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Cycling & Urban Commuting:
Results of Behavioural Mode and Route Choice Models

M Wardman, M Page, M Tight, Y L Siu

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1. INTRODUCTION AND OBJECTIVES

The research reported here was undertaken as part of an Economic and Social Research Council Project (R000237103) entitled *Cycling and Urban Mode Choice*. The scope of the study is entirely commuting within an urban context.

The objectives of the study were:

- to better understand the interactions between car, bus, cycle and walk in an urban context and to explain observed variations in cycle trip rates across towns.

- to be able to forecast the effect of a range of improvements to cycling facilities on mode choice

- to use the estimated models to evaluate some actual schemes

- to provide end users (eg consultants, local authorities, cycling organisations) with a tool to determine the effect of policy measures. In particular, to create models which will enhance the performance of strategic, integrated transport studies.

The objectives of this paper are:

- to describe the methodology that was used to examine cycling within an urban mode choice context

- to outline the collection of data required to estimate behavioural models

- to report the results of the estimated mode and route choice models

- to provide illustrations of how the model can be used to appraise improvements to cycle facilities and cycling conditions.

The structure of this paper is as follows. Section 2 gives a brief overview of the policy context of work on cycling in the UK and previous work in the area. Section 3 describes the methodology used to collect the Revealed Preference (RP) and Stated Preference (SP) data necessary for the model. Section 4 describes the data that was collected. Section 5 gives details of the development of the model and some empirical results from the model that was developed. Section 6 illustrates how the model could be used to appraise improvements in cycle facilities and cycling conditions. Section 7 draws some conclusions from the work.

2. BACKGROUND

In the UK, the Government has endorsed the National Cycling Strategy (NCS) and the National Cycle Network (DETR, 1998; DoT, 1996). Consideration for cycling is expected to form a key part of the Local Transport Plans which UK local authorities are now preparing (DETR, 1999). The NCS targets specify ambitious increases in cycle use and it is clear that it is hoped that these increases will come about as a result of people choosing to cycle rather than drive. With this increased interest, there is likely to be increasing demands for rigorous evaluation of proposed schemes in terms of increases in levels of cycling, modal shift and, ultimately, the quantified benefits to existing and potential cyclists. Local authorities and others need to be able to assess cycle facilities to enable them to make decisions about whether to invest in provision and to decide between different schemes in a situation where funds are not unlimited. It is anticipated that the models derived from the research described in this paper will be used to help appraise different cycle facilities and proposed schemes, to predict the modal share consequences and to evaluate the benefits of investment.

In contrast with the vast amount of research which has been conducted into understanding the demand for motorised modes of transport, relatively little attention has been paid to the slower modes of walking and cycling. In addition, what work there has been on possible demand for cycling has been qualitative in nature, indicating the general concerns of cyclists and non-cyclists, rather than any quantitative evaluation of the magnitude of different factors.

This work has built on previous work in this area which has applied SP techniques to both cycle route and mode choice to generate more limited quantitative models. Hopkinson and Wardman (1996) showed, with a study of cycle facility provision in Bradford, West Yorkshire, that different values were placed on different attributes of alternative cycle routes. They found that, for a commuter journey of about 5 km, a bus and cycle lane on a busy road was valued at 7 pence, a widened lane on a less busy alternative was valued at 18 pence, a segregated path alongside the less busy route was valued at 30 pence and a completely segregated cycleway was valued at 71 pence. An important conclusion from this work was that it showed that some new cycle facilities can be economically justified on the basis of benefits to current cyclists, even in circumstances of relatively low cycle use.

Wardman et al. (1997) managed to derive estimates of values of time for cycling in different weather conditions and using different facilities. It was found that the value of time for cycling varied from 2.87 pence per minute for a trip in fine weather on a segregated cycling facility to 21.28 p/min for cycling in rainy and windy weather where there were no facilities. Based upon fine weather conditions a fully segregated and continuous cycle path was estimated to reduce the value of cycle time by 6.7 p/min, which implied that such a facility would be worth about 201 pence for a cycle journey of 30 minutes, or the same as a 21 minute journey time reduction. In the same study the value of car/bus time was estimated to be 1.54 p/min. The value of some cycle facilities were also valued as part of this study and it was found that a considerable premium of 66 pence was attached to the provision of secure cycle parking.

Wardman et al. (1997) also forecasted the percentages of car users and bus users who would cycle, given certain changes in cycle facilities, these ranged from 4.4% of car users and 4.6% of bus users cycling (compared to a base of 3.0%) if an unsegregated cycle lane were available for their whole journey, to 12.9% of car users and 16.7% of bus users cycling if a segregated path with a 20% time saving, secure cycle parking and shower facilities were available.

This research project has looked at the factors which might induce more people to cycle in the urban context, with the primary aim of estimating the potential for reducing car traffic. Models are discussed in this paper which can be used to explain people's choices between car, getting a lift, bus, cycle and walk for the commuting trip. These models are based on detailed surveys of people's actual mode choices and the facilities available to them, the surveys also included hypothetical questions posed about people's mode choice if various aspects of their journey were changed, in particular, if specific cycle facilities were made available.

3. METHODOLOGY

The study adopted a joint Revealed Preference (RP) and Stated Preference (SP) approach to the analysis of cycling within a mode choice context. In addition, the SP approach was also used to examine cyclists' route choices.

The main reasons for developing models on both RP and SP data are:

- RP data provides a firm basis in actual behaviour, and in particular provides the forecasting model with appropriate mode specific constants and the appropriate scale.
- SP methods provide additional data which allows more precise estimates to be obtained.
- SP methods can examine factors which do not currently exist, such as being paid to cycle to work and, for most people, improved cycle facilities, particularly cycleways and segregated on-road facilities.
- SP methods are more suited to the analysis of factors which have what might be termed a secondary influence on mode choice, such as the provision of facilities at work.

Given the absence of suitable route choice contexts in Britain, an RP approach to cyclists' route choice is not feasible and hence the analysis of these issues relies on SP data.

We set out the RP approach in section 3.1, the SP mode choice approach in section 3.2 and the SP route choice approach in section 3.3.

3.1 Revealed Preference Mode Choice

The intention had always been to use the RP approach to provide a firm analytical basis in commuters' actual mode choices. However, as the study progressed, it emerged that National Travel Survey (NTS) data could be used to enhance the modelling opportunities based solely on the data we had proposed to collect. The discussion below therefore distinguishes between the NTS data that can be used for modelling commuters' mode choices and the RP data we have ourselves collected.

3.1.1 National Travel Survey Data

The National Travel Survey (NTS) is a government funded survey of personal travel, and yields information on weekly travel behaviour along with socio-economic and demographic details relating to the individual, the household and the trips being made. The first NTS was undertaken in 1965/66, with further periodic surveys up to 1985/86. In 1988, the NTS has been conducted on an annual basis, involving approximately 8000 individuals per year.

This study has made use of data for 1985/86 and for the annual surveys between 1988 and 1997, and was obtained from the ESRC data archive at the University of Essex.

The advantages of NTS data are that:

- it contains a very large amount of information on mode choice for the journey to work
- it is based on individuals' actual choices
- it can be taken to be broadly representative of travel behaviour
- it can examine temporal variations as well as cross-sectional variations in behaviour

It therefore provides a valuable source of information which can be used to enhance considerably models based on the much more limited sample size obtained in our data collection. Moreover, our RP sample turned out be unrepresentative, with oversampling of cyclists, whereas NTS provides a much more representative picture. Inded, Freeth et al. (1999) state that, "The NTS is the only source of national information on subjects such as cycling and walking which provide a context for the results of more local studies".

NTS indicates the usual means of travel to walk, with the key modes of interest to this study being car, passenger, bus, train, walk and cycle.

The travel variables contained in NTS which are of use in modelling commuting mode choice are travel distance to work, bus service frequency, walk time to bus stop, walk time to railway station and bus time to railway station. Whilst the individual is asked for times and costs involved in travelling to work by the chosen mode, a deficiency as far as mode choice modelling is concerned is that details of the rejected modes are not included.

We have therefore engineered the times and costs for all modes on the basis of the evidence that is supplied for each of the chosen modes. This is converted into costs and times specific to an individual by relating costs per mile and speeds for each mode derived from the survey evidence to the distance travelled. As a result of this, our initial modelling of this data proceeded with caution, exploring the extent to which this has introduced a source of error into our modelling.

3.1.2 Purpose Collected Revealed Preference Data

By the use of a screening questionnaire, it was ensured that all respondents to the main survey were regular commuters, with a relatively short journey to work and that they felt that cycle facilities could be made sufficiently attractive for them to consider cycling to work. All those who passed the screen were also asked about their age and their gender and house type was also recorded.

Table 3.1 The Alternative Modes

	Usual Mode				
Alternative modes	Car Driver	Car Passenger	Bus	Cycle	Walk
Car Driver	n/a	no	yes if car available	yes if car available	yes if car available
Car Passenger	no	n/a	yes *only* if car not available but lift *is* available	yes *only* if car not available but lift *is* available	yes *only* if car not available but lift *is* available
Bus	yes if bus available	yes if bus available	n/a	yes if bus available	yes if bus available
Cycle	yes	yes	yes	n/a	yes
Walk	yes	yes	yes	yes	n/a

As part of the main survey a range of data were collected about respondents' current mode and possible alternative modes. Respondents were initially asked their address, and various questions designed to elicit which alternative modes were feasible for them. All respondents were asked about their journey by their current mode, Table 3.1 shows the range of alternative modes that respondents were asked about. Since they had already said that they might cycle if conditions were improved (as part of the screening survey), they were always asked about cycling to work and they were always asked how long it would take them to walk to work, but they were only asked about bus, car driver and car passenger modes if they were available to them.

The respondent was always asked about their current mode first and then the range of alternatives. The basic questions asked about each mode are given in the following sections. While the wording varied according to whether the questions were being asked about the current mode or a possible alternative, most of the basic information requested was the same.

Questions for current or potential car drivers

- door to door travel time
- time spent in congested conditions
- walk to work time after parking the car
- fuel costs
- parking costs
- details of any other occupants of the car
- what the car driver might do if the car journey became much less attractive, in terms of alternative modes, changing job or moving house (this question was only asked if car driver was the current mode)

Questions for current or potential car passengers

- door to door travel time
- time spent in congested conditions
- walking and waiting times associated with the lift to work
- contributions to fuel and parking costs
- what the car passenger might do if the car journey became much less attractive, in terms of alternative modes, changing job or moving house (this question was only asked if car passenger was the current mode)

Questions for current or potential bus users

- walk time to bus stop
- wait time
- bus frequency
- bus journey time
- time spent in congested conditions
- walking time from the bus stop
- whether a change of buses was required
- ticket price
- what the bus user might do if the bus journey became much less attractive, in terms of alternative modes, changing job or moving house (this question was only asked if bus was the current mode)

Questions for current or potential walkers

- walk time

Questions for current or potential cyclists

The questions concerning cycling as the respondent's main mode or as an alternative were more detailed and covered:

- Travel time, broken down according to time spent on five different types of road or cycle provision, these were:

a) Completely segregated cycleway with no motorised traffic on it, an example of this type of provision might be the routes developed by Sustrans on converted railway trackbeds.
b) Segregated on road cycle lanes, that is provision which follows the line of the road but is segregated from it.
c) Non segregated on road cycle lanes on major roads, these could be bus lanes or cycle lanes on the road segregated by a broken white line only.
d) Major roads with no facilities for cyclists.
e) Minor roads.

- Time to walk to work after parking the bicycle.

- Facilities available at work, such as secure cycle parking, changing rooms, lockers and shower facilities.

- How the respondent rated various aspects of their actual or possible cycle journey, including hilliness, traffic danger, air pollution and their own cycling ability. Non cyclists were also asked about why they don't currently cycle to work.

3.2 Stated Preference Mode Choice

Non cyclists (those whose current mode was not cycling) were presented with scenarios which gave them a choice between their current mode and a cycling alternative (a mode choice scenario).

Each respondent was presented with a single type of SP exercise, but the contents of these exercises were varied from respondent to respondent, based upon certain answers to the RP survey. Table 3.2 gives details of the SP exercises presented to non cyclists. SP1 was presented to those non cyclists who suggested there were no cycle facilities available for their use if they were to cycle to work (all their journey time reported in the RP survey consisted of time spent on d) and e) above), SP2 was presented to those who said there were facilities available. Different versions of the different SPs were presented in equal proportions to respondents. The times and costs suggested for the current mode were based upon the times and costs supplied as part of the RP survey. Most respondents were presented with 9 different scenarios randomly selected from 16, where the levels of the different attributes were varied in a systematic manner. Respondents were told that all other aspects of their journey by the current mode and the journey by cycle were the same as now. They were asked to make a choice between current mode, making the journey by cycle, using another mode and simply not making the journey at all.

Table 3.2 SP Exercises Presented to Non Cyclists

SP number	Current mode		Cycle alternative		
SP1a	Time	Cost	Time on segregated cycleway	Time on major roads without facilities	Time on minor roads
SP1b	Time	Cost	Time on segregated on road cycle lane	Time on major roads without facilities	Time on minor roads
SP1c	Time	Cost	Time on non segregated on road cycle lane	Time on major roads without facilities	Time on minor roads
SP2a	Time	Cost	Level of local population cycling	Level of cycle trip end facilities	
SP2b	Time	Cost	Level of work colleagues cycling	Level of cycle trip end facilities	
SP2c	Time	Cost	Level of local population cycling	Level of cycle trip end facilities	
SP2d	Time	Cost	Payment received for cycling	Level of cycle trip end facilities	

The SP1 exercises were designed to assess respondents' preferences towards different types of on and off road cycle route facilities. The amount of time spent on the new facility was varied, but the total travel time by cycle was kept constant (and the same as the respondent had reported in the RP survey) by also varying the amount of time on major and minor roads.

SP2a to c were designed to assess whether the level of cycling (either in the general population or in the place of work of the respondent) would influence propensity to cycle (SP2c was the same as SP2a except that larger increases in the time and cost of the current mode were used). The percentages cycling presented were based upon the known percentages of people cycling to work in the survey areas. SP2d was designed to incorporate cost into the valuation of different cycle facilities, respondents were asked to imagine that they would receive an allowance to cycle to work, perhaps as a result of a government project to encourage cycling. All of SP2a to d were also designed to assess the attractiveness of different levels of trip end facilities for cyclists.

As an example, SP2d asked about what the respondent would do if they were paid to cycle to work and there were changes to the trip end facilities offered at their place of work. Each of the 9 questions posed were of the form:

Time on current mode: One of a range of 4 times based upon the journey time given in the RP questionnaire.

Cost by current mode:	One of a range of 4 costs based upon the cost calculated from the responses to the RP questionnaire.
Payment received:	A daily payment of either 50, 100, 150 or 200 pence.
Facilities at work:	Either 'no facilities', 'outdoor cycle parking', 'indoor cycle parking' or 'shower/changing facilities and indoor cycle parking'.

The respondent was had to choose one of the following options for each of the questions:

- current mode
- cycle
- another mode
- not make journey

3.3 Stated Preference Route Choice

Cyclists (those who had said that their current mode was cycling) were asked to choose between their current route and a cycleway alternative (a route choice scenario).

Table 3.3 gives details of the SP exercises presented to cyclists. SP3 was presented to those cyclists who said that their cycle journey to work had a hilliness rating of greater than 50 (out of 100), SP4 was presented to the remaining cyclists. The time associated with the current route were based upon the time supplied as part of the RP survey. Respondents were presented with 9 different scenarios randomly selected from 16, where the levels of the different attributes were varied in a systematic manner. There was a cost associated with the new cycleway and it was stated that it could be used for 'all your journey to work except for about 1 minute getting to and from it'.

Table 3.3 SP Exercises Presented to Cyclists

SP number	Current route	Cycleway alternative		
SP3	Time	Time	Cost	
SP4	Time	Time	Cost	Cycleway surface

The description of the new cycleway presented varied between the two SP exercises, in SP3 it was described as taking the 'flattest possible gradient between your home and work' (but other aspects of the new cycleway were specified as being similar to the current route) whereas in SP4 it was described as 'free from both the air pollution and noise caused by traffic'. SP4 was also designed to try and derive estimates for the value cyclists put on different types of surface, the 4 possible different types of surface were:

- road quality tarmac - a surface equivalent to that found on a good road
- footway quality tarmac - a less smooth surface such as might be found on the footway
- cinder - the type of crushed stone surface often found on segregated cycle tracks outside built up areas

- bridleway - a surface not specifically prepared for cycle use and which could be muddy in wet weather

4. DATA COLLECTION

The main questionnaire was computerised and administered as a door to door household survey. Once respondent had passed an initial screen, the interviewer entered their responses on a laptop computer.

The initial screening survey ensured that only those respondents satisfying certain criteria were questioned in detail. The criteria were:

- The respondent travelled to work or college at least twice a week, using one of the five modes to be modelled (car as driver, car as passenger, bus, walk, cycle)
- The journey from home to work/college was 7.5 miles (12 km) or less
- The respondent would be prepared to cycle to work/college if cycle facilities and provision were made sufficiently attractive

This meant that only those prepared to cycle to work were questioned in detail about their trip making behaviour. In addition existing cyclists who passed the screen were asked about their trip making behaviour and their route choice.

Over 1000 questionnaires were completed in four different locations across the UK in Autumn 1998. Table 4.1 gives details of those passing the screening questionnaire by location. Results drawn from the screening questionnaire and from a further, wider survey along similar lines are covered in Siu et al. (2000).

Table 4.1: Number of Respondents Passing the Screening Questionnaire by Location

Site	Number who passed screen	
	non cyclists	cyclists
Leicester	220	23
Norwich	333	55
York	172	90
Hull	119	47

The actual questionnaire was broken into three main sections. The first two sections asked questions about the respondent's actual journey to work and possible alternative and was designed to elicit revealed preference (RP) data on the choices the respondent was actually making in real life between different modes. The third (SP) section posed a range of different sets of hypothetical questions about mode choice under specified changes in certain aspects of the respondent's journey which might influence them to change mode.

Table 4.2 shows a breakdown of the number of SP exercises administered by SP type. Note that these numbers are for the pre cleaned data and therefore don't match up exactly with the dataset used for modelling.

Table 4.2 SP Exercises Administered

SP	Number
SP1a	100
SP1b	99
SP1c	96
SP2a	110
SP2b	115
SP2c	117
SP2d	113
SP3	24
SP4	297

5. EMPIRICAL RESULTS

We here present the findings of the behavioural modelling that has been conducted in this study. An accompanying paper (Siu et al., 2000) reports on the analysis conducted on choice set composition and specifically whether non cycling commuters would even consider making the journey to work by cycle.

Prior to discussing the results of the mode choice modelling and the route choice modelling, we consider a number of issues relating to the modelling approach adopted.

5.1 Modelling Approach

Where there are variables which are common to different data sets, it makes sense where possible to undertake a joint estimation on the combined data. There are two principal reasons for this:

- To obtain more precise coefficient estimates than would be the case if the data sets were analysed separately

- To allow for what is termed the scale factor problem, whereby SP models have a different scale to RP models which has implications for forecasting.

The discrete choice data is analysed using the logit model. This is by far the most common means of analysing disaggregate choices. A property of such models is that, unlike regression models, the coefficients are estimated in units of residual variation. This accounts for the effect of unobserved influences on choice, with the result that the greater the amount of random error underlying the choices then the lower the coefficient estimates will be.

Since different data sets may have a different amount of random error, for example, because of errors in SP responses over and above that encountered in real world choices or because the specification of the SP exercise and resulting modelling of the data does not account for all the key influences on choice, then they should not be combined without allowing for the difference in scale.

A procedure has been developed involving a hierarchical logit specification which allows for different scales across data sets (Bradley and Daly, 1991). If we have, say, RP and SP mode choice data and wish to estimate a single set of parameters to variables which are common to each, we could simply enter the data into a single logit model. Given that there is a choice associated with both the RP and the SP alternatives, rather than a single choice across all alternatives, the unavailability command is used to model the RP choices given that the SP alternatives are unavailable and the SP choices given that the RP alternatives are unavailable.

It is a straightforward matter to constrain the parameter estimates for each variable to be the same across the RP and SP choices. However, this does not allow for the different scales that may be implicit in each, and the resulting coefficients will therefore be scaled relative to some average of the residual variation in the RP and SP choices. A simple solution to this problem is to specify separate coefficients for variables according to whether they relate to the RP or SP data set. However, this defeats the whole objective of estimating a single model since we have effectively estimated two separate models.

The joint estimation procedure that we have adopted which allows two data sets to be combined assumes that the two data sets provide the same information up to a scale transformation of the parameters. It uses a hierarchical logit specification where the SP choices are entered within a lower nest and the RP choices are entered into the upper nest. The non-availability feature is again invoked so that the RP choice is modelled from amongst the RP alternatives alone and the SP choice is modelled from amongst the SP alternatives alone. The difference compared to standard hierarchical logit models is that each SP alternative has its own nest, and hence there are as many dummy alternatives as there are SP alternatives.

The result of this artificial construct is that the logsum variable in each nest collapses to the utility of the alternative in that nest, and hence the parameter estimated to the logsum variable reflects the different scale of the SP data when the coefficients of the RP and SP models are constrained to have the same coefficients. It is typical to constrain the scale factor to be the same across alternatives.

The coefficient on the logsum variable (θ) is interpreted as the ratio of the error standard deviations in the RP and the SP models. Hence if the SP model contains more random error than the RP model, θ will be less than one. Unlike the standard hierarchical logit model, θ can logically exceed one.

The coefficients which are common to the RP and SP data are scaled relative to the residual deviation in the RP model, with the θ parameter allowing for the different scale implicit in the SP coefficients. Variables which are not common but specific to the SP data remain estimated relative to the standard deviation of the errors in the SP choices and hence must be rescaled for comparability with the other coefficients and for use in forecasting. Variables which are not common but specific to the RP data are estimated relative to the standard deviation of the errors relevant to RP choices. Further details on this procedure for joint estimation of RP and SP data are contained in Ortuzar and Willumsen (1994).

Quite apart from the use of hierarchical logit for joint estimation across different data sets whilst allowing for different scales, there is also the issue of using the hierarchical logit model regardless of data type to overcome the independence of irrelevant alternatives property of multinomial logit. The latter property implies that the cross elasticity of, say, mode z with respect to mode x is the same as the cross elasticity of mode y with respect to mode x yet this may not be empirically justified.

5.2 Mode Choice Results

There was a concern that the use of time and cost data 'engineered' on the basis of the times and costs reported for chosen mode rather than each individuals' perceived times and cost, the necessity of which was outlined in section 3.1.1, would lead to deficiencies in a model estimated to NTS data. In early versions of the joint model, we therefore distinguished the time and cost parameters between the NTS data and our RP data, as well as allowing the latter to have a different scale to the former.

The time coefficients obtained from the NTS and our RP data were remarkably similar, which was an encouraging finding. However, the cost coefficient estimated to NTS data was wrong sign and significant. This may be because journey time can be estimated more accurately than costs, particularly given that the perception of costs can very considerably across individuals, whilst public transport costs differ according to whether some kind of travelcard or season ticket is used and whether a zonal or graduated fare system is in place whilst the fare per mile can varies considerably across distances.

Our solution was to constrain the cost coefficient relating to NTS data to be the same as that in our RP data, where thr latter was based on perception and related to the amount that was or would actually be paid by the individual. The imposition of this constraint had a negligible impact on the other coefficient estimates.

The mode choice results estimated to the combined NTS data and the RP and SP data collected in this study are reported in Table 5.1.

After removing journeys of over 7.5 miles and cases where there was missing information, we are left with a total data set of 30116 discrete choices. This is a very large data set for modelling purposes and is made up of:

- 23926 choices in the NTS data
- 969 choices in our RP data set
- 2115 choices in the SP1 data set
- 3106 choices in the SP2 data set

The model is hierarchical logit for the purposes of combining different sources of data. It was found that the scale of the NTS and RP data was almost the same (θ_{rp}=1.05) when the RP data was entered into a lower nest and hence no distinction is made between the two. This is an encouraging finding, since we would ideally expect different RP data sets addressing the same choice context to have the same scale. However, the two SP mode choice data sets were found to have different scales.

The variables which are common to both RP and SP are denoted with a • in Table 5.1. Those which are specific to SP, and hence need to be rescaled, are denoted ♦, with the remainder specific to the RP data.

With regard to the degree of competition between modes, the model takes the multinomial logit form. We examined various hierarchical structures but could find no convincing evidence to depart from the multinomial specification. This was so when we examined the our RP data on its own minus the NTS and SP data, since the approximations involved in creating the time and cost data in NTS might have militated against being able to detect a hierarchical structure whilst the SP data only ever involve binary choices.

The ρ^2 goodness of fit measure, specified with respect to a constants only model, of 0.28 is very respectable, and a large number of statistically significant and correct sign coefficients have been estimated. Monetary variables are specified in pence, in quarter 1 1999 prices, with the exception of income which is specified in pounds. Time variables are specified in minutes.

Different constants have been estimated for n-1 of the n modes for the NTS, RP, SP1 and SP2 data sets. This is because the NTS data set is taken to be representative of mode choice, whereas our RP sample contains too many cyclists, and the constants in SP models must be treated with caution since they can discern effects, such as SP response bias or the effect of attributes not contained in the SP exercises but which nonetheless influence choice.

The constants are denoted CAR, PASS, BUS, TRAIN and WALK, for each of the four data sets, and the omitted category against which the constants are interpreted is cycle. Train only enters in the NTS data set, since rail was not an option for urban commuting trips in the locations where the surveys were conducted.

As might be expected, there is a preference, other things equal, of most of the modes over cycling. The SP2 constants indicate a strong preference over cycle, and this is in part due to the absence of cycle time in the SP2 cycle alternative on the grounds that it was not varied in this SP experiment. The SP coefficients also need to be rescaled, and we return to the scaling issue below.

The key findings of this mode choice model are:

- The value of travel time (Time) for urban commuters is 6.5 pence per minute. This is highly plausible.

- Time spent cycling (Time-Y) is valued 2.9 times more highly than in-vehicle time. The latter can be generally taken to represent cycling where there are few or no facilities. Hence the high valuation of cycle time, amongst the general population of commuters, seems reasonable.

- Walking time (Walk) to access or egress a main mode is valued 1.9 times more highly than in-vehicle time. This is consistent with the conventional wisdom of valuing such time at twice the rate of in-vehicle time, although a little higher the value of 1.6 obtained by Wardman (1999) in a large scale review of British empirical evidence.

- Walking time where walk is the main mode (Walk-W) is valued 41% higher than where it is spent accessing or egressing a main mode. There may be a non-linearity effect at work here, whereby walking time incurs increasingly high marginal disutility as walking time increases and is therefore highly valued for the distances involved in this study.

- Headway is valued at 69% of in-vehicle time. This seems reasonable, and is little different to the value of 78% for commuters in the review by Wardman (1999).

The plausibility of these results, along with the statistical significance of the estimated parameters, indicates that the model provides a firm basis for the analysis of mode choice and for the joint estimation with the SP data which relates to the cycling specific attributes.

The SP1 exercise examined cycle time spent in different conditions. These were:

- Time spent on a completely segregated cycleway (Time-YA)

- Time spent in a segregated on-road cycle lane (Time-YB)

- Time spent in a non-segregated on-road cycle lane (Time-YC)

- Time spent on major roads with no cycle facilities (Time-YD)

- Time spent on minor roads with no cycle facilities (Time-YE)

Since the cycle coefficients for Time-YA through Time-YE are specific to SP data, they need to be rescaled using the scale factor relating to the SP1 exercise (θ_{sp1}) in order to be comparable with the coefficients, such as time, cost, headway and walk time, which are common across the RP and SP data.

When this is done, Time-YD and Time-YE are 0.096 and 0.095 respectively. These correspond remarkably well with the Time-Y coefficient, which is comparable with the former since it will reflect broadly the same travelling conditions.

The provision of non-segregated cycle lanes, as expected, reduces the value of time, and this reduction is quite appreciable. After rescaling, Time-YC becomes –0.035 which is similar to the time coefficient of –0.039 relating to vehicular travel.

As expected, the provision of segregated cycle lanes and a completely segregated cycleway both lead to further reductions in the disutility of travelling by cycle, with the latter facilities slightly preferred to the former. The value of cycling time is now around a third of that of vehicular travel, but conditions are remarkably safe, and in the case of the cycleway much more pleasant, whilst it must be borne in mind that the SP exercise relates to non-cyclists who would consider cycling if facilities were improved.

One of the issues examined by the second SP exercise was that of the facilities available at work. Relative to a base of no facilities, the SP exercise offered:

- Outdoor cycle parking facilities (O-Park)
- Indoor cycle parking facilities (I-Park)
- Shower/changing facilities and indoor cycle parking (ShI-Park)

The value of ShI-Park should logically exceed the value of I-Park and this was indeed the case. We would also expect I-Park to be preferred to O-Park and this turned out to be so. Since these coefficient estimates are specific to variables in the SP2 exercise, it is necessary to rescale them for comparability with the coefficients which are estimated in RP units. These coefficients are therefore multiplied by θ_{sp2}.

After rescaling the parameters, and using the Time-Y coefficient to convert into time units, O-Park, I-Park and ShI-Park are respectively valued at equivalent to 2.5, 4.3 and 6.0 minutes of cycle time. Again, we conclude that these values seem reasonable.

The SP2 exercise somewhat speculatively also included the proportion cycling to work as a variable in order to examine whether such factors as social norms, peer pressure and what is deemed to be 'normal' influence the propensity to cycle to work.. Whilst SP exercises are not particularly well suited to the analysis of such effects, given the inherent high levels of uncertainty and unfamiliarity, other methods also have deficiencies especially since the proportion cycling is clearly not independent of the factors which influence the level of cycling yet in an SP exercise it can be exogenously determined.

Some respondents were offered the proportion of the population in general who cycled to work (PropGen) whilst others were offered the proportion of their colleagues who cycled to work (PropCol). Increases on both these proportions would increase the probability of cycling to work, although the former was found to have a much larger effect than the latter and indeed PropCol was not statistically significant at the usual 5% level.

We do not find it surprising that PropGen has a larger effect, although a relevant issue is that varying the proportion of colleagues cycling to work is not as realistic as offering different proportions of the total population, whilst the absolute figures of the proportion of colleagues cycling might not have been realistic for some respondents but care was taken to vary the proportion of the population in general who cycle around the proportion for the sampled location.

The coefficients again need to be rescaled into RP units, and once this is done we find that a 10% increase in the proportion of the population cycling is equivalent to a one minute reduction in cycle time in terms of its expected impact on demand.

The remaining issue which is addressed in the SP exercises is that of being paid to cycle to work. The relevant coefficient (Reward) is positive, as expected, with a respectable t statistic. After rescaling with θ_{sp2}, the Reward coefficient implies that such a monetary gain is valued 2.2 times more highly than an equivalent monetary outlay.

There is the possibility that strategic response bias has influenced the results, with respondents sending message that increases the likelihood and magnitude of a payment for cycling. However, we do not find this to be entirely plausible, given that the sample is made up of non-cyclists who can hardly be expected to be so concerned with a mode that is not currently used. The monetary outlay does not relate to cycle, and its effect will have been deflated to the extent that some of these costs are not directly borne by travellers or indeed are disregarded as with petrol costs by some motorists, whereupon the outlay will have less effect than the reward.

Three variables in the model remain which are specific to cycling and whose inclusion stems from our survey work. Each relates to the RP exercise and hence their coefficients do not need to be rescaled.

The RP exercise asked for details about a number of aspects of cycling, each on a 100 point scale from what would be a very good position to what would be a very bad position. The variables related to hilliness, air pollution, noise, danger from traffic, personal security, tiredness and cycling ability.

Of these, three variables have been retained in the model reported in Table 5.1 and two of them have statistically significant coefficients at the 5% level. The three coefficients related to danger, tiredness and cycling ability. Although the danger element will be included in the valuation of cycle lanes and cycleways, this is here an independent effect since it stems from the RP data rather than the SP exercise.

Given that the upper point on the scale is least favourable to cycling, the coefficients are of the correct sign. Tiredness and cycling ability have similar effects on the probability of cycling. An increase in 10 points in the scale of tiredness would be equal to around a minute of cycling time.

We had expected the hilliness variable to turn out to have a significant influence on cycle demand, since it is well testified in census data that the proportion cycling to work is influenced strongly by the topography. However, the likely reason why we have failed to discern any effect is that the surveyed locations were all reasonably flat.

The remaining coefficients relate to socio-economic variables which can influence the probability of cycling. With the exception of time trend and income, which relates to household income, the variables are dummy variables. The effects of each are interpreted relative to the arbitrarily omitted category. The included categories of the age, socio-economic group and gender and two relating to car use:

- Male
- Age Group 30-39 (Age1)
- Age Group 40-49 (Age2)
- Age Group 50+ (Age3)
- Skilled Worker (Skill)
- Semi and Unskilled Worker (Semi)
- Clerical Worker (Cler)
- The probability that the respondent has a company car (Comp)
- Whether the car is used in the course of work (Used)

The results indicate that males are more likely to walk and to cycle but that there will be, as expected, a lesser propensity to cycle or walk as age increases. Increases in income will increase the numbers travelling to work by train, and there may also be a positive income effect on cycle use and the numbers travelling as passengers depending on whether the positive income coefficient can compensate for those who would be attracted to train and passenger as income increases.

Two time trends were statistically significant, relating to bus and train. The bus trend was, as expected. negative whilst the train trend was positive. Given that cycle does not generally compete with train, because of the limited availability of the latter outside London for short distance trips, the absence of any trend specific to cycle would mean that at least in the public transport market cycle share has not been experiencing trend decline.

However, we must bear in mind when discussing income and trend effects that there will be increasing car availability over time. In model calibration, car is made non-available for those who do not have access to car for the journey to work, but as car ownership increases this will lead to an increase in the proportions that the model would forecast to travel by car with implications for cycle use.

We also examine whether gender, age group and socio-economic group influenced how sensitive commuters' were to the cycling attributes as well as exploring whether income had an impact on how individuals responded to cost variations. This is in addition to the effects relating to these variables that are reported in Table 5.1 and which modify the constants and thereby influence the overall propensity to travel by each mode.

An income effect was apparent on the cost coefficients of the expected form but it was very minor and it is not included in the reported model. However, we could not obtain statistically significant and theoretically consistent effects from age, gender or socio-economic group on the coefficients relating to the cycling specific variables.

Table 5.1: Multinomial Logit Mode Choice Results

Variable	Coeff (t)	Variable	Coeff (t)	Variable	Coeff (t)
Car-NTS	3.045 (31.4)	O-Park ♦	1.120 (3.9)	Age3-Pass •	-0.334 (3.7)
Pass-NTS	-0.218 (2.1)	I-Park ♦	1.921 (4.9)	Age1-Bus •	-0.601 (8.2)
Bus-NTS	1.763 (13.6)	ShI-Park ♦	2.690 (5.2)	Age2-Bus •	-0.569 (6.6)
Train-NTS	0.601 (3.2)	Time-YA ♦	-0.039 (2.0)	Age3-Bus •	-0.376 (4.3)
Walk-NTS	3.358 (30.9)	Time-YB ♦	-0.049 (2.4)	Age1-Train •	-0.392 (3.7)
Car-RP	0.326 (1.3)	Time-YC ♦	-0.107 (4.0)	Age23-Train •	-0.794 (7.8)
Pass-RP	-1.882 (5.9)	Time-YD ♦	-0.292 (5.4)	Age1-Walk •	-0.315 (4.2)
Bus-RP	-0.217 (1.4)	Time-YE ♦	-0.287 (4.6)	Age2-Walk •	-0.366 (4.1)
Walk-RP	1.313 (6.0)	PropGen ♦	0.051 (3.0)	Age3-Walk •	-0.562 (6.1)
Car-SP1 ♦	-1.301 (2.5)	PropCol ♦	0.015 (1.3)	Age2-Cycle •	-0.217 (2.4)
Pass-SP1 ♦	0.941 (1.3)	Reward ♦	0.050 (4.9)	Age3-Cycle •	-0.338 (3.7)
Bus-SP1 ♦	-1.736 (2.2)	Danger	-0.004 (1.3)	Semi-Bus •	-0.189 (2.1)
Walk-SP1 ♦	1.325 (4.2)	Tired	-0.013 (3.4)	Skill-Bus •	-0.315 (3.4)
Car-SP2 ♦	7.646 (6.3)	Ability	-0.011 (2.9)	Cler-Bus •	0.399 (4.9)
Pass-SP2 ♦	8.598 (5.7)	Trend-Bus	-0.014 (2.6)	Semi-Train •	-1.926 (12.3)
Bus-SP2 ♦	6.512 (6.5)	Trend-Train	0.030 (3.3)	Skill-Train •	-1.579 (11.7)
Walk-SP2 ♦	7.246 (6.8)	Comp	0.663 (8.9)	Cler-Train •	-0.596 (6.0)
Time •	-0.039 (23.0)	Used	0.518 (6.2)	Semi-Walk •	-0.335 (5.2)
Time-Y •	-0.116 (35.6)	Male-Pass •	-0.384 (6.9)	Skill-Walk •	-0.678 (9.0)
Walk •	-0.075 (22.8)	Male-Train •	0.613 (7.0)	Inc-Pass •	0.000013 (7.5)
Walk-W •	-0.106 (50.5)	Male-Walk •	0.789 (13.1)	Inc-Train •	0.000028 (11.2)
Headway •	-0.0268 (17.7)	Male-Cycle •	1.296 (20.0)	Inc-Cycle •	0.000007 (3.4)
Cost-NTS	-0.006	Age1-Pass •	-0.496 (5.9)	θ_{sp1}	0.33 (5.6)
Cost •	-0.006 (4.3)	Age-2-Pass •	-0.413 (5.3)	θ_{sp2}	0.26 (5.6)

5.3 Route Choice Results

The route choice results are presented in Table 5.2. Both data sets were analysed in a single model since there proved to be not justification for separating them. The SP3 exercise provided 189 choice observations whilst the SP4 exercise provided 2259, making a total of 2448 upon which the model is calibrated.

The reason why SP3 forms so little of the overall sample is because we had originally specified that those cyclists who provided a 'hilliness' rating in excess of 50 would be given SP3 but in the event the surveys were conducted in relatively flat locations and we overlooked to amend the criterion relating to the distribution of SP3.

The route choice results are presented in Table 5.2. The goodness of fit of 0.16 is, in our experience, quite respectable for SP choice exercises, whilst the coefficients are of the correct sign and statistically significant.

There are many fewer variables than the mode choice model since the socio-economic variables relevant to explaining the pattern of mode choices are not relevant here. However, we did examine whether gender and age influenced the sensitivity to the various types of cycle time but no significant and consistent effects were apparent.

Time-Y denotes the time in minutes spent in current conditions and cost is the charge in pence to use the cycleway. Time-CW1 is time spent on the cycleway which is so designed to be as flat as possible. Time-CW2 represents time spent on a tarmac segregated cycleway. The two types of tarmac surface considered in the SP exercise were found to have very similar coefficients and hence a single term was specified. Similarly, the bridleway and cinder surfaces were found to have very similar coefficients and these have been constrained to be the same and are represented by Time-CW3.

As expected, time spent on the flat and tarmac cycleways has a lesser disutulity than time spent in typical road conditions. However, it may be that respondents have had difficulties appreciating the admittedly highly artificial concept of a cycleway which has the minimum possible gradient between the origin and destination, particularly if to achieve this the journey time relative to the current route is not realistic. It can also be seen that cyclists actually prefer to cycle in current conditions than on a cycleway with a less satisfactory surface than is currently experienced. This is a surprising finding and one which requires validation either with other comparable quantitative evidence or else with qualitative research findings.

Table 5.2: Route Choice Results

Variable	Coeff (t)
Time-Y	-0.127 (9.1)
Time-CW1	-0.107 (7.4)
Time-CW2	-0.076 (6.1)
Time-CW3	-0.137 (11.0)
Cost	-0.043 (17.3)

The value of time for a tarmac cycleway is 1.77 pence per minute. Even though this relates solely to cyclists, it seems to be on the low side, and it might be concluded that there has been a bias toward paying to use the cycleway which has resulted in an inflated cost coefficient. However, when we translate the cost coefficient into the same units as the mode choice model, through comparison of the Time-CW2 coefficient estimated here with the Time-YA coefficient estimated in the mode choice model, the implied cost coefficient is –0.007 which is very similar to the cost coefficient of –0.006 estimated in the mode choice model. Such a degree of similarity is encouraging.

6. APPLICATIONS

The mode choice model can be applied to forecast not only the effect on cycling of a number of improvements but, at a less detailed level, it can forecast the impact of a wide range of other attributes on the demand for a number of other modes. Of particular importance in this context is the inclusion of walk as a mode in the choice model.

Similarly, the route choice models can be used to appraise significant improvements in cycle facilities and the benefits of such measures to cyclists as well as the

We illustrate the potential uses of the mode choice model by providing some forecasts of the effects of various improvements to cycle conditions.

We have obtained forecasts incrementally from the base market share positions for car, passenger, bus, walk and cycle indicated in the most recent NTS data for 1997 and for journeys of 10 miles or less.

The incremental form of the logit model was used to obtain forecasts. This takes the form:

$$P_y^f = \frac{P_y^b e^{\Delta U_y}}{P_y^b e^{\Delta U_y} + P_c^b e^{\Delta U_c} + P_p^b e^{\Delta U_p} + P_b^b e^{\Delta U_b} + P_w^b e^{\Delta U_w}}$$

where the subscripts denotes the modes of car (c), passenger (p), bus (b), walk (w) and cycle (y) and the superscripts denote either the base (b) or forecast situation. The revised market share for cycle (P_y^f) is therefore based on the base market shares (P_y^b) and the changes in utility (ΔU) for each mode. The calculation is performed for each person in the RP data set and the revised market share for cycle is the average of the revised shares across each individual.

We also recognised that some commuters would never switch to cycle, and another aspect of this research examined the extent to which commuters would be prepared to consider cycling (Siu et al., 2000). The figure used here is that 50% of commuters would not consider switching to cycle and the forecasts have been adjusted accordingly.

Table 7.1 sets out forecasts for a range of improvements for cycling to work. Time can be spent in any one of the following conditions:

- On a completely segregated cycleway (A)
- In a segregated on-road cycle lane (B)
- In a non-segregated on-road cycle lane (C)
- On major roads with no cycle facilities (D)
- On minor roads with no cycle facilities (E)

Our survey indicates that in the current situation the average cycle time to work would be 15 minutes, and on average the proportion of time spent in the each type route is 6% for cycleway, 4% for segregated on-road cycle lane, 19% for non-segregated on-road cycle lane, 53% for time spent on major roads with no cycle facilities and 18% for time spent on minor roads with no cycle facilities.

Table 7.1: Forecast Impact of Improved Cycling Conditions

Scenario	P_c	P_p	P_b	P_w	P_y
Base	65.9	9.9	10.9	8.8	4.5
Half of D and E to C	65.5	9.8	10.8	8.7	5.2 (+15.5%)
Half of D and E to B	65.2	9.8	10.8	8.7	5.5 (+22.2%)
Half of D and E to A	65.2	9.8	10.8	8.7	5.6 (+24.4%)
All of D and E to C	64.7	9.7	10.7	8.6	6.3 (+40.0%)
All of D and E to B	64.3	9.6	10.6	8.6	6.9 (+53.3%)
All of D and E to A	64.1	9.6	10.6	8.6	7.1 (+57.8%)
All of D and E to C plus 5 mins	65.1	9.8	10.8	8.7	5.6 (+24.4%)
All of D and E to B plus 5 mins	64.4	9.7	10.7	8.6	6.6(+46.7%)
All of D and E to A plus 5 mins	64.1	9.6	10.6	8.6	7.1(+57.8%)
All C, D and E to B	64.1	9.6	10.6	8.6	7.1 (+57.8%)
All to A	64.0	9.6	10.6	8.5	7.3 (+62.2%)

The first scenario therefore evaluates the impact of introducing non-segregated cycle lanes which replace half of the time spent on major roads with no facilities and half of the time spent on minor roads with no facilities.

It can be seen that although there are sizeable forecast increases in the proportion cycling to work, the impact on the other modes is minor. In the most favourable possible case, where all time would be spent on a completely segregated cycleway, only 7.3% of commuters are forecast to cycle to work, an increase of 62% over the base situation.

Table 7.2 considers the impact of rewarding commuters for cycling to work, and reports the forecasts effect of different daily payments to cycle to work.

Table 7.2: Effect of Daily Payments to Cycle to Work

Scenario	P_c	P_p	P_b	P_w	P_y
Base	65.9	9.9	10.9	8.8	4.5
£0.50 per day payment	65.4	9.8	10.8	8.7	5.3 (+17.7%)
£1.00 per day payment	64.8	9.7	10.7	8.7	6.1 (+35.5%)
£1.50 per day payment	64.1	9.6	10.6	8.6	7.1 (+57.8%)
£2.00 per day payment	63.3	9.5	10.5	8.4	8.3 (+84.4%)
£3.00 per day payment	61.3	9.2	10.1	8.2	11.2 (+148.9%)
£4.00 per day payment	58.8	8.8	9.7	7.9	14.8 (+228.9%)
£5.00 per day payment	55.7	8.4	9.2	7.4	19.3 (+328.8%)

In contrast to the impact of improved cycle lanes, payment for cycling to work does have a big impact on the demand for cycling. A payment of £2 per day is not far from doubling the amount of cycling and has a larger impact than the ideal scenario of cycling to work being spent entirely on completely segregated cycleways.

Analysis of the impact of improving facilities at work is hampered because the data we collected in the RP survey about currently available facilities did not match up with the improvements offered in the SP exercise. We have therefore assumed that in the base situation no facilities are provided and evaluate the impact of introducing outdoor cycle parking, indoor cycle parking, and showers and indoor parking.

Table 7.3: Effect of Facilities at Work

Scenario	P_c	P_p	P_b	P_w	P_y
Base	65.9	9.9	10.9	8.8	4.5
Outdoor parking provided	65.5	9.8	10.8	8.7	5.2 (+15.5%)
Indoor parking provided	65.1	9.8	10.8	8.7	5.6 (+24.4%)
Showers and indoor parking	64.7	9.7	10.7	8.6	6.3 (+40.0%)

It can be seen that quite appreciable improvements in cycle market share result from the provision of facilities at work, particularly the provision of showers and indoor parking. However, these figures provide an upper bound to the effect of these improvements since we have here assumed that there are no facilities in the base case whereas in fact there will be some. Indeed, the survey indicated that 26% had access to shower facilities at work and secure cycle parking was provided in 35% of cases.

Table 7.4 provides forecasts that can be made with the parameters we have estimated in our model. It reports on the impact of increases in the proportion of the population and colleagues cycling, departing from the base share of 4.5%. It also examines what would happen if the danger, tired and ability ratings were halved, which form improvements as far as the attractivness of cycling is concerned, where the current average ratings for danger, tiredeness and ability and 57, 25 and 31.

As expected, given the relative magnitude of their coefficient estimates, increases in the population cycling is forecast to have a much larger encouragement to cycling than increases in the number of colleagues cycling to work. Given that we did not examine the two issues together, we cannot establish to what extent these are entirely independent effects. However, the proportion of the population cycling would seem to be a more usable variable and, although we must bear in mind the uncertainties surrounding this aspect of our analysis, it does seem that what might be regarded to be 'social norms' can have an impact, albeit not large, on cycle commuting.

Table 7.4: Other Effects

Scenario	P_c	P_p	P_b	P_w	P_y

Base	65.9	9.9	10.9	8.8	4.5
10% Population Cycle	65.8	9.9	10.9	8.8	4.6 (+2.2%)
20% Population Cycle	65.6	9.9	10.8	8.8	4.9 (+8.9%)
30% Population Cycle	65.4	9.8	10.8	8.7	5.3 (+17.8%)
10% Colleagues Cycle	65.9	9.9	10.9	8.8	4.5 (+0.0%)
20% Colleagues Cycle	65.8	9.9	10.9	8.8	4.6 (+2.2%)
30% Colleagues Cycle	65.7	9.9	10.9	8.8	4.7 (+4.4%)
Danger Rating Halved	65.7	9.9	10.9	8.8	4.7 (+4.4%)
Tiredness Rating Halved	65.5	9.9	10.9	8.8	4.9 (+8.9%)
Ability Rating Halved	65.5	9.9	10.9	8.8	4.9 (+8.9%)

Although the danger rating is far less favourable to cycle than either the tiredness or the ability ratings, the latter two variables have a larger bearing on the utility of cycling. However, even if it were possible to have a significant impact on cycling ability or the degree to which cycling is regarded to be tiring, such measures are forecast to have only a minor effect on cycle demand. The small forecast effect from changing the danger rating is not entirely consistent with the forecast effects of introducing improved cycle conditions, as outlined in Table 7.1. However, improved cycle conditions can offer other improvements, such as less exposure to noise, air pollution, traffic conflicts and delays, over and above the safety issue.

Table 7.5 considers the impact of providing a cycleway for the whole journey but charging for its use. The charge coefficient is obtained from the route choice model, rescaled using the value of time for a cycleway to have the appropriate scale for the mode choice model. This yields a cost coefficient of –0.007 which, as we discussed in section 5.3, is very similar to the mode choice estimated coefficient of –0.006.

Table 7.5: Charging for Improvements

Scenario	P_c	P_p	P_b	P_w	P_y
Base	65.9	9.9	10.9	8.8	4.5
All Cycleway	64.0	9.6	10.6	8.5	7.3 (+62.2%)
All Cycleway +20p	64.3	9.7	10.6	8.6	6.8 (+51.1%)
All Cycleway +50p	64.7	9.7	10.7	8.6	6.3 (+40.0%)
All Cycleway +£1.00	65.4	9.8	10.8	8.7	5.3 (+17.8%)

Even after a £1 charge to use the cycleway, and assuming that the alternative options are to switch modes and not routes, the demand for cycling is higher than in the base situation. This would seem to suggest that there is scope for improved cycling facilities to be either paid for by direct charging or else justified through cost benefit analysis.

Finally, we examine some route choice implications of providing high quality cycling conditions. The route choice model can be used to forecast the proportions of cyclists choosing between their current route and a new cycleway in a variety of scenarios. Table 7.6 presents the forecast proportions of existing cyclists who would choose the cycleway (P_{cw}) under various scenarios.

Given cyclists' existing times to be the same by the cycleway as their current route, the introduction of the cycleway is forecast to capture 66% of cyclists. Even if the cycleway is somewhat longer than the current route, it manages to retain a reasonable share. However, even relatively small charges to use the cycleway have a large impact on forecast use such that only a very small proportion would choose the cycleway if it was only a few minutes longer and cost around 50 pence. At current journey times, even a small charge of 25 pence per journey is forecast to have a large impact on demand. The apparently greater sensitivity to cost in this route choice context than in the mode choice context is because the two routes are closer substitutes for each other than are the cycle and the competing modes.

Table 7.6: Cyclists' Route Choices

Scenario	P_{cw}
Cycleway	65.8
Cycleway +5 mins	57.0
Cycleway +10 mins	47.7
Cycleway +15 mins	38.6
Cycleway + 5mins + 25p	31.6
Cycleway + 5mins + 50p	13.8
Cycleway + 5mins + 75p	5.2
Cycleway + 5mins + £1	1.9

The models we have estimated could also be used to examine the effect on mode shares of changes in the costs and service qualities of the other modes, and to evaluate the social benefits of such changes. They could be use in transportation models to forecast, at either a strategic or more detailed level, urban mode choice under a variety of scenarios, with particular emphasis on cycling.

7. CONCLUSIONS

7.1 Summary of Research

As far as we are aware, this is the first study that has jointly estimated mode choice models to NTS data and to purpose collected survey data involving both RP and SP information. It is also the first study in the British context to examine in detail cycling alongside other modes using data based on actual choices.

The mode choice model that has been developed is as extensive as any that have been developed in the British context, and certainly contains far more choice observations than is typically the case where RP data is dominant. Not only can it be used to appraise the demand and social welfare consequences of a range of measures to improve cycling, it can also be used more widely in the examination of urban mode choice involving car, passenger, bus, train, walk and cycling for the journey to work.

The mode choice model contains a number of desirable features in terms of the relative importance of a range of different attributes. The valuations of in-vehicle time, walking time, cycling time and frequency are all highly plausible, as are the valuations of a number of cycling specific attributes. The forecasts obtained from the mode choice model tend to be highly plausible, and indicate that increasing cycle demand appreciably in the British context would be difficult to achieve.

The route choice model demonstrates the importance of improved cycle conditions, even for existing cyclists, and provides evidence on the relative importance of different surface types, route choice behaviour, and the willingness to pay for improved cycling conditions.

Another novel feature of the research, reported in an accompanying paper (Siu et al., 2000), was the development of a choice set model which explains the probability of individuals even considering cycling to work as a function of gender, current mode and topography.

It is hoped that the results presented in this paper can be used in the evaluation of investment schemes and policies which impact on cycling in particular or indeed which have broader mode choice implications.

7.2 Recommendations for Further Research

We have developed what we believe is in the British context the most comprehensive and largest model which handles cycling within mode choice. The model has produced a range of plausible results and demand forecasts. However, a number of areas for further research remain:

- Where improvements have been made to cycle facilities, there is a need to monitor their impact on cycling levels and mode choice in general and to compare the outcome with what models of the form developed here would predict.

- the study has not addressed the impact of topography to the extent that we would have wished. Further research is needed to obtain a better understanding of the impact of hilliness on cycling trip rates and how it interacts with the effectiveness of new cycle facilities in inducing modal switch

- although we have exploited the information provided in the National Travel Survey, which has allowed analysis to a very large data set, the census contains much information which could be used to further enhance commuting mode choice models containing cycle.

- the study has focussed on commuting and should be extended to cover other journey purposes.

- A number of cycle attributes have been covered in this study. However, we have not examined very specific cycling improvements, such as advanced stop lines, toucan crossings, innovative roundabout designs and facilities shared with pedestrians. These issues warrant further quantitative attention.

- In locations where there are cycle facilities, it may be possible to examine cyclists' route choice using the RP approach. This will provide a firmer behavioural basis, provided suitable trade-off situations can be identified, and the development of such an approach should be considered.

- the health implications of the slower modes warrants further attention.

- This study, unlike most mode choice models, has addressed walking as a mode. However, the study was not specifically concerned with walking and further quantitative research in this area, particularly regarding the benefits of improved facilities for pedestrians, would be worthwhile.

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