitioners.

Shortly after, the ESRC Transport Studies Unit disbanded as an entity. The seven researchers who had carried out the programme are now continuing their activities at six different locations[1] in three countries, though maintaining contact and continuing to disseminate and extend the results of the ten years work. Transport research of course continues at both Oxford University (TSU in the School of Geography) and UCL (CTS in the Department of Civil and Environmental Engineering).

The ambiguity of 'changing'

The phrase 'changing travel behaviour' is ambiguous – changing as a description of what actually happens, and changing as an active intent by public or private agencies. The twin underlying propositions are that travel behaviour does change, and by understanding this travel behaviour can be changed.

There is a third, implied statement, that travel behaviour *should* be changed. This goes beyond the research programme. All three statements are controversial, but the controversies are resolved by different methods, from empirical and theoretical analysis to public debate. All three underpin the need to understand the processes of behavioural change, and to incorporate this understanding in the tools for appraising both transport investment and – as became apparent during the period of the research – other transport policies as well.

The logical structure used for this report (in part developed retrospectively in the course of planning for the TSU final event) has five parts: (1) establish the nature of the changes in travel behaviour that have actually happened; (2) consider the specific effects of two of the most important general influences, namely income, and demographic forces; (3)

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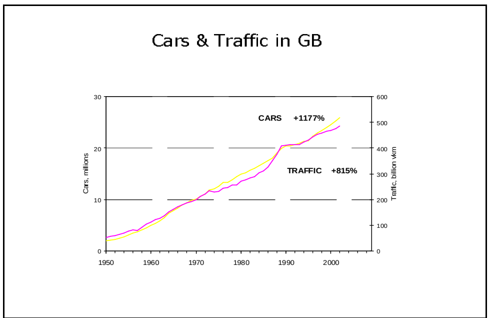
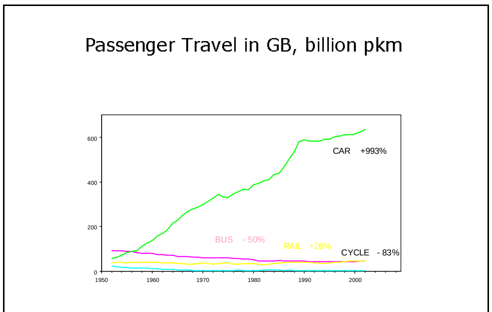
consider the evidence on the effect of transport policy, including both investment and non-investment initiatives. Those studied include new opportunities such as park-and-ride, increases and reductions in road capacity, increases and reductions in public transport fares and motoring costs, the effects of soft measures such as travel plans and information provision; (4) consider some theoretical and practical understanding of the nature of changes in behaviour; (5) discuss the policy implications of the work

1 Establishing the changes

Since 1950 the number of cars in Britain increased nearly 1200%. Today 75% of households have access to a car, compared to only 14% in 1950. The increase in car ownership has been the main impetus to increasing traffic, over the same period traffic increased by over 800%.



As we are all well aware, the car has allowed people to travel further distances. 50 years ago the average person travelled 4000 km per year. Today it is 3 times as far - over 12000 km, even without including air travel



During this period total passenger kms travelled by car increased by over 900%, while rail increased by 26%. All other modes have declined: bus travel by 50%, cycle by 83% and walking probably by more.

However, what we see here are aggregate net changes, which are composed of separate changes in travel behaviour by individuals. As we will see not all these individual changes go in the same direction. Such changes on an individual level are rarely considered in transport analysis. This is because empirical work has largely been based on aggregate time series data, which can only detect net changes, or disaggregate cross-section data, which contains no information about changes at all.

What we need for this is a different sort of data, in which the behaviour of individuals, or in some cases groups of individuals, is actually tracked over time, namely panel data. The analysis of panel data has been at the heart of much of our analytical work. First we give a few descriptive examples of what we can learn about travel behaviour on the basis of such data. Later we consider what information these data can give us about the factors determining travel behaviour over time.

At the start of the research programme we used panel data from South Yorkshire and found that apparently relatively slow and steady increases in car ownership across the whole population were actually made up of many households losing cars and many (usually more) gaining them, with the largest group showing no change.

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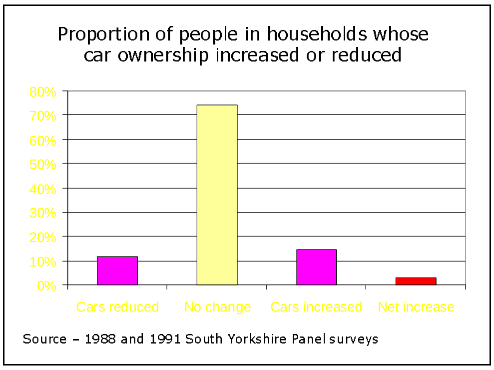
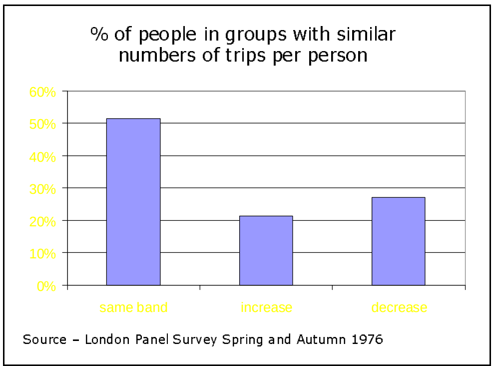


Between five separate panel surveys between 1981 and 1991 a similar pattern was observed. Car ownership would rise by about 3 or 4% over a 2 or 3 year period, but this would be made up by about 13 or

14% of people in households increasing the number of cars in their household, and 8-10% reducing the number of cars in the household. This graph shows the figures for 1988 to 1991, and is fairly typical of the other surveys. The individual changes are much larger than what you see if you take 'snapshots' of aggregate data. This has been described as 'churn'.



The same was true of the number of trips people made. Re-analysis of quite old data from London panel surveys showed that over a six month period there were some major changes. For over 5000 people surveyed there was a very small reduction in the average number of journeys made during the diary week. But even just over this six month period 52% made a similar number of trips in each survey, 21% made significantly more trips, and 27% made significantly fewer. This survey was done in the aftermath of London's "cheap fares" experiment, and things were changing fast, but the pattern of greater churn is clear again.

We also found the same was true of total time spent travelling. In aggregate terms this is remarkably constant over time (60 to 65 minutes for each 'average' person), and from time to time it has been suggested that the travel time budget is a sort of universal constant. But that only applies at the aggregate level – for individuals, there is no sign of stability or constancy at all: it changes quite radically with major life transitions, and also, apparently, randomly.

However, despite their usefulness for analysis of travel behaviour, transport panel surveys in the UK and abroad typically cover a small geographic area and a short time period. Because of this, much of our work has been based on the British Household Panel Survey, BHPS, which contains information on car ownership and commuting mode & time, along with a large number of socio-economic and demographic variables important in determining travel behaviour.

Using BHPS we see that over the past decade the number of cars per household has increased by 0.2% p.a. on average.

This small net increase conceals the fact that a relatively large number of households, 15.8%, change the number of cars they own between any two years. Slightly less than half of these, 7.6% reduce the number of cars they own, and 1.9% give up car ownership totally.

A similar volatility is noted for commuting mode – nearly 18% of commuters change main travel mode between any two years.

Main Commuting Mode, % of commuters

	rail	tube	bus	m'cyc	car driver	car pass.	cycle	walk
ave. yr	3.3	1.4	6.2	1.5	66.9	7.4	3.3	9.7
at least n years								
1	7.8	3.9	16.5	4.7	83.1	25.0	9.4	22.1
2	5.6	2.6	11.5	3.1	79.3	13.9	6.2	16.4
3	4.9	1.9	8.4	2.2	76.3	9.4	3.9	12.9
4	3.4	1.6	6.7	1.5	73.4	7.2	3.4	10.6
5	2.9	1.2	5.4	0.9	70.8	5.3	2.8	8.5
6	2.5	0.9	4.4	0.7	67.8	4.5	2.3	7.4
7	2.0	0.6	3.6	0.7	63.9	3.5	1.7	6.5
8	1.6	0.4	2.7	0.5	58.7	2.6	1.3	5.6
9	1.2	0.4	1.8	0.4	53.4	1.9	1.2	4.3
10	1.1	0.2	1.4	0.2	42.4	0.9	0.9	2.4

Here we track 'main' modes of transport for the journey to work for a sample of people for whom data are available over a 10 year period. For example, we see that for the average year, about 7.4% of journeys to work were made as car passengers. Of these, less than 1% were car passengers in every year out of the ten. But almost three times as many, 25%, commuted mainly as car passengers for at least one year out of the decade. It is a similar picture for the other modes – for rail, for example, nearly three times as many people are dependent on rail for a period of their life, than appears in any one year.

What this implies is that although only a small proportion of the population may use a particular mode in any given year, they are not the same individuals each year, so that over a period of years the number of individuals using the mode in one year or another is much greater. Of course, if we include trips for purposes other than commuting, we would find the proportion of individuals using any given mode over a longer time period is even greater.

To summarise: at the aggregate level, average travel behaviour has changed enormously during the period of one life time – mostly, apparently, in the same direction. But underlying that, individual behaviour changes more than the average, and includes substantial proportion of people changing in the opposite direction to the average. For whatever reason, behaviour is evidently very volatile. Virtually all established appraisal, even at disaggregate level, ignores churn and volatility in assessing the scale of change in behaviour.

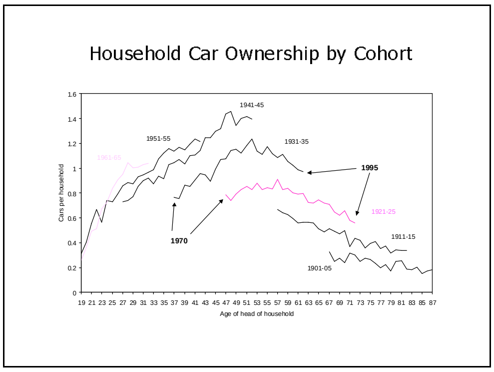
2. Exogenous drivers of change: demographic factors and income

Simply to establish that change happens is important, in a policy debate where one argument is that nothing moves. But that is not useful information until we know something more about what drives those changes. We start with the factors that are normally not considered to be transport policy instruments at all, demographic trends, and movements in income.

Since existing panel surveys for the UK have relatively little travel information – like the BHPS – or are only for a specific region – like the South Yorkshire and London panel, it is necessary to devise methods of looking at the process of behavioural change from other types of data. Pseudo-panels, which had not previously been used in the transport field, proved interesting.

Pseudo-panels use cross-section data collected at different points in time to construct something resembling a panel – not of individuals, but of individuals sharing the same characteristics. Such groups of individuals, generally called cohorts, are then followed in each of the annual data sets, and the average values for car ownership, income etc are treated as observations in a panel.

Extending work reported in the first term, we constructed a pseudo-panel data set able to show some changes in life cycle and income effects, from the annual UK Family Expenditure Surveys over a period of 25 years. We define the cohorts by the year of birth of the head-of-household in 5-year bands. These cohorts are then followed over time using the annual data sets.



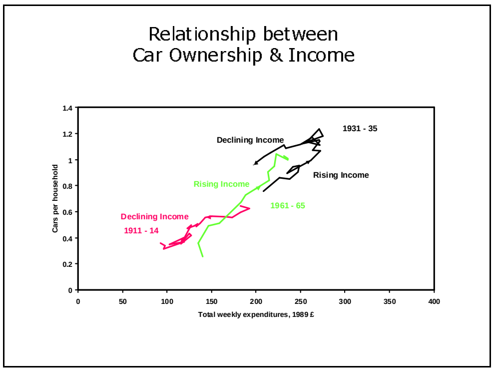
The graph shows car ownership for a selection of these cohorts over time. The age of the household head is given on the horizontal axis, and car ownership on the vertical. The lines represent the different cohorts, with the birth-year bands given adjacent. The initial data point for each cohort is obtained from the first survey in which an observation for the cohort is available, generally 1970, while the final data point is obtained from the last survey containing a comparable observation, generally 1995. For example, for the cohort in turquoise, the head was born between 1931 and1935. His/her mean age was 37 in the 1970 survey and 62 in the 1995 survey. The average household in this cohort owned about 0.75 cars when the head was 37 years of age. Household car ownership increased until the head approached the age of 50, reaching a maximum of 1.2 cars, thereafter declining to 1 car by the age of 62.

Two effects are discernable in the figure: a *life-cycle effect* - car ownership increases until the head is in his/her early 50s, and then declines; and a *generation effect* - at every ‘age’ car ownership is higher for more recent cohorts than for earlier ones. A similar pattern of lifecycle and generation effects can also be seen for car use.

This pattern can partially be explained by differences in household income over the life cycle and differences in real income between generations. Household income increases up until the head reaches his/her late 40s and declines thereafter. Similarly, at each age, real incomes are higher for more recent generations, due to general real income increases over time.

The change in number of adults in the household over the life cycle is clearly an important determinant of household income, car ownership and car travel. As young adults form households, income increases, and first, then perhaps second, cars are purchased and car travel increases. This is compounded as the children grow up and learn to drive - often contributing to the household income and obtaining cars of their own. Later, both car ownership and use decline, as adult children leave home taking their car with them or through the disposal of second cars, and finally predominantly through the death of a spouse.

In contrast to the aggregate trends shown earlier, this approach does provide for individual household level car ownership and car travel to go down as well as up over time. Although this is largely a systematic and sensible relationship with changes in income and household composition over the life-cycle, there is evidence that the relationship between car ownership and car travel and income may not be symmetric. This is shown in the diagram.



The vertical axis shows car ownership per household while the horizontal axis is real income. The earliest cohort shown (red line) is representative of pensioner households. The head ages from 59 to 80 over the observed time period and both car ownership and income are declining. The most recent cohort shown (in green) is an example of a relatively young household, with the head ageing from 20 to 30. Both income and car ownership are increasing rapidly.

Comparing these two cohorts, it is apparent that the slope of the line indicating the car ownership/income relationship is greater for the increasing income case (green line) than it is for the decreasing income case (red line). Rising income leads to increased car ownership, but when incomes fall car ownership is not reduced to the same degree.

This asymmetry is clearly exemplified in the middle-aged cohort shown in yellow. Here, we follow the cohort as the head ages from 35 to 60. Between the ages of 35 and 50, household income and car ownership are increasing; while after the age of 50 or so both income and car ownership begin to decline. But the same path is not followed. As income declines, car ownership declines, but to a lesser degree than it rose as income increased. For each income level we have **two** rather than **one** level of car ownership depending on whether income is increasing or decreasing. Thus there is no unique car ownership use-income relationship, but rather what we call a hysteresis[2] loop. The explanation for this is a simple one: households have become accustomed to the advantages car travel. Such car dependency is not easily reversed, so there is a tendency to maintain car ownership in spite of falling income.

To summarise: we identify the powerful effects of demographic influences, and of income. This in itself is not new – everybody accepts they are powerful. What is new is the *nature* of that influence, and in particular that the relationships take place over very long periods of time – decades – and the two factors interact with each other. The feature of asymmetry, or hysteresis, is important. It means that even though change is universal, it is more difficult to reverse a long-established trend than to accelerate it. It is established both that behaviour changes, and also that the relationships themselves change.

3. The Impact of Policy Initiatives

Policy initiatives, whether to provide improved infrastructure or to improve services and management, normally either are intended either to provide capacity for demand growth, or to reduce or reverse that growth. If hysteresis applies, the two would not be opposite and equal, and the appraisal of moving from 'A' to 'B' is not equivalent to the appraisal of moving from 'B' to 'A'. Part 1 demonstrated that habits cannot be overwhelmingly powerful, but part 2 suggested that they still have a degree of power. It follows that the effects of policies cannot be inferred from observation of the effects of other changes, or differences, in the world: it is necessary observe the effects of a policy initiative directly.

Here we must confront an analytical problem in the tradition of transport studies. The longest-established methods of forecasting the effects of a new policy or facility is to use a model which is itself based on observing differences in choices made by different people at a point in time, not on changes made by the same person over time. The presumption is that relationships based on differences can be used to predict changes.

That is not always true, and it can be very misleading. If hysteresis is a possibility, observation that people with cars make fewer public transport trips than people without cars cannot tell us what happens if a non-car owner buys a car, and if a car owner stops being so, since these may be different from each other.

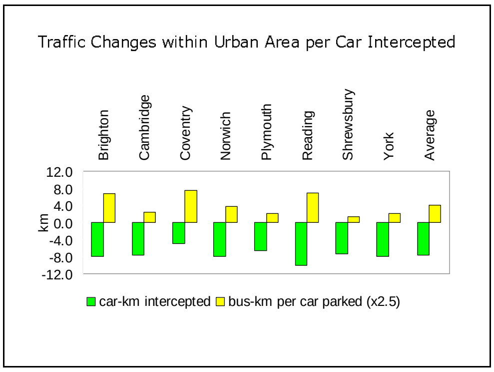
So what we have done is to seek contexts where such a change has happened, and observe or measure the change in travel behaviour that follows, in real time during the project or by retrospective before-and-after enquiry, but always over time.

Park-and-ride

One unexpected example of complex behavioural responses to a new system emerged from investigations of the effects of bus park and ride schemes.

The policy intention behind park-and-ride was reasonably straightforward: by placing car parks at the edge of the urban area and linking them to the town centre using superior bus services, targeted specifically at motorists, it would be possible to capture cars before they entered the congested urban area.

This work was initially focussed in Oxford and York, and was later extended to consider data from around ten other towns and cities.



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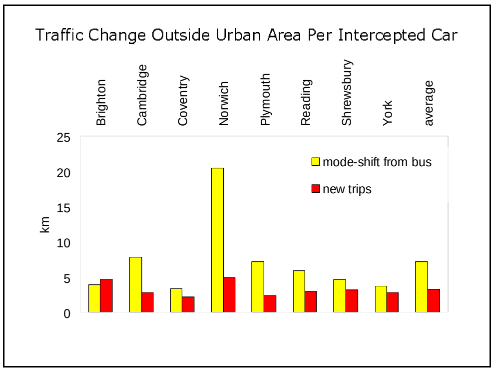
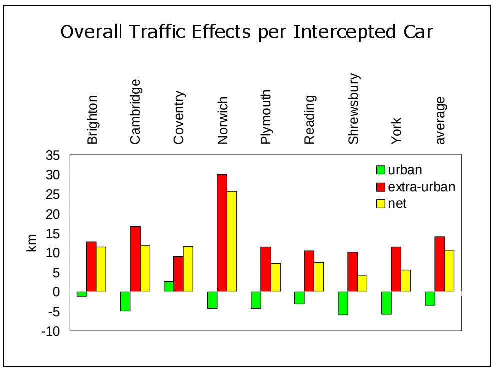
[2] A term from the study of magnetism, relating to the energy of a system where particles are subjected to, and lose, magnetic properties.



The first key finding was that around half of park and ride users were people who would have driven all the way to the town centre but were instead intercepted at the car park and travelled the last stage of their journeys on the P&R bus.

An increase in bus traffic occurs, in providing the additional park and ride bus services. But overall some traffic in the central area is avoided.

The problems associated with the policy emerge when considering the other half of users who showed two other types of response. Some users indicated that their trips to the particular town were in some way extra compared to the period before park and ride had been made available. This was sometimes the case because a life event such as a new job had led them to alter travel patterns, or perhaps as a result of realising that P&R turned out to be a cheaper way to travel than using either car only, or bus only, to access the city centre, for example if the park and ride scheme is subsidised.



Creating additional traffic to a traditional town centre is not necessarily always a bad thing. But the observation was that an often sizeable minority of users had changed mode of travel from public transport-all-the-way to park and ride, rather than from car-all-the-way to park and ride. As the park and ride sites were located at the edge of the city, some of the trips now made by car as far as the park and ride site, would be relatively long ones, of perhaps 15-20 km.

This means that only relatively few public transport users with a car available choosing to transfer to park and ride would be necessary for the reduction in traffic in the town centre to be more than compensated for by the growth in traffic outside the urban area.

The result that investing in park and ride facilities for motorists reduced the use of public transport was not the intention of either the local authorities or the bus companies. Since the first intimations of this effect where published at the beginning of the research programme (and then progressively asserted with more confidence as the data base increased), it was possible to observe some effects of the research itself on policy development. After an initial resistance, awareness that there are disadvantages to park and ride as well as advantages has grown. Whilst the problems have not disappeared, park and ride schemes are now generally being better integrated with policies to discourage car use and in some cases innovative approaches to park and ride provision are being pursued, such as providing the car parks on existing bus routes, and locating the car parks further from the towns they serve, so more of the car trip can be intercepted.

In general, although this is not the highest profile of strategic policy initiatives, we count the work on park-and-ride as a successful example of how initially embarrassing research findings can illuminate and inform subsequent policy development.

Road Traffic Increases due to Road Building

The next example is that of induced traffic due to road building, which is summarised briefly because it has been widely discussed. The work was built from membership of the SACTRA team which produced the famous report on induced traffic in 1994, at the beginning of the TSU programme of work, and the empirical side of this was extended later in a number of articles, local studies, and international comparisons, most recently in joint research with R Noland of Imperial College, 2003.

We now have observations of hundreds of cases where road capacity has been increased, for reasons of reducing, or displacing, or pre-empting, congestion and traffic has subsequently increased. This is very widely reported, (TSU itself was by no means the only or necessarily the most important agency to do so).

The empirical case is that induced traffic exists. Its size, of course, varies according to circumstances: an average road improvement had induced roundly 10% of the base traffic in the short run, and about 20% in the long run, and there were some schemes with induced traffic at double this level. The biggest levels of induced traffic were on the alternative routes that the schemes were intended to relieve.

If there is little congestion to start with, or expected, then the induced traffic from its relief will naturally be small. But in the average conditions where road capacity increases are considered in the UK, existing or expected congestion is usually rather high. As a rule of thumb, we can say that when extra road capacity initially reduces congestion, which saves some time for drivers, something between half of the time saved, and all of the time saved, will be ploughed back into more, or longer distance, travel, which erodes the benefits and creeps back – sometimes rushes back – towards the conditions of congestion observed before.

When considering the effect of this research on established methods of appraisal, we can say that in one sense research has solved a dispute. The formal recommended procedures do recommend that induced traffic should be estimated and included. But even now some highways schemes are still being assessed on the basis of an argument that induced traffic can be ignored, and statements from various stake-holders (most recently the CBI) still assert from time to time that the phenomenon is invented. An important new development (for which TSU research was a helpful input, though far from the only influence) has been the growing emphasis since 2003 by the Department for Transport on the concept of 'locking-in' – referring to the importance of having complementary policies to make sure that improvements in traffic conditions are not eroded by the extra traffic that the improvements themselves attract. This is a useful and original policy response to induced traffic.

The significance of the induced traffic discussion for 'Changing Travel Behaviour' was that it provided evidence of changes which were big enough to be seen, and to be important, at the aggregate level: it was not possible to argue that detailed changes by individuals would get lost in the great volumes of traffic: rather the aggregate effects of these disaggregate changes are big enough radically to affect total volumes of traffic, and therefore influence appraisal of policies aimed at providing for it. It is simply the existence of induced traffic which undermines the legitimacy of the simplest version of 'predict-and-provide' – for logical reasons, not political ones. Since the provision influences the prediction, appraisal must be recursive. This is now accepted in principle, though not always in practice.

Road Capacity Reductions

Following on from the SACTRA report, which showed that increasing road capacity could induce traffic, there was strong interest in the opposite question. What happens if you reduce road capacity, by taking space away from cars? As demonstrated above, not all relationships are precisely reversible. But even if they are only approximately reversible, you would expect reductions in capacity to have some effect on travel choices.

London Transport and the Department for Transport, Environment and the Regions commissioned TSU to collect and review the evidence on this question, in collaboration with Carmen Hass-Klau, who brought together the evidence from European cities, and MVA who did a parallel study of the modelling implications. The evidence base was formed from examples where road capacity already had been reduced. Many changes to town centres, eg large pedestrianisation schemes affecting the whole centre, or small schemes affecting only a couple of streets, all involve taking some road capacity away from traffic. Road space for cars is also usually reduced by nearly all bus priority schemes, street-running light rail systems, cycle lanes, and pavement widening. There are a large number of other reductions in capacity due to earthquakes, bridge maintenance, road works and other unintended events which, though not being policy initiatives, still provide evidence on behavioural responses. In the initial study, augmented by an updating exercise in 2002 in collaboration with S Atkins of the Strategic Rail Authority, we have now been able to analyse information from over 70 locations, in 11 different countries.

When it is planned to take road space away from cars, there are often dire predictions of ‘traffic chaos’. However, in retrospect these predictions rarely, if ever, prove accurate. Where congestion is already bad, it does often stay bad, sometimes with short-term disruption, and problems on specific local streets. However, wide-scale, long-term major inability to cope is simply not reported.

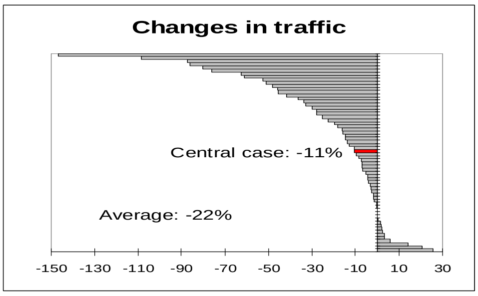
THE DAILY TELEGRAPH
it was far better than expected
Changes to Central Athens, 1995

UITP EXPRESS
Road transport experts are still trying to figure out where the 80,000 or so cars a day have gone
Repairs to a major freeway in Los Angeles, 1996.

EVENING STANDARD
the predicted traffic chaos failed to materialise. "It's not as bad as we feared", a spokesman said.
Day 1, Hammersmith Bridge closure, 1997.

This phenomenon of a repeated difference between expectations and outcome represents a problem for appraisal of such policies, especially where various simplified methods of estimating traffic effects, not allowing for full adaptation, are used: this is often the case because the small scale of the scheme does not seem to justify the use of expensive appraisal methods.

With some caution (the caveats being fully spelled out in the published reports) it is possible to collate a simplified presentation of the empirical evidence, shown in the figure below.



Each bar corresponds to an individual case study of road capacity reduction, and shows the overall change in traffic after road capacity was reduced.

In most cases, traffic levels went down on the streets where capacity was reduced, and some traffic, but not all, reappeared on neighbouring streets. Across all case studies, the average traffic reduction overall was 22%, with a median of 11%. Thus in half the cases more than 11% of the traffic previously using the affected street or area could not be found on the local network afterwards.

The data we had have not yet been sufficient to test for hysteresis directly, ie to determine whether the decrease in traffic caused by a reduction in capacity is equal and opposite to the increase in traffic caused by an increase in capacity. However, the orders of magnitude seem similar with observations of 20% and more being not uncommon in both cases. This suggests that hysteresis may not here be a substantial problem. At least, we can assert that appraisal of capacity reductions must allow for 'disappearing' traffic as much as appraisal of capacity increases must allow for induced traffic.

The research has been used in a number of practical applications, including the pedestrianisation of the north side of Trafalgar Square. The Institution of Civil Engineers awarded its prestigious George Stephenson Medal for our 2002 updating study, and a consortium of 'green' organisations commissioned us to do a study of simplified appraisal methods that could accommodate its findings without the need for excessive consultancy fees, this being then discussed with DfT officials in a generally positive way.

Price

Elasticity measures the sensitivity of the volume of travel to influences such as price, speed, etc. It is a dimensionless constant, very easy to interpret: an elasticity of -0.5, for example, means that if price goes up to 10%, demand will go down by 5%. It is always driven by individual disaggregate choices by specific people for specific journeys, but usually expressed for the whole market.

For decades, it was thought that these measures were reasonably well established. The bus fare elasticity, for example, was -0.3. If you put bus fares up by 10%, you'd lose 3% of your market, but still make extra revenue. And the fuel price elasticity was smaller. The DfT assumed, for a while, a figure of about -0.1 to -0.15, ie an increase in fuel price of 10% would reduce traffic volume a little, 1% or so, but not enough to make a difference to anything in practical terms.

Many empirical elasticities had been derived from an equilibrium approach, generally estimating static models on the basis of cross-section data. The elasticities resulting from equilibrium models are hard to interpret, since they relate to differences in behaviour *between* individuals at *one* point in time rather than *changes* in the behaviour of individuals *over time*. Because of this, static models cannot take into account asymmetry, habit or expectations, nor can they measure the effect of factors which vary little at one point in time – for example, prices. It is thus unlikely that they capture true long-term effects. In fact nothing is known about **when** the response occurs. The elasticities typically used for policy analysis had been generally estimated using an equilibrium approach and thus most probably underestimate the true long-run response.

The TSU work rejected equilibrium modelling in favour a dynamic approach, because the response to changes in prices, policy etc is a process which occurs over time. This must be the case arising from the existence of factors such as habits, uncertainty, imperfect information, and costs of adjustment. To analyse this process we thus need to observe how travel behaviour changes over time. This can be only be done with longitudinal data, for example, aggregate time-series data for the country or a region; a combination of cross-section time-series data including pseudo-panels, or true panel data.

Dynamic Model

$$D_t = f(X_t, X_{t-1}, \ldots, X_{t-N} D_{t-1}, \ldots, D_{t-M})$$

$D_t =$ rail kms, bus journeys, car ownership

$X_t =$ prices, income, other characteristics of individuals or modes

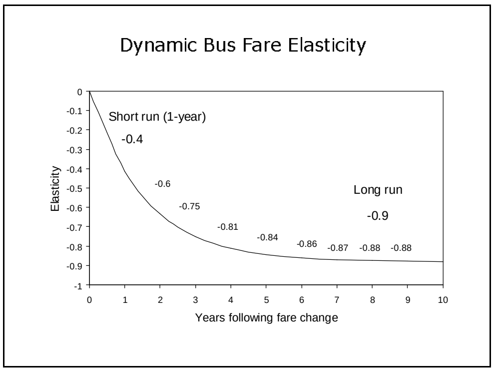
Dynamics represented by demand and/or X in earlier periods (t-1, t-2,...)

A dynamic model necessarily contains variables relating to different time periods: demand (D) in period t is related not only to values of the explanatory variables (X) in the same period, but also to demand and/or values of the explanatory variables in previous periods (t-1, t-2 etc). Dynamic models do not result in a single elasticity, but a series of elasticities measuring the effects over different periods of time. The short-run elasticity is the defined by the time period of the data. For example for annual data, the short-run price elasticity would be the effect on demand that occurs within one year of the change. The long-run elasticity is the total response after all adjustment has been made. The time period required for full adjustment is estimated from the data.

One of the most important themes of our work has been to provide more reliable estimates of price sensitivities. Our estimates are obtained from the application of econometric – or statistical – methods to dynamic models using various sorts of longitudinal data. The models aim to give as full a representation as possible of all of the factors determining demand – prices, income and other socio-economic and demographic factors. We report two specific sets of results, first for bus patronage, and then for car ownership.

Bus Fares

The study of bus fare elasticities was carried out for the Department for Transport in collaboration with TAS Partnership Ltd. The main objectives were to estimate elasticities which could be used in policy calculations to project the change in bus patronage nationally as a result of a given ‘average’ fare change. We used national, regional and county data on bus patronage, fares, service and income over time and a dynamic model.



The estimated fare elasticity for Great Britain as a whole was about –0.4 in the short run (close to the received wisdom), but –0.9 in the long run (very far from received wisdom). This means that if the average fare of all operators in a local market increases by 10%, total patronage will decline by 4% within one year. The complete response takes around 7 years, by which time patronage will have declined due to the fares change, by a further 5%, giving 9% in total, not taking account of changes due to other factors such as income, car ownership, or inflation. The dynamic elasticity is illustrated in the figure. The fare elasticity increases over time, but at a declining rate, finally to reach its long-run value. Clearly, the estimated long-run elasticity of -0.9 is much higher than the elasticity of -0.3 previously taken as given.

Other results of this study were that the fare-elasticity increases at higher fare levels, and is greater for non-urban than in urban areas. Service – in terms of vehicle kms – is also found to have a substantial impact on patronage.

In 2004 TRL published a major literature review written by a large consortium of research institutes on the Demand for Public Transport. In it, this TSU work by Dargay and Hanly was described as the leading representative of the most important new research findings since the previous such overview in 1980, and lent support to their conclusion that long term fare elasticities are high enough to put serious doubts on fare increases as a secure method of raising revenue.

Car ownership and car traffic

Estimates of elasticities for car ownership and car travel have been obtained by applying suitable dynamic models to the pseudo-panel data shown earlier. A number of different model specifications were estimated and the results shown here are average values.

Average Elasticities

	Car ownership		Car travel	
	short run	long run	short run	long run
Car purchase costs	-0.1	-0.2	-0.3	-0.4
Fuel price	0	0	-0.1	-0.2
Income	+0.3	+0.7	+0.7	+1.0

Again we find a significant difference between short- and long-run elasticities. Car travel response more strongly and more quickly to price and income changes than car ownership. Both car ownership and car travel are more sensitive to car prices than to fuel prices, but income is the most important determinant of both.

The modelling work also provides evidence of differences in elasticities between individuals. For example, households in rural areas are less price-sensitive than urban households regarding car ownership and use – opposite to what we found for bus use. In addition, high income households are less-price sensitive than others. Both of these findings have implications for the distributional effects of price-related policies.

We also find statistical evidence of saturation – the income elasticity declines at higher levels car ownership and use – and of asymmetry with respect to income.

This work was supported by a new review of the literature as a whole commissioned by the Department for Transport, which led to the conclusion that the elasticity of traffic with respect to the fuel price is of the order of -0.1 in the short run and -0.3 in the long run. This is about half the elasticity of fuel consumption with respect to the fuel price, implying that a significant part of the response to fuel price increases is through the use of more fuel efficient vehicles.

Elasticities wrt Fuel Price per Litre
Literature Review

	short term	long term
fuel consumption	-0.25	-0.60
traffic volume	-0.10	-0.30

The work, together with an independent literature review carried out in parallel by S Glaister and D Graham at Imperial College, was influential in enabling the DfT to change the price elasticities it uses in national traffic forecasting (and, consequently, the effects of changes in travel times which are linked to the fare elasticities in their model). This has now been done for the Department's own model. Proposals were developed by TSU, at the request of the DfT, to replace or enhance their model by a new form of forecasting in which the dynamics were explicit rather than implicit, but these did not win support.

Soft Factor Policies ('Smart Choices')

In terms of affecting travel behaviour, as well as interest in pricing and road provision, there has also been increasing interest in the quality of transport alternatives, and the information and perceptions that people have about those alternatives. This is the so-called 'softer' side of transport policy, and there are various policies which specifically aim to alter the quality of alternatives, people's knowledge and perceptions about them, or which aim to provide new opportunities not presently available.

At the request of the Department for Transport, we formed a collaborative team, together with Lynn Sloman, Carey Newson, Jillian Anable and Alistair

Kirkbride, to assess the present and potential effects of the following soft policy measures.

- workplace and school travel plans
- personalised travel planning
- public transport information and marketing
- travel awareness campaigns
- car clubs and car sharing schemes
- telework and teleconferencing, and
- home shopping schemes.

Most of these policies are relatively new – dating back 10 years or less - although the amount of local authority experience of implementing them is growing rapidly, largely because there are some very positive reports of their effects particularly in terms of their effectiveness at cutting traffic levels.

The work involved a major literature review and critique, collation of evidence and visits to all the leading initiatives we were able to identify, and interviews with those responsible for organising them.
The research report is some 700 pages in two volumes, and the detailed methodologies used for a set of very disparate circumstances are not given here.

In summary, our conclusions were that they might lead to:

- a 21% cut in urban peak hour traffic
- a 14% cut in non-urban peak hour traffic
- an 11% reduction in national traffic, overall

These figures are significantly higher than the Department for Transport had previously assumed in guidance given for the multi-modal studies, where a cautious 'eventual' figure of 5% traffic reduction was suggested. Therefore there was considerable interest in testing the reasons for, and credibility of, our results.

In part, the difference derived from the new evidence which had become available, and in part from the changing policy assumptions about how much effort local authorities (and the government) might be willing to put into such initiatives over a ten year period. But in addition to these there is a strong relationship with the other strands of research discussed above.

Achieving this scale of traffic reduction would obviously involve a large number of people changing their behaviour over the next ten years. It only seems credible to assume that such changes are possible, because there is so much volatility in what people do anyway.

This research was swiftly published, in full, by the Department for Transport as one of the supporting papers with the 2004 Transport White Paper. Publication drew attention to a strong caveat we had made, derived from the evidence on induced traffic: if car use amongst one group of people is reduced, freer road conditions may attract others onto the roads, unless the benefits of the soft factor policies are carefully 'locked in' using other traffic restraint measures.

To summarise: we have looked altogether at about twenty different influences on travel choice that transport policy uses as instruments. Effects are larger than has generally been assumed: changes of 10%-30%, at the aggregate level, in relatively short periods of time, are quite common even in conditions that we might describe as within the bounds of 'normal life', as most people perceive it, not those of extreme emergency or revolutionary change.

The problem is that these changes are complex, take a long time to work through, and are easily offset by other unintended changes especially where the policy instruments are not all pulling in the same direction, which is common.

4. Analytical Approaches to Understanding the Process of Behavioural Change

Travel behaviour does change significantly and quite naturally, over the years. The question then arises of how far established models – or indeed, people themselves - comprehend this process? When people are asked questions about their behaviour in a survey, they will naturally be very much more preoccupied with how their life is now than how it was 10 years ago, or how it will be in ten years time. Several strands of the work have addressed this issue, including the econometric modelling reported above, qualitative research into perceptions and self-understanding, experimental development of a fuzzy modelling framework, and review of survey evidence on the components of behavioural change.

Self-awareness and memory

We had the opportunity to consider this early in our programme of work, through monitoring the effects of providing the Supertram light railway as a new travel opportunity in Sheffield, concerning the match between people's own predictions about what use they would make of it and their actual behaviour two years later when the system opened.

In part, the findings confirmed common sense

- Since individuals could not accurately foresee their own circumstances in two years time, it was hard for them to predict accurately what their behaviour would be.
- And in any case, people often do not plan routine local travel even days in advance, never mind years ahead.

Some made it clear that they would wait until the opportunity was a real, operating one, before investing time in finding out how it would work, and whether it would be useful to them.

This does raise questions about the usefulness of research which seeks to discover people's future stated travel intentions at one point in time, in one set of circumstances, when those circumstances are very likely to have changed by the point in time in the future for which we are seeking to make the prediction.

Other interesting results came from a particular focus within the study on the importance of people's mental images or maps in their decision-making about whether the tram was attractive and relevant for their needs. What emerged was the importance of a person's own history and sense of place, in determining those perceptions.

For some of those over the age of about 40, there were strong expectations about what the routes ought to be like, based on experience earlier in life of the Sheffield trams that ran until 1960. That is, memories of the 'old' tram were still important in determining attitudes to the new one.

Alterations to the existing built and natural environments created negative attitudes for some observers. This could result from permanent change, such as the felling of trees, or temporary interventions, as shown in this picture, due to the effects of construction. In contrast, others welcomed novelty in the environment, and for them this was a motivation to try out the new network.

For Sheffield adults in general, understanding of the most direct, logical routes between places was usually strong. This did cause conflicts between expectations and reality, because it had been decided to operate the tram along some routes which were neither those of the former tramway, nor the most direct ones.

In one important case, routing decisions resulted in the tramline leaving the direct route on the road network to travel through open fields known by many to be outside the city boundary. Although some enjoyed the views, others perceived this to be a time-consuming detour.

Such planning decisions were taken for traffic engineering, social and economic reasons – and each had its rational justifications. The outcome was, though, that the route as constructed did not fit with some respondents' expectations about the logical routing. This was one reason for the appeal of the system being lower than had been hoped.

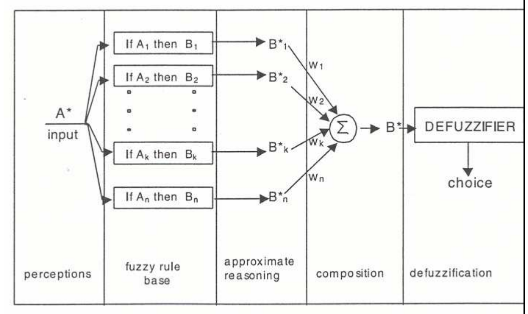
Fuzzy Modelling

Therefore it is of interest to try to develop a new formulation of the mechanism that represents the way that travel choice decisions are made.

Most conventional models of travellers' choice behaviour are based on the random utility framework which follows the utility maximisation concept, and introduce an error term to capture the uncertainties and ambiguities inherent in the choice problem, and account for the unrealistic assumptions implied by the deterministic utility maximisation principle. These include the assumptions that travellers

- Have economically rational choice behaviour
- possess perfect information regarding the attributes of the available alternatives,
- have unlimited information processing capabilities and
- formulate complicated utility functions which they try to maximise.

The econometric methods we have used to analyse time series data with a dynamic specification themselves relax some of these assumptions, replacing the presumptions of perfect knowledge and achieved utility maximisation. The process of adaptation in a dynamic model is underpinned, in part, by the idea of imperfect information and non-achieved utility maximisation, these being the forces which drive the will to adapt. But a different approach to formal modelling is to consider a different view of the decision-making process itself. Suppose, in reality, that travellers do not compare alternatives in terms of exact values of their attributes. This may be handled by the representation of a general model of fuzzy decision making shown below.



The fuzzy decision making framework

The traveller's perception A is matched to the premises of each rule k. An implication mechanism called approximate reasoning, is then used to deduce the resulting implications C, given the perceptions A. The rules are processed simultaneously and a composition mechanism aggregates all implications C to a fuzzy preference D, expressed in terms of its membership function. Each rule is assigned a weight (w) that captures the importance of the particular rule in the decision making process.

The nature of this modelling approach which assumes that during the decision making process a number of rules are executed simultaneously and are then processed in parallel implies that this framework can be represented by a neural network structure.

Survey evidence on the components and triggers of behavioural change

As soon as we consider any dynamic formulation, the question arises, what happens on the second day? And the next week, next month, next year? Do drivers learn from their experience, and how do the effects build up over time?

There are some insights about this from the work on reducing road capacity, since one of the things we looked at was - what do people do when road capacity is reduced for a significant period of time? The evidence suggested a wide range of responses, which can be broadly divided into three groups.

In the first instance, traffic does not reduce, it intensifies, as people change their driving styles - driving closer together, getting through traffic lights quicker - in order to maximise the road space.

Second, traffic spreads out over time and space, with people swapping to alternative routes, or changing their journey times by leaving earlier or later.

- **3. Traffic 'disappears'**

Changes in…
- how to travel
- where to go
- how often trips are made
- car share
- do more than one thing on the same journey
- who does what within a household
- whether trips are made at all
- where new developments are built
- job location
- home location

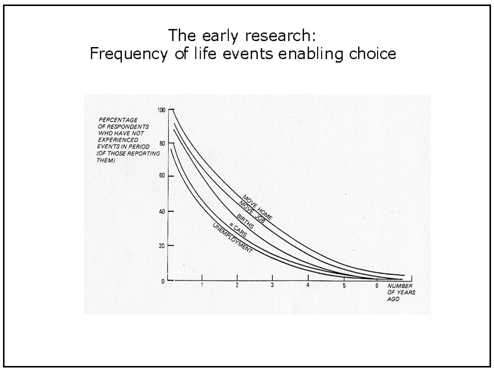
Third, as it becomes more difficult to make such adjustments, a whole variety of changes get mentioned in surveys, which would explain why traffic can disappear from a network overall. These range from people saying that they've altered how they travel, or where they go, right through to moving job or moving home.

The evidence suggested that in general, people do not make such changes 'just because' of a change in road capacity. But precisely because of the natural variability in travel choices for other reasons, a change in road conditions may help to tip the balance in which change is chosen.

This also makes sense of earlier work in South Yorkshire. Habits and constraints, based on existing circumstances, may be so strong as to prevent changing behaviour in response to some policy initiative, because the constraints of life simply do not allow it. Even so, after a while, there will certainly be a 'life-shock' of some sort, and then some change in behaviour is unavoidable. This can be done in a way that enables a response to the new circumstances, higher costs, lower costs, more reliable buses, or less road space.

The interesting thing is that, as the diagram below shows, year by year fewer and fewer people will be left who have not had some such upset in their routine. The time-scale – 1 to 5 years, for the majority of the population – is very close indeed to the sort of lags that the econometric results found for elasticities.

Thus the people who have had the biggest changes in their lives were also the people who showed the largest response to policy effects such as, in this case, bus fares.



So the policy monitoring work, and the econometric analysis, converge. The elasticities are an estimate of the combined effect of all these different responses. Of course, that's why long term elasticities, in general, are higher than short term ones. It is precisely because people learn, and adapt, and are able to include in their behaviour not only the change of route, but a different pattern of life.

This process, the dynamics of travel behaviour, is therefore an important strand unifying the empirical, theoretical and practical side of the work. What we have done is actually identify a number of quite separate dynamic processes, each of which require longitudinal data. In part 1, we found that changes in the opposite direction to a well established aggregate trend are very common at the individual level. Churn is invisible in cross section surveys. In part 2 we discovered that the 'upwards' and 'downwards' movements are not necessarily symmetrical – what goes up does not necessarily come down, or at least not until later, or with greater difficulty. Hysteresis requires knowledge of the history or path that a process has followed. In part 3 we discovered that the distinction between short and long run is crucial to estimating the effects of policies, which cannot be done without defining the time period and process of change.

The existence and importance of dynamics is one of our key findings. As illustrated early on in our research, ignoring the inter-temporal nature of the response to policy will lead to a bias in the evaluation of consumer surplus and thus in cost-benefit analysis.

5. Policy Implications

It is in the nature of policy-related research that there is always room for disagreement on interpretation of evidence and in inferences about what follows. But some general conclusions are suggested.

Public transport fare elasticities: our results imply that attempts to raise revenue by fare increases will work in the short run, but so erode the market that in the long run the net advantage in the long run is very small indeed, financially, and negative in terms of congestion and environmental impacts. What can we do about the dynamics of revenue, in a world where the accountants do not really want to look beyond next year? And where, then, would the funding come from for the continued environmental improvement of public transport systems?

The effects of motoring costs. The results imply that traffic levels do respond to these – up and down – which strengthens the transport effectiveness of road pricing, but raises less revenue than expected – a lot, but not quite so much. This affects national budgets.

Soft measures. This work presupposes a very big increase in the priority of these measures at local level, and at the moment some local authorities do not even count the staff employed in this area as being on the proper establishment. They are the poor relations, the staff on bursaries or temporary contracts – unlike the engineers in the drawing room, whose career track is simpler, and a lot more favourable. And then, suppose that a local authority does decide to treat this area as a proper job, and does put priority on it – but does *not* manage to secure support for the complementary traffic policies to prevent induced traffic. This is a live policy problem in many areas.

Road building. 'Locking-in' is the answer to one question: if we have the right road scheme, how to protect its benefits. But a programme of locking in, and demand management, and congestion charging, and soft measures, and public transport improvements: taken together, these change our definition of what constitutes the right road scheme. The entire list of schemes in the current programme has been inherited from assumptions on policy and behaviour that no longer apply.

Dynamic analysis. On the analytical side, at root, the concepts of dynamics are simple – simpler, in fact, than the standard transport models based on a utility maximising achieved equilibrium, whose precepts about behavioural change are, at heart, self-contradictory and elusive. But there is a problem of familiarity. Where are the consultants who will offer a dynamic forecast with as much confidence as they now offer an equilibrium forecast? Understanding of change cannot be derived from observation of states at a point in time but only from consideration of pathways, history, and the process of adaptation. That requires observations of data over time, and models using dynamic methods, which need to become more part of the standard toolbox than the off-the-shelf surveys and models now used.

*Very long term and unprecedented issues. E*verything we have done has really been in the context of a world in which, we assume, there is time to develop policies, and adapt them, and make errors, and use concepts like five year or ten year plans. We have not focussed on the sixty year horizon that DfT appraisal rules now allow, because we do not know how to make and sensible forecasts such a long time ahead. Nor have we addressed the issues of how to handle a different degree of urgency, if environmental requirements do not allow normally adaptive time scales.

Conclusion

Travel behaviour is very much more volatile and changeable than is usually assumed. Car ownership and use do go down as well as up, though the strength of the effects is different. In this context the effects of policy on behaviour are bigger than has been thought, though more complex, not always in the intended direction, and take several years to work through. Overall, the conclusion is that policy makers and transport industries have more scope to influence travel behaviour than they think, but only if transport interventions are consistent with each other, maintained over a lengthy period, and supported by analytical methods and appraisal frameworks that are not yet commonplace.

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Note: those reading this table in electronic format will find highlighting giving hyperlinks to summaries and in some cases full texts on the UCL and other websites. (2004 publications with hyperlinks are included again, but not the most recent ones for which links have not yet been set up)

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Joyce Dargay	Mark Hanly	**Land Use and Mobility**	Paper written for presentation at the World Conference on Transport Research, Istanbul, Turkey, July 2004
Joyce Dargay		**The Effect of Prices and Income on Car Travel in the UK.**	Paper written for presentation at the World Conference on Transport Research, Istanbul, Turkey, July 2004
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Sally Cairns	A Davis, C Newson and C Swiderska	**Making travel plans work: Case study summaries**	Department for Transport
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Sally Cairns		**Cutting car use for work travel**	Town and Country Planning, November, pp.272-273
Joyce Dargay	M Hanly	**The determinants of the demand for international air travel to and from the UK**	34th Universities' Transport Studies Group Conference, Civic Centre, Edinburgh, January
Joyce Dargay		**Determinants of car ownership in rural and urban areas: a pseudo-panel analysis**	Transportation Research E 38(5), pp.351-366
Joyce Dargay	Mark Hanly	**The demand for local bus services in England**	Journal of Transport Economics and Policy 36.1 pp.73-92
Joyce Dargay	M Hanly	Bus patronage in Great Britain: an Econometric Analysis	Transportation Research Record, 1799, pp 97-106
Joyce Dargay		Pseudo-panel analysis of household car travel	April (Ref No 2002/04)
Joyce Dargay		Road vehicles: future growth in developed and developing countries	Sustainable Transport, special issue of Municipal Engineer
Joyce Dargay	P B Goodwin and Mark Hanly	**Development of an aggregated transport forecasting model (ATFM)**	Contract PPAD 9/65/92
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Mark Hanly	J Dargay and P B Goodwin	**Review of income and price elasticities in the demand for road traffic**	Final report, March 2002
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Parkhurst, Graham		New road vehicle technologies and the future of motoring taxation	ESRC TSU publication 2001/2
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Parkhurst,		New road vehicle	Ref No 2001/2

Graham		technologies and motoring taxation: the top of the escalator	
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Phil Goodwin	Steffan Persson	Assessing the benefits of transport	ECMT report
Phil Goodwin	J Dargay	Bus fares and subsidies in Britain: is the price right?	in Any More Fares? Delivering Better Bus Services ed T Grayling
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Joyce Dargay		Road vehicles: future growth in developed and developing countries	Municipal Engineer 151.1
Joyce Dargay		**The effect of income on car ownership: evidence of asymmetry**	Transportation Research A 35(9), 807-821
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Sally Cairns		**Rethinking transport and the economy**	Town and Country Planning 69.1 January, pp.6-7
Sally Cairns		Reactions and developments following the report: 'Traffic impact of highway capacity reductions -- assessment of the evidence'	Reallocating roadspace conference
Sally Cairns		**Coming of age - the travel of young adults**	Town and Country Planning, April, pp.106-107

Sally Cairns		**The importance of the multi-modal studies**	Town and Country Planning, July/September
Sally Cairns		Future trends in shopping behaviour in the UK, report to members of the European Council for Automotive Research and Development	(Ref No 2000/16) Goes with 2000/23 and 2000/24
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Sally Cairns		Traffic impacts of highway capacity reduction: a summary of work in progress (also available in Japanese)	Proceedings of Japanese Institute of Civil Engineering
Joyce Dargay	Jean-Loup Madre and Akli Berri	Car ownership dynamics seen through the follow-up of cohorts: comparison of France and the United Kingdom	Transportation Research Record 1733, 31-38
Joyce Dargay		Pseudo-panel analysis of dynamic transport demand relationships	International Conference on the Analysis of Repeated Cross-Sectional Surveys
Phil Goodwin		The Transport Bill: advance or retreat	ICE Seminar (Ref No 2000/12)
Mark Hanly	J Dargay	Car ownership in Great Britain: a panel data analysis	Transportation Research Record 1718, pp.83-89
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Parkhurst, Graham		The EMITS monitoring project and the Oxford Transport strategy public inquiry	(Ref No 2000/26)
Parkhurst, Graham	Sally Cairns	Potential role of bus-based park and ride within the Milton Keynes sustainable integrated transport strategy	March 2000 (Ref No 2000/6)
Parkhurst, Graham		A longer-range strategy for car-bus interchange: the 'Link and Ride' strategy	Traffic Engineering and Control, September, 319-324
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Parkhurst, Graham		Opinion on proposals for Park and Ride and a guided busway at Hoole Road, Chester	January 2000 (Ref No 2000/30)
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Phil Goodwin	J Dargay	The spread of congestion in Europe	ECMT Round Table 110
Phil Goodwin		Action or inertia? One year on from 'A New Deal for Transport'	Transport Planning Society meeting at ICE (Ref No 1999/15)
Phil		**Transformation of**	Transportation Research A

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Sally Cairns		**Winning friends and influencing people**	Town and Country Planning 68.1 January, pp.10-11
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Sally Cairns		The impact of reallocating roadspace on accident rates: some initial evidence	Note for Road Danger Reduction Forum conference (Ref No 1999/8)
Sally Cairns		**Walking back to healthiness**	Town and Country Planning 68.4, April, pp.110-111
Sally Cairns		Reallocation of roadspace in favour of cyclists	Note for meeting convened by London Cycling Campaign (Ref No 1999/10)
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Sally Cairns	G P Parkhurst	A qualitative evaluation of the Children's Traffic Club	Report produced for dbda, executive summary available (Ref 1999/19)
Sally Cairns		**Moving towards well-being**	Town and Country Planning, August/September
Sally Cairns	D Davies (ed)	Promoting walking	Providing for journeys on foot, IHT
Joyce Dargay	Petros C Vythoulkas	**Estimation of a dynamic car ownership model**	Journal of Transport Economics and Policy 33 (3), 287-302
Joyce Dargay	Dermot Gately	**Income's effect on car and vehicle ownership, worldwide: 1960-2015**	Transportation Research A 33 (2), 101-138
Joyce Dargay		Car ownership and motor fuel demand: a pseudo-panel	22nd Annual Conference, IAEE

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Joyce Dargay	M Hanly	**Bus fare elasticities**	Report to the DETR December 1999 (ESRC TSU Ref No 1999/26)

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Joyce Dargay	P B Goodwin	The spread of congestion in Europe	ECMT Round Table 109
Joyce Dargay		Survey approaches for transport impact studies	Conference on 'Les mesures d'impact d'une nouvelle infrastructure sur la mobilite: le cas de TGV Nord'
Joyce Dargay		**Estimation of a dynamic car ownership model for France using a pseudo-panel approach**	In Modelisation du Trafic, Actes du groupe de travail
Joyce Dargay	S Perrkarinen	**The effects of public transport subsidies on bus travel demand-regional bus cards and city travel tickets in Finland**	8th World Conference on Transport Research
Joyce Dargay	P Vythoulkas	**Estimation of dynamic transport demand models using pseudo-panel data**	8th World Conference on Transport Research
Joyce Dargay		**Modelling car ownership in France and the UK: a pseudo-panel approach**	Ref No 98/05
Joyce Dargay	A Puyana	Competitividad del Petroleo Colombiano: Una revision de factores externos (Competitiveness of Colombian oil, an examination of external factors	Creset-Coliencias, Colombia
Joyce Dargay	D Gately	A Gepjarmuhasznalat Kornyezeti Hatasa (Effects of the use of motor vehicles on the environment)	Statisztikai Szemele (translation of Energy Policy , 25, Nos. 14-15, pp.1121-1127)
Sally Cairns		Home delivery: the impact	Logistics Europe
Sally Cairns		Delivering the future: how can car-borne shopping	Local Transport Today 9/4/98

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Sally Cairns		Shopping and personal business trips	Seminar on 'Car Dependence: Influencing travel patterns' (Ref No 98/10)
Sally Cairns		**Promises and Problems: Using GIS to analyse shopping travel**	Journal of Transport Geography 6 (4), 273-284
Sally Cairns		**Formal demise of predict and provide**	Town and Country Planning 67.9 October
Sally Cairns	C Hass-Klau and P B Goodwin	**Traffic impact of highway capacity reductions: assessment of the evidence**	Landor Press, ISBN 1 89965010 5
Phil Goodwin		Extra traffic induced by road construction: empirical evidence, economic effects, and policy implications	ECMT Round Table 105
Phil Goodwin	C Hass-Klau and S Cairns	**Evidence of the effects of road capacity reallocation on traffic levels**	Traffic Engineering & Control, June
Phil Goodwin	S Cairns and C Hass-Klau	**Better use of road capacity - what happens to the traffic?**	Public Transport International, 47 (5), September, UITP, Brussels
Phil Goodwin		Has transport methodology kept pace with transport policy?	Keynote address, International Conference on Demand Management (Ref No 98/18)
Phil Goodwin		Transport and economic growth	Presidential Conference, IHT (Ref No 98/19)
Phil Goodwin		New statistics for new policies: data requirements for monitoring the success of the White Paper on traffic and transport habits	Seminar, TSUG, London (Ref No 98/20)
Phil Goodwin		Beyond the White Paper	Third Heathrow Conference (Ref 98/21)
Phil Goodwin		Evidence to the Environment, Transport and Regional Affairs Committee, House of Commons	November 1998 (Ref No 98/22)
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Phil Goodwin		Unintended effects of transport policies	In Transport Policy and the Environment (ed David

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Phil Goodwin	Are transport policies driven by health concerns?	In Health at the Crossroads - Transport Policy and Urban Health (eds T Fletcher and A J McMichael) John Wiley and Sons: Chichester, 271-276.
Phil Goodwin	Transport: the New Realism	Putting the Car in its Place: Transport Seminar Brisbane City Council and Queensland University of Technology See Goodwin (1991)Transport: the New Realism, TSU, Univ of Oxford
Phil Goodwin	**The politics of traffic restraint**	The Design Council. Transport and the Environment -- Discussion Report
Phil Goodwin	Have panel surveys taught us anything new?	Chapter 3 of Panels for Transportation Planning: Methods and Applications
Phil Goodwin	The value of the AA Foundation's research: an	How Safe? Foundations for the Future, AA

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Phil Goodwin		**Solving congestion (when we must not build roads, increase spending, lose votes, damage the economy, or harm the environment and will never find equilibrium**	Inaugural Lecture for the Professorship in Transport Policy, UCL (Ref No 97/60)
Phil Goodwin		EMITS report	Oxfordshire County Council (Ref No 97/48)
Parkhurst, Graham	J Parkin, A Merrall, and P B Goodwin	Experiences from the Supertram Monitoring Study	Proc. 25th European Transport Forum, Seminar E: Monitoring Studies, PTRC, London, 1997
Parkhurst, Graham		Compared results from the before and after qualitative data	South Yorkshire PTE and Dept of Transport (Ref No 97/43)
Parkhurst, Graham		**Who goes there? Social and spatial perception in a cross-border region**	Introductory paper to course: Regional Development in Border Regions under Dispute (Ref No 97/62)
Parkhurst, Graham		**The importance of target group preconceptions to forecasting (revised)**	Paper to "Forecasting Demand for Travel" Conference, Aston University
Parkhurst, Graham		**Changing tracks**	D.Phil Thesis submitted to the University of Oxford (Ref No 97/65)
Sally Cairns		**Potential traffic reductions from home delivery services: some initial calculations**	Ref No 97/45
Sally Cairns		Menu for change	Transport Retort, Issue 20(5)
Sally Cairns		And now over to the travel unit	Planning Week 5.3
Sally Cairns		Use of GIS for analysing shopping developments	Proceedings, Seminar convened on GIS by London Transport and University of London CTS
Sally Cairns		**Home shopping and other viable ways to reduce travel for food shopping**	Proceedings 9th Annual TRICS Conference
Joyce Dargay	S Pekkarinen	**Public transport pricing policy: empirical evidence**	Transport Research Record No 1604

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Joyce Dargay	D Gately	**The demand for transportation fuels: Imperfect price-reversibility?**	Transportation Research B 31(1), 71-82
Joyce Dargay	D Gately	**Vehicle ownership to 2015: implications for energy use and emissions**	Energy Policy , 25, Nos. 14-15, pp.1121-1127

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Joyce Dargay	J Dodgson, C Holman, P B Goodwin, R Mackett, P Vythoulkas	TESS: Phase 1 report to the Department of the Environment on the development of a model to estimate carbon dioxide emissions from transport	Report of Phase 1 study to the Department of the Environment, October (Ref No 96/09)
Joyce Dargay	S Pekkarinen	Public transport pricing policy: empirical evidence of regional bus card systems in Finland	Transportation Research Record 1604 pp146-152
Joyce Dargay	S Pekkarinen	**Public transport subsidies: the impacts of regional bus cards on travel demand and energy use in Finnish urban areas**	Paper presented at: DES/IAEE Regional European Conference on Transport, Energy and the Environment, October 1996, Helsingør, Denmark
Sally Cairns		**Reducing car use for food shopping**	Revised version of 1995 PTRC paper (Ref No 96/11)
Sally Cairns		**Approvisionnement courant et livraisons a domicile: un nouveau defi pour le transport urban de marchandises**	Transports urbains no 91, avril-juin 1996, Courbevoie, Paris
Sally Cairns		**Delivering alternatives: success and failures in providing home delivery services for food shopping**	Transport Policy 3(4), 155-176
Vythoulkas, Petros C		Investigation of artificial neural network performance in predicting congestion in motorway networks	ESRC TSU Ref. 96/31
Vythoulkas, Petros C	H Koutsopoulos	A neuro-fuzzy approach to discrete choice modelling	ESRC TSU Ref 96/32

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Parkhurst, Graham		An interim analysis of attitudinal-perceptual findings about South Yorkshire Supertram from qualitative interviews	South Yorkshire PTE and Dept of Transport (Ref No 96/39)
Parkhurst, Graham		**The influence of perceptions of space and opportunity on users' responses to a new public transport system**	Proc. 24th European Transport Forum, Seminar F: Public Transport Planning and Operations PTRC, London, 1996
Parkhurst, Graham		**The economic and modal-split impacts of short-range park and ride schemes: evidence from nine UK cities**	ESRC TSU Working paper (Ref No 96/29)
Phil Goodwin		Empirical evidence on induced traffic	in Transportation 23(1), 35-54
Phil Goodwin		Not only traffic: other claimants in the contest for scarce road space	Rees Jeffreys Road Fund
Phil Goodwin		Finding a clear way ahead	in Parliamentary Review
Phil Goodwin		Beyond the manifestos - policies and the economy after the election: Robinson College Cambridge	Cambridge Econometrics Annual Conference (Ref No 96/19)
Phil Goodwin		Transport: a tale of two cities	Sixth Hoskins lecture at St Anne's College, Oxford (Ref No 96/37)
Phil Goodwin		Road traffic growth and the dynamics of sustainable transport policies	Transport Policy and the Environment, Oxford UP

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Joyce Dargay	P B Goodwin	Evaluation of consumer surplus with dynamic demand	Journal of Transport Economics and Policy, 29(2), May 1995, pp. 179-93

Phil Goodwin		Summary - Car dependence	RAC Foundation for Motoring and the Environment
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Stokes, Gordon		Travel behaviour in south Yorkshire in 1993: analysis of the South Yorkshire Household Travel Survey	Report to South Yorkshire PTE
Stokes, Gordon	G Parkhurst	Change through interchange: making complex journeys easier	ESRC Transport Studies Unit, University of Oxford, ESRC TSU Ref. 838
Polak, John		The perils of panels: some cautionary notes on the pre-analysis of panel data	UTSG Conference, Cranfield, January
Vythoulkas, Petros C	H N Koutsopoulos and T Lotan	A neural-fuzzy approach to modelling travel behaviour	International Symposium on Neural Network Applications in Transport, Helsinki, April
Phil Goodwin		The end of hierarchy? A new perspective on managing the road network	Council for the Protection of Rural England, Warwick House, 25 Buckingham Palace Road, London SW1W 0PP
Stokes, Gordon	B Taylor	Where next for transport policy?	in British Social Attitudes: The Eleventh Report, Jowell, Curtice, Brook & Ahrendt (eds.), Dartmouth, Aldershot
Joyce Dargay	D Gately	The imperfect price-reversibility of non-transportation oil demand in the OECD	Energy Economics, Vol. 17(1), pp.59-71
Joyce Dargay	D Gately	The response of world energy and oil demand to income growth and changes in oil prices	in Annual Review of Energy and the Environment, Socolow, Anderson and Harte (eds.), Annual Reviews Inc., Palo Alto, CA, USA
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Stokes,		Rural transport policy in the	Proceedings of the

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Sally Cairns		**Car-less shopping: carrying on without the car**	Town and Country Planning Nov 1995 pp. 315-316
Sally Cairns		Travel for food shopping: the fourth solution	Traffic Engineering and Control, July/Aug
Sally Cairns		Carrying on without the car	Town and Country Planning
Phil Goodwin		Transport policy and road inquiries: new proposals from the Royal Commission on Environmental Pollution	Road Law and Road Law Reports, Vol.10 (8), pp. 504-9

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Parkhurst, Graham		Park and ride: determining policy aims, evaluating their success	Urban Transport and Urban Development, London Press Centre, December
Stokes, Gordon		Transport interchange for rural and tourist areas. Report to the Countryside Commission	ESRC TSU Ref. 819
Sally Cairns		Delivering alternatives: what is the experience of providing food shopping delivery services?	ESRC TSU Report 843, Oxford
Vythoulkas, Petros C	H N Koutsopoulos	Modelling discrete choice behaviour using concepts from fuzzy set theory, approximate reasoning and neural networks	ESRC TSU Ref. 817
Vythoulkas, Petros C	H N Koutsopoulos	Modelling multicriteria decision making using fuzzy-connective-based hierarchial aggregation networks	ESRC TSU Ref. 831
Vythoulkas, Petros C	P B Goodwin	Combining fuzzy set and neural network theory to model travel behaviour.	ESRC TSU Ref. 830