Article:

Wardman, M.R., Tight, M.R. and Page, M. (2007) Factors influencing the propensity to cycle to work. Transportation Research A, 41 (4). pp. 339-350. ISSN 0965-8564

https://doi.org/10.1016/j.tra.2006.09.011

Published paper
Wardman, M.R.; Tight, M.R.; Page, M (2007) *Factors influencing the propensity to cycle to work.* Transportation Research A 41(4) May 2007, 339-359

FACTORS INFLUENCING THE PROPENSITY TO CYCLE TO WORK

Mark Wardman[a1]

[a]Institute for Transport Studies, University of Leeds, Leeds, LS2 9JT, UK

email: mwardman@its.leeds.ac.uk

Miles Tight[b]

[b]Institute for Transport Studies, University of Leeds, Leeds, LS2 9JT, UK

email: mtight@its.leeds.ac.uk

Matthew Page[c]

[c]Institute for Transport Studies, University of Leeds, Leeds, LS2 9JT, UK

email: mpage@its.leeds.ac.uk

ABSTRACT

This paper describes the development of a mode choice model for the journey to work with special emphasis on the propensity to cycle. The model combines revealed preference (RP) and stated preference (SP) data to form a very large and comprehensive model. RP data from the National Travel Survey was combined with a specially commissioned RP survey. A number of SP surveys were also undertaken to examine the effects of different types of en-route and trip end cycle facilities and financial measures to encourage cycling.

[1] Corresponding Author: Mark Wardman, Institute for Transport Studies, University of Leeds, Leeds, LS2 9JT, UK. email: mwardman@its.leeds.ac.uk. Tel: 44 (0) 113 343 5349. Fax 44 (0) 113 343 5334

The development of the model is described in detail. The model was used to forecast trends in urban commuting shares over time and to predict the impacts of different measures to encourage cycling. Of the en-route cycle facilities, a completely segregated cycleway was forecast to have the greatest impact, but even the unfeasible scenario of universal provision of such facilities would only result in a 55% increase in cycling and a slight reduction in car commuting. Payments for cycling to work were found to be highly effective with a £2 daily payment almost doubling the level of cycling. The most effective policy would combine improvements in en-route facilities, a daily payment to cycle to work and comprehensive trip end facilities and this would also have a significant impact on car commuting.

Keywords: Cycling, Mode Choice, Commuting, Demand, Revealed Preference, Stated Preference.

1. INTRODUCTION AND OBJECTIVES

Cycling is widely recognised as an environmentally friendly and healthy mode of transport. However, cycling has been in long term decline in most developed countries for many years. In Great Britain, cycle traffic declined from 23 to 4.5 billion passenger kilometres between 1952 and 2003, though there is some evidence of a slight increase since the late 1990s (DfT, 2004a). Between 1992 and 2002 the number of trips per person made by bicycle fell by 20% and the average distance travelled by 11% (DfT 2005). The proportion cycling to work in Great Britain fell from 3.8% in 1981 to 3.0% in 1991 and 2.9% in 2001 (ONS, 2003). Internationally, the United States and Canada have even lower levels of cycling, with approximately 1% and 2% of urban trips made by bicycle in these countries respectively. In contrast, much higher levels of cycling are apparent in some parts of Northern Europe, with 28% of urban trips in the Netherlands made by bicycle (Pucher and Dijkstra, 2003), perhaps partly as a result of provision of high quality facilities and recent initiatives to promote policies such as bike and ride (Martens, 2006).

To try to reverse the decline in cycling, the UK Government developed a National Cycling Strategy in 1996 (DoT, 1996) which set a target of quadrupling the number of cycling stages per person from a base of 17 in 1996. The Government’s 10 year plan for transport (DETR, 2000) adjusted that target to a tripling of the 2000 cycling level of 18 stages and the most recent Government document on the future of transport (DfT, 2004b) continues to endorse this target and makes clear the hope that increases would stem from people choosing to cycle rather than drive. Gaffron (2003) has shown that 46% of local authorities in the UK now have a stand alone cycling strategy document and just over half have a Cycling Officer post to promote cycling development.

This increased UK interest in cycling and the wider need to promote non-motorised transport from health, environmental, energy and congestion perspectives is mirrored elsewhere (European Commission, 1999; Pucher and Dijkstra, 2003), but little research has been conducted into understanding the demand for the slower modes of walking and cycling compared to the motorised modes of transport. There are likely to be increasing demands for the rigorous evaluation of proposed schemes in terms of their potential to increase cycling levels and mode share and to quantify the benefits to existing and potential cyclists.

The research reported here developed models which can forecast future trends in commuter cycling and how the propensity to cycle to work can be increased. The commuting market was selected because it represents a significant proportion of trips and ones where congestion is worst, environmental problems most concentrated, data availability greatest, and the salient issues can be addressed by analysis of mode choice without the need to consider the more uncertain and complex issues surrounding the generation of new trips. The research builds upon a number of previous studies and is novel in several respects.

Firstly, joint use is made of Revealed Preference (RP) data based on individuals' actual choices and Stated Preference (SP) data based on choices between hypothetical alternatives.

Previous studies with an emphasis on cycling have not exploited the complementary nature of these two forms of data. Aggregate RP cycling models estimated to mode share data are not uncommon (Ashley and Banister, 1989; Crespo Diu, 2000; Parkin, 2004; Rietveld and Daniel, 2004; Waldman, 1977) but are not well suited to the analysis of cycling attributes in detail. At a disaggregate choice level, the vast majority of the very many urban mode choice studies do not extend the choice set to include cycling. Specific RP studies of cycling (Noland and Kunreuther, 1995) are limited to examining those facilities that currently exist whilst the concern with the few SP mode choice studies (Ortúzar et al., 2000; Wardman et al., 1997) is that the scale of the model may be inappropriate for forecasting (Wardman, 1991) and response bias, particularly of a strategic nature, might have influenced the results. Although there have been studies of improved cycle conditions using route choice (Bovy and Bradley, 1985; Hopkinson and Wardman, 1996), these are limited to the preferences of current cyclists and cannot address the key policy issues of concern here.

Secondly, many policy sensitive cycle facilities, attributes and incentives that could be used to influence cycle use are here simultaneously examined. Quantitative studies tend not to cover such a wide range of issues. Finally, a large number of important external factors are examined; such as income levels, socio-demographic features and time trends, and these are critical to an understanding of the spatial and, more importantly, temporal variations in cycle mode share.

The models reported here can be used to forecast commuters' choices between car, getting a lift, bus, train, walk and cycle, but with a distinct emphasis on cycling. Section 2 describes the mode choice data sources. Section 3 presents the estimated mode choice model and section 4 applies the model to illustrate likely levels of cycle use and the impacts on other modes across a wide range of scenarios. Concluding remarks are provided in section 5.

2. DATA SOURCES AND COLLECTION

The analysis has been based on four large and complementary data sets. They cover trips to work made at least twice a week and, given the interest in competition between cycling and other modes, only journeys of 7½ miles (12km) or less were considered to be of interest.

The National Travel Survey (NTS) provides the largest amount of choice data used here and a firm basis in actual behaviour. It contains details on individuals' travel patterns recorded in a 7 day travel diary and was available for the years 1985/6, 1988 through to 1993 and 1995 through to 1997. This covers 23926 commuting records spread fairly evenly across years and representing car driver, car passenger, bus, train, walk and cycle. NTS data contains information which supports analysis of a wide range of socio-economic, location and demographic characteristics of individuals and their households, with a key attraction being its ability to examine temporal effects. It provides a representative picture of travel and indeed 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". Its main weaknesses are that details of the costs and service quality of modes other than the chosen are not collected, whereupon we must 'engineer' them, and it contains no detailed information relevant to cycling. We opted for primary data collection to explicitly address the limitations of NTS data.

Purpose collected RP data covered individuals' choices for the commuting journey amongst car driver, car passenger, bus, walk and cycle. In addition to the traditional time and cost attributes, we also asked for details about a number of aspects of cycling. Cycle travel time was broken down into whether it was on a completely segregated off-road cycleway, a segregated on-road cycle lane, a non-segregated on-road cycle lane, major roads with no facilities or minor roads. In addition, respondents were asked to indicate whether parking and changing room facilities were provided at work and how they rated the journey to work by cycle, on a 100 point scale, in terms of hilliness, air pollution, noise, danger from traffic, personal security, tiredness and their cycling ability. This exercise added 969 observations to our data set.

The main purpose of the SP exercises was to examine specific cycling features that either do not currently exist or whose effect is relatively minor and could not be expected to be discerned in an RP model. A computer assisted mode choice experiment offered car users, car passengers, bus users and those who walked to work comparisons of their current mode and cycling. One version (SP1) described cycling in terms of the same five categories of cycle time listed above, with a maximum of three categories presented to any one individual. The other version (SP2) characterised cycling in terms of the provision of outdoor parking, indoor parking and shower facilities at work, a financial 'reward' for commuting by cycle, and either the proportion of colleagues or of the general population cycling to work. SP1 added 2115 choices and SP2 3106 choices.

The surveys were conducted in Autumn 1998 in Leicester, Norwich, York and Hull. It is important when dealing with a minor mode such as cycling to recognise that many commuters would never contemplate switching to cycle no matter how much facilities were improved. A model is hardly needed to predict the behaviour of such individuals and their actual choices or SP responses would provide little information for modelling purposes. These people, who typically represent around 60% of commuters, were screened out. A study by Gatersleben and Appleton (2006) showed roughly 61% of a sample of workers at the University of Surrey in the UK, who lived within 5 miles of their workplace, to be either ‘precontemplators’ (had never used or considered using a bike to get to work) or ‘contemplators’ (had never used, but had sometimes thought about using a bike).

3. MODE CHOICE MODEL

A hierarchical logit model was developed to simultaneously estimate parameters to the two forms of RP mode choice data and the data from the two SP mode choice exercises within a single model whilst allowing for the scale of the parameters to differ between the different data sets (Bradley and Daly, 1991). The parameters are estimated in units of residual variation of the upper nest and hence the data set expected to have the most appropriate residual variation for forecasting should be placed in the upper nest.

Information on the socio-economic and demographic variables was available for all choice observations. The times and costs involved in using each mode were available for all data sets except those for NTS which relate only to the chosen mode. We therefore engineered the times and costs for alternative modes on the basis of the evidence supplied for each of the chosen modes which was converted into cost per mile and speed to enable individual specific values to be calculated according to the distance travelled to work.

Data on time trends, whether a company car was available and whether a car was used during the course of the job were specific to the NTS data. Ratings of the actual commuting journey by cycle in terms of hilliness, air pollution, noise, danger from traffic, personal security, tiredness and their cycling ability were specific to the purpose collected RP data.

The cycle time variables which distinguish by type of route were obtained to explain the choice behaviour in the purpose collected RP data and were a feature of SP1 whilst the facility variables were obtained from the purpose collected RP data and SP2. The information on the financial incentives for cycling and the proportion cycling to work is specific to SP2.

We expect one of the RP data sets to provide the most suitable scale for forecasting purposes. It turned out that the scale of the NTS and purpose collected RP data was almost the same (θ_{rp}=1.05) when the RP data was entered into the lower nest and hence no distinction needs to be 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 scale parameters θ associated with SP1 and SP2 were 0.33 and

0.26. These indicate that the residual variation in the SP data is between three and four times larger than in the RP data.

The mode choice model estimated to the combined data of 30116 choices for commuting journeys of less than 7½ miles is reported in Table 1. The ρ^2 goodness of fit of 0.28, specified with respect to constants only, 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. Although distance to work does influence mode choice, there is also an element of circularity since the mode chosen can influence the journey length. Given this, and that the range of distance is small, it was not included as an explanatory factor.

TABLE 1 ANYWHERE AFTER HERE

Quite apart from the use of hierarchical logit for joint estimation across data sets, there is also the issue of using it to overcome the independence of irrelevant alternatives property of multinomial logit. This is not relevant in the SP nests, which relate to binary choices, but it is an issue with the RP data.

We examined various hierarchical structures but could find no convincing evidence to depart from the multinomial specification. Whilst the approximations involved in creating the time and cost values in the NTS data might have militated against being able to detect a hierarchical structure, this result emerged even when we examined the purpose collected RP data on its own.

There was a concern that the use of engineered time and cost data rather than each individuals' perceived times and costs would lead to deficiencies in a model estimated to NTS data. We therefore distinguished the time and cost parameters between the NTS data and the purpose collected RP data. The time coefficients obtained from the NTS and the RP data were remarkably similar, but the cost coefficient estimated to NTS data was the wrong sign yet significant. This may be because journey times can be estimated more accurately than costs because 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. Our solution was to constrain the cost coefficient relating to NTS data to be the same as that in the RP data which is based on perceptions. This constraint had a negligible impact on the other coefficient estimates.

Different constants have been estimated for n-1 of the n modes for each data set. Although the NTS data set is representative of mode choice, the RP sample contains too many cyclists and constants in SP models must be treated with caution since they can discern effects such as response bias or the effect on choices of attributes not contained in the exercise.

The omitted category against which the constants are interpreted is cycle. As might be expected, there is generally a preference, other things equal, for most of the modes over cycling. The SP2 constants indicate a strong preference over cycle, in part due to the absence of cycle time in the SP2 cycle alternative since it was not varied in this SP experiment. Modifications to these modal preferences occur as a result of the socio-economic characteristics of the individual.

The estimated value of travel time (*Time*) for urban commuters in quarter 1 1999 prices was 6.5 pence per minute. This seems plausible and is in line with other studies. A meta-model based on a large amount of British empirical evidence (Wardman, 2004) would, for a five mile journey, predict a value of car time for car users of 5.0 pence per minute, a value of bus time for bus users of 3.4 pence per minute and a value of rail time for rail users of 6.4 pence per minute.

Walking time to access or egress a main mode (*Walk*) is valued 1.9 times more highly than travel time. This is consistent with the conventional wisdom of double weighting walk time and with the findings of the large scale review reported by Wardman (2004). 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. This would be consistent with the non-linearity apparent in the Wardman (2004) meta-model, where the elasticity of the value of walk time with respect to the level of walk time was 0.27, and is in line with the sharp drop off in walking trips with distance. Headway is valued at 69% of travel time which is little different to the value of around 60% for a 5 mile journey that would be predicted in the meta-model reported by Wardman (2004).

Time spent cycling (*Time-Y*) is valued almost three times more highly than travel time for the other modes (*Time*). The former can generally be taken to represent cycling where there are few facilities which can be expected to incur higher disutility than time spent in a car or bus because of the greater effort involved and the more hazardous and unattractive travelling conditions. However, it would also be expected that the value of time spent cycling would vary according to the facilities offered. Rather than simply estimating an overall benefit for, say, a segregated cycle facility, it must be recognised that the benefit obtained can be expected to depend upon the amount of time spent using it. This is entirely analogous to the value of time varying according to the cycle facilities.

Cycle time spent on major roads with no cycle facilities (*Time-YD*) was, surprisingly, valued essentially the same as time spent on minor roads with no cycle facilities (*Time-YE*). These are not greatly different from the RP based valuation (*Time-Y*) which largely relates to these conditions. However, the provision of non-segregated on-road cycle lanes (*Time-YC*) reduces the value of cycle time to 37% of that spent on roads with no facilities. As expected, the value of cycling time is further reduced when the facilities are further improved. Time spent on a segregated on-road cycle lane (*Time-YB*) is valued at only 17% of the time spent on roads with no facilities whilst it is only 14% when the time is spent on a completely segregated cycleway (*Time-YA*). On a twenty minute journey on roads with no facilities, the introduction of a segregated cycleway for the entire route would have the same benefit as a reduction in journey time to about three minutes.

These benefits of cycle facilities are appreciable and in line with other evidence suggesting that a principal deterrent to cycling is the perceived level of danger involved (Hopkinson and Wardman, 1996; Davies et al, 1997; Wardman et al., 1997; Guthrie et al, 2001). However, we feel that *Time-YA* and *Time-YB* are too low. It is not plausible that cycle time even in such improved conditions is valued so much less than vehicular travel time (*Time*), and there may well have been an element of strategic bias at work here. We can note, however, that *Time-YD* and *Time-YE* are about 0.02, in absolute terms, lower than the RP based value *Time-Y*. If we used this difference to adjust the SP based coefficients for *Time-YE*, *Time-YD*, *Time-YC*, *Time-YB* and *Time-YA*, they would become -0.115, -0.116, -0.055, -0.036 and -0.033. Not only would we then have consistency between the RP and SP values when there are no facilities but cycle time when there are excellent facilities (*Time-YB* and *Time-YA*) is now valued around the same as travel time on other modes (*Time*) and are now a much more reasonable 31% and 28% of the value without facilities. Interpretation of these values of cycle time must also bear in mind that they are driven by the responses of commuters who would at least be prepared to consider cycling. They could be expected to be higher if those who would never consider cycling had been included.

A number of cycling specific factors were examined through their effects on actual choices. These were hilliness, air pollution, noise, danger from traffic, personal security, tiredness and cycling ability. Three variables, representing danger, tiredness and ability to cycle, were retained, two of which were statistically significant and the other not far removed. Given that a rating of 100 represents the worst possible level, these had the correct negative sign. Surprisingly, the danger coefficient has the smallest effect of the three. A 50 point change in the rating of the largest effect, relating to tiredness, is equivalent to 5.6 minutes of cycle time. Thus tiredness and, as expected, cycling ability will act as quite significant barriers to cycling. The failure to discern a significant effect from hilliness, which is expected to be a key determinant, may be because the surveys were conducted in relatively flat locations.

We now turn to the benefits of providing facilities for cycling at the destination. Outdoor cycle parking facilities (*O-Park*) were equivalent in value to 2.5 minutes of *Time-Y*. As expected, due to the improved security offered, indoor cycle parking facilities (*I-Park*) were valued more highly at 4.3 minutes. Shower/changing facilities and indoor cycle parking together (*ShI-Park*) were valued at 6.0 minutes. Workplace facility improvements have more than trivial valuations, as in previous research (Wardman et al., 1997), and can be expected to provide a useful addition to the benefits of improved on-road facilities in any attempts at persuading more commuters to cycle to work.

It is widely felt that commuters are more likely to cycle where cycling levels are high, other things equal. Such a virtuous circle might be related to cultural factors, and explain why cycling levels in some areas of Northern Europe are particularly high. There are also issues relating to image (Ortúzar et al. 2000) whilst car drivers tend to be more aware of and considerate to cyclists when there are larger numbers of them. The best way to address this effect would be within the RP model, with a combination of data relating to the actual shares cycling to work and respondents' attitudes to image, peer pressure, car driver awareness and their perceived link to the attractiveness of cycling. However, the four survey locations did not differ greatly in terms of the proportions cycling. It was therefore decided to tackle the issue within the SP exercise.

This analysis of the effect of the proportion cycling to work is clearly speculative. However, a significant and correct sign effect was obtained with respect to the proportion of the general population who cycled (*PropGen*). It is not surprising that this has a larger impact than the proportion of colleagues cycling (*PropCol*) since it would imply a stronger cycling culture. It was found that a 10 percentage point increase in the proportion of the population cycling to work would have the same effect on demand as a one minute cycle time reduction.

Commuters were very sensitive to financial rewards for cycling to work. Economists tend to regard monetary costs of different types to have the same disutility, yet it was found here that money in the form of being paid to cycle (*Incentive*) is valued around twice as highly as an equivalent monetary outlay. Whilst there may be an element of strategic bias at work here, it may also be the case that respondents do genuinely respond to gains and losses differently.

A range of socio-economic variables were found to have a statistically significant influence on mode choice. These operate to modify the modal preference. However, we could not obtain statistically significant and theoretically consistent interactions from age, gender or socio-economic group on the coefficients relating to the cycling specific variables, and an expected effect from income level on the sensitivity to cost variations was weak.

There was no strong time trend relating to cycling, although from a cross-sectional perspective those on higher incomes (*Inc*) were more likely to cycle as well as use train or be a car passenger. A positive underlying trend was apparent for train but, as expected, there has been trend decline in bus use. Given that cycle does not generally compete with train, the absence of any trend specific to cycle means 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.

As expected, males were found to be more likely to cycle than females, as well as being more likely to walk and to be a train user and less likely to be a car passenger. The three age groups entered were 30-39 (*Age1*), 40-49 (*Age2*) and 50 and over (*Age 3*). The probability of cycling to work falls as age increases, which is to be expected, although an even stronger effect is apparent for walking. There were no direct effects on cycling from the socio-economic groups of skilled workers (*Skill*), semi and unskilled workers (*Semi*), and clerical workers (*Cler*) relative to the professional and managerial category. However, there will be indirect effects insofar as some of these impact on the probability of using the other modes. Finally, those with a company car (*CompCar*) and those who used a car in the course of their work (*Used*) would be much more likely to commute by car.

4. FORECASTING APPLICATIONS

Table 2 indicates the 1997 commuter market shares in the NTS data. Amongst those who commute 7½ miles or less, 62% have a car available for their journey to work. The vast majority of these use it and the cycle share is very minor. As would be expected, cycle picks up a much larger share of those who do not have a car available, although its share of the non car market is similar. To serve as a contrast, the figures for commuting over 7½ miles are given and cycle has a negligible share, justifying the emphasis here on cycle competing with other modes for shorter distance commuting. Across all commuting trips, the share of cycle in 1997 was 4%.

TABLE 2 HERE

Forecasts of trends in cycling and the impacts of improvements in the attractiveness of cycling for the journey to work are here obtained incrementally from the base market share positions for car driver (c), passenger (p), bus (b), train (t), walk (w) and cycle (y) indicated in the NTS data for 1997 and for journeys of 7½ miles or less. The incremental form of the logit model is:

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

The forecast market share for cycle (P_y^f) depends on the base (b) market shares and the changes in utility (ΔU) for each mode.

Table 3 reports forecasts of the underlying trends in the market share of each mode. Income is assumed to grow at 2½% per annum, although the forecasts are not particularly sensitive to the assumed income growth, and, in line with trends in our NTS data, car availability is assumed to grow at 1 percentage point per annum.

Over the forecast period, the proportion cycling to work falls from 5.8% to 2.4%, largely as a result of increasing car availability which drives the significant increase in the proportion using car. The negative time trend for bus but positive trend for train underpin the demand changes on these modes. There is also a large reduction in the number forecast to walk to work, quite independent here of any further dispersal of the pattern of residential and employment locations. Across all journeys to work, and assuming the same very minor cycle share over 7½ miles as now, then only 1.5% of commuting trips would be by cycle in 2027. If the car availability growth is halved, the proportion of commuting journeys less than 7½ miles made by cycle is forecast to be 3.9% by 2027 and the car share increases to 62.2%. Even under this more 'optimistic' scenario, the prospects for cycling in the absence of any specific measures are bleak, and there would be a significant increase in the number of cars on the road in the most congested period.

TABLE 3 HERE

Table 4 sets out forecasts for a range of improvements for cycling to work. Time can be spent in any one of the following conditions:

- Completely segregated off-road cycleway (A)
- Segregated on-road cycle lane (B)

- Non-segregated on-road cycle lane (C)
- Major roads with no cycle facilities (D)
- Minor roads with no cycle facilities (E)

The survey results indicate that in the current situation the average cycle time to work would be 15 minutes, and on average the proportion of time spent in each type of 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 facilities and 18% for time spent on minor roads with no facilities.

The forecasts here, and in the subsequent examples below, are reliant on the SP parameters, in contrast to the NTS based parameters for the forecasts in Table 3. Whilst all parameters are returned in RP units, whereupon we are effectively using a rescaled SP model to forecast, the SP questions were only asked of those who would consider cycling if conditions improved. Thus the 60% who would not consider cycling are assigned a zero probability of changing behaviour. As a contrast, however, Table 4 also gives the figures without this adjustment in brackets.

TABLE 4 HERE

The first scenario 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 is a sizeable forecast increase in the proportion cycling to work (14%) the impact on the other modes is minor. This remains so when cycle time is converted to be entirely on a completely segregated cycleway as in scenario 3 where there is 21% growth in the proportion cycling. Even in the most favourable possible case, represented by the final scenario, where all time would be spent on a completely segregated cycleway, only 9.0% of commuters are forecast to cycle to work, an increase of 55% over the base situation, and car demand is only 3% less than the base case.

The forecasts seem reasonable. When no allowance is made for those who would not consider cycling to work, the cycle market shares are clearly somewhat higher, although the impact on the other modes remains relatively minor. The failure to allow for such 'non traders', whose behaviour seems entirely reasonable to us, may lie behind the more optimistic forecasts in Wardman et al. (1997) when cycle facilities are improved. In general, the issue of non-response bias, whereby those who have no interest in the alternative behaviour being covered by an SP exercise do not participate but who are effectively treated the same as those who are more predisposed to it, could be the reason why the forecasts for new and improved public transport and 'slow' modes can appear to be on the optimistic side and tend not to materialise in practice.

Table 5 considers the impact of rewarding commuters for cycling to work. In contrast to the impact of improved cycle lanes, payment for cycling to work does appear to have a large impact on the demand for cycling. A payment of £2 per day is not far from achieving a doubling of the amount of cycling and has a larger impact than the ideal but unachievable scenario of cycling to work being spent entirely on completely segregated cycleways. It would yield a 5.4% reduction in car demand, increasing to a very appreciable 23.6% for a £5 daily payment. A number of studies have clearly shown the low perceived status of cycling in some locations, no better exemplified by Ortúzar et al. (2000) who talk of public ridicule of cyclists on network television stations in Chile. It is possible that the provision of monetary incentives, however undertaken, could go a long way towards rectifying such negative status by providing a degree of economic value to the activity.

TABLE 5 HERE

The forecast effects of providing facilities at work are illustrated in Table 6. The survey indicated that 26% of employees had access to shower facilities, 35% had secure parking and 17% had both. The forecasts relate to the provision of these facilities for all employees. It can be seen that worthwhile improvements in cycle market share result from the provision of facilities at work, particularly the provision of showers and indoor parking, but that the impact on other modes is limited.

TABLE 6 HERE

Finally, Table 7 considers the impact of adopting a package of measures to increase cycling and to reduce dependency on car travel. The forecasting exercises reported above have illustrated that on their own improved cycle conditions have only limited impact and that, although financial incentives can have a significant effect, the sorts of levels that might be countenanced would only have a modest effect. Nonetheless, a £2 incentive is not unrealistic in the context of the hidden subsidy to car drivers of subsidised/free parking at work.

TABLE 7 HERE

These figures demonstrate that it is feasible to develop policies based around a package of measures which will have a significant bearing both on the amount of cycling and car dependency for commuting trips. Ambitious government targets could be achieved by converting half of the time spent on routes with no facilities to those with facilities, providing good facilities at work and offering a £2 daily financial incentive, whereupon cycle share is forecast to increase around three-fold and car commuting for trips less than 7½ miles would fall by around 13%. Even larger increases in cycle share and reduction in car use could be achieved with more generous monetary incentives and providing for a larger proportion of cycling trips on safe routes. To these measures could be added specific improvements at junctions, land use planning leading to more localisation, road pricing, stricter enforcement of driver behaviour and the virtuous circle of more people cycling. However, these forecasts relate to locations whose topography is favourable to cycling. The extent to which hilliness interacts with the valuations of improvements to cycling and therefore provides an additional barrier to increased use is not known.

5. CONCLUSIONS

This study has developed what we believe to be the most comprehensive and largest model which handles cycling within mode choice, at least within the British context. The model can be used to forecast, at either a strategic or more detailed level, urban mode choice under a variety of scenarios, with particular emphasis on cycling which is a neglected area of research but which is expected to become increasingly important because of the recognition of its potential in terms of health promotion and reducing negative transport externalities such as noise, pollution and congestion. The model is novel in its use of both RP and SP data to understand likely cycle commuting and in having both a temporal and spatial dimension. It also covers the very much under-researched issue of walking as a mode of travel in its own right rather than simply a means of accessing other modes.

The model has produced a range of plausible results and demand forecasts. These indicate that the future for cycle commuting in the absence of measures to make it more attractive is bleak, largely as a result of increases in car availability. However, the model also demonstrates that improved en-route and at work cycle facilities have only a minor impact on cycle and car use, offsetting the changes that would occur in only a few years.

There have been schemes which provide a financial incentive to cycling but indirectly through reducing the costs of purchasing a cycle and associated hardware for employees who will use it predominantly for commuting (Booost UK, 2005). We have here considered a more direct stimulus to cycling through a daily payment to those who commute by cycle, and this has been found to offer considerable potential to significantly impact mode share.

When a package of measures is considered, including modest financial incentives, cycle facilities for around half the journey to work and good parking and shower facilities at work, cycle emerges as a much more significant mode and has an appreciable impact on car share. As such, cycling could play its part alongside other policies aimed at improving public transport in reducing the environmental, energy, social and congestion concerns surrounding high and increasing levels of car use, whilst also delivering important health benefits. It should be recognised that those who may be willing to contemplate cycling are not necessarily a homogenous group (Gatersleben and Appleton, 2006) and hence packages of measures containing a range of stimuli to promote cycling is likely to be the most profitable approach to increase levels of cycling.

Although the study has covered a wide range of cycle related issues, a number of important avenues of research remain. The study has not established whether adverse topography has an added disincentive to increasing cycle use through interactions which significantly negate the benefits of new facilities. There also remains the possibility that some would not switch to cycling unless it were entirely safe, implying a threshold effect at the point at which the entire journey can be made away from the danger of motorised traffic, and this warrants attention.

There remains a scepticism in some quarters that improvements to cycling can deliver what is promised by its advocates and by studies such as this. Whilst we have taken measures to avoid the forecasts of increased cycle use being too optimistic, there remains a need to monitor the impact of significant improvements in facilities on cycle demand and to assess this against predicted increases. The study has focussed on commuting and should be extended to cover other journey purposes and leisure activities.

6. ACKNOWLEDGEMENTS

The authors would like to thank the Economic and Social Research Council who sponsored the research (grant R000237103) and the numerous cyclists and non-cyclists who agreed to take part.

7. REFERENCES

Ashley, C.A. and Banister, C. (1989) Cycling to Work from Wards in a Metropolitan Area. 3 Testing the Model. Traffic Engineering and Control 30 (9), September.

Booost UK (2005) Provide your employees with a bike for 50% less than retail prices. Accessed through www.booost.uk.com, February 2005.

Bradley, M.A. and Daly, A.J. (1991) Estimation of Logit Choice Models Using Mixed Stated Preference and Revealed Preference Information. Proceedings of 6th International Conference on Travel Behaviour. Quebec, Vol 1, pp.117-133.

Bovy, P.H.L. and Bradley, M.A. (1985) Route Choice Analysed with Stated Preference Approaches. Transportation Research Record 1037, pp.11-20.

Crespo Diu, F. (2000) Cycling to Work in Great Britain: A Quantitative Analysis. MA Dissertation, Institute for Transport Studies, University of Leeds.

Davies D. G., Halliday M. E., Mayes M. and Pocock R. L. (1997) Attitudes to Cycling: a qualitative study and conceptual framework. TRL report 266, Transport Research Laboratory, Crowthorne.

Department for Transport (2004a) Transport Statistics Great Britain 2004 Edition, London: TSO

Department for Transport (2004b) *The Future of Transport a Network for 2030* Cm6234. http://www.dft.gov.uk/stellent/groups/dft_about/documents/divisionhomepage/031259.hcsp.

Department for Transport (2005) Focus on Personal Travel 2005 Edition, London: TSO

Department of the Environment, Transport and the Regions (2000) *Transport 2010 the 10 Year Plan*. http://www.dft.gov.uk/trans2010/

Department of Transport (1996) The National Cycling Strategy. HMSO, London.

European Commission (1999) Cycling: the way ahead for towns and cities. European Commission DG XI – Environment, Nuclear Safety and Civil Protection, Brussels

Freeth, S., Barton, J., Noble, B., Sullivan, C. and Williams, D. (1999) National Travel Survey: Technical Report 1997. Office for National Statistics, London.

Gabersleben, B. and Appleton, K.M. (2006) Contemplating cycling to work; attitudes and perceptions in different stages of change. Accepted for publication in Transportation Research Part A.

Gaffron, P. (2003) The implementation of walking and cycling policies in British local authorities. Transport Policy 10, pp235-244.

Guthrie, N., Davies, D.G. and Hardner, G. (2001) Cyclists' assessments of road and traffic conditions: the development of a cyclability index. TRL Report 490, Transport Research Laboratory, Crowthorne, Berkshire.

Hopkinson, P. and Wardman, M. (1996) Evaluating the Demand for New Cycle Facilities. Transport Policy 3 (4), pp. 241-249.

Martens, K. (2006) Promoting bike-and-ride: the Dutch experience. Accepted for publication in Transportation Research A.

Noland, R.B. and Kunreuther, H. (1995) Short-run and long-run policies for increasing bicycle transportation for daily commuter trips. Transport Policy, Vol 2(1), pp 67-79.

Ortúzar, J de D., Iacobelli, A. and Valeze, C. (2000) Estimating demand for a cycle-way network. Transportation Research A, 34, pp353-373.

Parkin, J. (2004) Determination and Measurement of Factors which Influence Propensity to Cycle to Work. PhD Thesis, Institute for Transport Studies, University of Leeds.

Pucher J and Dijkstra L (2003) Promoting Safe Walking and Cycling to Improve Public Health: Lessons from the Netherlands and Germany, American Journal of Public Health, vol 93, no 9.

Rietveld, P. and Daniel, V. (2004) Determinants of bicycle use: do municipal policies matter? Transportation Research A, 38, pp531-550.

Waldman, J.A (1977) Cycling in Towns: A Quantitative Investigation. LTR 1 Working Paper 3, Department of Transport, London.

Wardman, M (1991). Stated Preference Methods and Travel Demand Forecasting: An Examination of the Scale Factor Problem. Transportation Research, 25A, pp.79-89.

Wardman, M. (2004) Public Transport Values of Time. Transport Policy 11, pp.363-377.

Wardman, M., Hatfield, R. and Page, M. (1997) The UK National Cycling Strategy: Can Improved Facilities Meet the Targets? Transport Policy 4 (2), pp. 123-133.

Table 1: Joint RP-SP Multinomial Logit Mode Choice Model

Variable	Coeff (t)	Variable	Coeff (t)	Variable	Coeff (t)
Car-NTS	3.045 (31.4)	O-Park	0.291 (3.9)	Age3-Pass	-0.334 (3.7)
Pass-NTS	-0.218 (2.1)	I-Park	0.499 (4.9)	Age1-Bus	-0.601 (8.2)
Bus-NTS	1.763 (13.6)	ShI-Park	0.699 (5.2)	Age2-Bus	-0.569 (6.6)
Train-NTS	0.601 (3.2)	Time-YA	-0.013 (2.0)	Age3-Bus	-0.376 (4.3)
Walk-NTS	3.358 (30.9)	Time-YB	-0.016 (2.4)	Age1-Train	-0.392 (3.7)
Car-RP	0.326 (1.3)	Time-YC	-0.035 (4.0)	Age23-Train	-0.794 (7.8)
Pass-RP	-1.882 (5.9)	Time-YD	-0.096 (5.4)	Age1-Walk	-0.315 (4.2)
Bus-RP	-0.217 (1.4)	Time-YE	-0.095 (4.6)	Age2-Walk	-0.366 (4.1)
Walk-RP	1.313 (6.0)	PropGen	0.013 (3.0)	Age3-Walk	-0.562 (6.1)
Car-SP1	-1.301 (2.5)	PropCol	0.004 (1.3)	Age2-Cycle	-0.217 (2.4)
Pass-SP1	0.941 (1.3)	Incentive	0.013 (4.9)	Age3-Cycle	-0.338 (3.7)
Bus-SP1	-1.736 (2.2)	Danger	-0.004 (1.6)	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)	CompCar	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)

Table 2: NTS 1997 Commuting Mode Shares

	Car	Pass	Bus	Train	Walk	Cycle
Car Available	830	15	17	19	35	14
≤ 7½ miles	89.2%	1.6%	1.8%	2.1%	3.8%	1.5%
No Car Available	0	141	174	46	139	74
≤ 7½ miles	0.0%	24.6%	30.3%	8.0%	24.2%	12.9%
Overall	830	156	191	65	174	88
≤ 7½ miles	55.2%	10.4%	12.7%	4.3%	11.6%	5.8%
Overall	661	59	26	78	0	5
> 7½ miles	79.8%	7.1%	3.1%	9.4%	0.0%	0.6%
Overall for all	1491	215	217	143	174	93
Distance	63.9%	9.2%	9.3%	6.1%	7.5%	4.0%

Table 3: Forecast Trends in Urban Commuting Market Shares

	1997	2002	2007	2012	2017	2022	2027
Car	55.2	59.4	63.2	66.9	70.1	72.7	74.5
Passenger	10.4	9.5	8.5	7.5	6.4	5.2	4.0
Bus	12.7	10.3	8.2	6.3	4.6	3.2	2.1
Train	4.3	5.1	6.1	7.2	8.6	10.3	12.5
Walk	11.6	10.4	9.2	7.9	6.7	5.6	4.5
Cycle	5.8	5.3	4.8	4.2	3.6	3.0	2.4

Table 4: Forecast Impact of Improved Cycling Conditions

	Scenario	Car	Pass	Bus	Train	Walk	Cycle
	Base	55.2	10.4	12.7	4.3	11.6	5.8
1	Half of existing D and E, change to C	54.7 (54.0)	10.3 (10.2)	12.6 (12.4)	4.3 (4.2)	11.5 (11.3)	6.6 (7.9)
2	Half of existing D and E, change to B	54.6 (53.5)	10.3 (10.1)	12.5 (12.3)	4.2 (4.2)	11.5 (11.3)	6.9 (8.6)
3	Half of existing D and E, change to A	54.5 (53.5)	10.3 (10.1)	12.5 (12.3)	4.2 (4.2)	11.5 (11,2)	7.0 (8.7)
4	All of existing D and E, change to C	54.1 (52.3)	10.2 (9.9)	12.4 (12.1)	4.2 (4.1)	11.4 (11.0)	7.7 (10.6)
5	All of existing D and E, change to B	53.6 (51.1)	10.1 (9.6)	12.3 (11.8)	4.2 (4.0)	11.3 (10.8)	8.5 (12.7)
6	All of existing D and E, change to A	53.6 (51.0)	10.1 (9.6)	12.3 (11.7)	4.2 (4.0)	11.2 (10.8)	8.7 (12.9)
7	All existing C, D and E, change to B	53.5 (50.7)	10.1 (9.6)	12.3 (11.7)	4.2 (4.0)	11.2 (10.7)	8.8 (13.3)
8	All change to A	53.3 (50.6)	10.0 (9.5)	12.3 (11.6)	4.2 (3.9)	11.2 (10.6)	9.0 (13.8)

Table 5: Effect of Daily Payments to Cycle to Work

Scenario	Car	Pass	Bus	Train	Walk	Cycle
Base	55.2	10.4	12.7	4.3	11.6	5.8
£0.50 per day payment	54.7	10.3	12.6	4.3	11.5	6.6
£1.00 per day payment	54.1	10.2	12.4	4.2	11.4	7.7
£1.50 per day payment	53.3	10.0	12.3	4.1	11.2	9.1
£2.00 per day payment	52.2	9.8	12.0	4.1	11.0	10.9
£3.00 per day payment	49.5	9.3	11.4	3.9	10.4	15.5
£4.00 per day payment	46.0	8.2	10.7	3.6	9.7	21.8
£5.00 per day payment	42.2	7.9	9.7	3.3	8.9	28.0

Note: These daily payments are halved at the forecasting stage since the model is estimated in one-way units.

Table 6: Effect of Facilities at Work

Scenario	Car	Pass	Bus	Train	Walk	Cycle
Base	55.2	10.4	12.7	4.3	11.6	5.8
Outdoor parking provided	54.9	10.4	12.6	4.3	11.5	6.3
Indoor parking provided	54.7	10.3	12.6	4.3	11.5	6.6
Showers and indoor parking	54.5	10.3	12.5	4.2	11.4	7.1

Table 7: Forecast Impact of Package of Improved Cycling Conditions

Scenario	Car	Pass	Bus	Train	Walk	Cycle
Base	55.2	10.4	12.7	4.3	11.6	5.8
Half of D and E to C, £1, All facilities	51.7	9.7	11.9	4.0	10.9	11.8
Half of D and E to B, £1, All facilities	51.2	9.7	11.8	4.0	10.8	12.5
Half of D and E to C, £2, All facilities	48.7	9.2	11.2	3.8	10.2	16.9
Half of D and E to B, £2, All facilities	48.1	9.1	11.1	3.8	10.1	17.8
Half of D and E to C, £3, All facilities	45.1	8.5	10.4	3.5	9.5	23.0
Half of D and E to B, £3, All facilities	44.5	8.4	10.2	3.5	9.3	24.1
Half of D and E to C, £5, All facilities	38.3	7.2	8.8	3.0	8.0	34.7
Half of D and E to B, £5, All facilities	37.9	7.1	8.7	3.0	8.0	35.3

Note: Converting to A instead of B only marginally changes matters and hence is not reported.