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Barriers to cycling: an exploration of quantitative analyses

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CHAPTER THREE

Barriers to cycling: an exploration of quantitative analyses

John Parkin, Tim Ryley and Tim Jones

Introduction

After many years when cycling was left in the policy wilderness in the UK, the Conservative Government established a strategy for cycling in 1996 (Department for Transport 1996). An often quoted target of the strategy was to double cycle use by 2002 and double it again by 2012 relative to the 1996 level. In a policy atmosphere increasingly aware of environmental issues, the newly elected Labour Government in 1997 maintained this aspiration but moderated the target in its Ten Year Transport Plan (Department for Transport 2000) to trebling 2000 levels by 2010. The Transport White Paper of 2004 (Department for Transport 2004a) lengthens the timescale for transport planning to 2030 and contains a policy aim simply to increase cycle use, making it more convenient, attractive and realistic for short journeys, especially those to work and school. At the time of writing, therefore, there is no specific national cycling target, although guidance as part of the Local Transport Plan process\(^1\) mandates local authorities to set ‘sharper and more focused’ local targets.

While cycling is increasingly considered important for inclusion in local transport policies, there is little evidence of widespread growth in cycling. This is despite the realisation of some infrastructure measures and promotion initiatives deemed appropriate for increasing cycle use. It is important to understand the relative contributions that different policy instruments might make to increasing cycle use, and

\(^{1}\) Local Transport Plans are the mechanism by which local highway authorities in the UK set out their periodic bids for central government transport funding.
this is the subject of a small but growing body of work within the field of transport studies. It could be argued that, despite cycling policy failing to deliver positive results, cycling remains high on the transport agenda because of its potential contribution to policies on climate change, social inclusion, health, exercise, obesity and sustainable development. Close scrutiny of cycling-related data may reveal reasons for the gap between potential and delivery, and indicate the appropriate direction in which policy measures ought to be taken in order to become more effective.

This chapter examines a range of quantitative analyses of cycling behaviours, and within a UK policy setting, explores some implications of those analyses. It reviews quantitative evidence, and discusses the relative contributions made by different factors to cycling levels; these include social and demographic factors such as class and age, physical factors such as climate and hilliness, and highway design factors. The chapter begins by describing the different quantitative approaches open to cycle planners and analysts, particularly differentiating between data derived from monitoring studies and outcomes from the analysis of relationships between cycle use and influencing factors. It goes on to describe and evaluate findings from a range of recent quantitative analyses. Finally, it recommends developments to enhance the contribution of quantitative methods to our understanding of the important issues affecting cycle use, and comments on the implications of the findings for the promotion of cycling.

**Quantitative methods in cycle planning**

This section is divided into three parts. First, we briefly discuss UK cycling data derived from monitoring studies. Second, by way of preparation for the main part of the chapter, we discuss at a relatively general level the quantitative techniques which are
available for analysis of the relationships between (actual and hypothetical) cycle use and a wide range of factors which potentially influence cycle use. Third, we outline potentially useful future developments in quantitative research into cycling.

*Monitoring cycling levels*

Estimates of historic travel patterns are produced from either counts taken on the highway or surveys of trip making undertaken at the level of the household. For UK road transport there are two main statistics at a national level: the National Road Traffic Estimates (NRTE), measured in vehicle kilometres by class of vehicle and estimated from highway counts; and the National Travel Survey (NTS), showing person kilometres by type of vehicle, derived from household surveys.

Using 1996 as a base year, the National Road Traffic Estimates show an increase in cycle traffic of 10.7% to a level of 4.5 billion cycle kilometres in 2003. Over the same period, The National Travel Survey shows a decline of 10.5% to 34 miles per person per year in average distance cycled, and a decline in the average number of bicycle trips made of 22.2% to 14 trips per person per year. Differences in trends and year-to-year volatility in estimates from the National Travel Survey, the National Road Traffic Estimates and other independently produced estimates (for example those of Sustrans (Cope et al. 2005), which also cover routes that do not form part of the public highway and which are not covered by either the NRTE or NTS) are partly due to the relatively low volume of cycle traffic. This leads to wide confidence intervals.\(^2\) Such differences are also due to the effects of the sampling methodology (Department for

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\(^2\) A confidence interval is a range over which an estimate may vary, defined by a probability of lying within that interval, for example we may be 95% certain that an estimate lies in the confidence interval.
The structure of both main data sets is aggregated to a national level, and neither data set is valid at a more geographically disaggregate level. The use of appropriate statistical techniques to analyse the data as a time series (for example, Parkin 2001; Cope et al. 2005) has a part to play in monitoring, and more development in this field of inquiry is required.

A further source of national data on cycling is the census. This provides a comprehensive picture of mode choice, but only for the journey to work, and only at a single point in time, early spring every ten years. It should also be noted that the use of the bicycle for access journeys, for example to railway stations, is not reflected in census data as only the mode of transport used for the longest leg of a multi-leg journey is recorded. This results in under-reporting of actual cycle use. Table 1 shows the overall percentage of journeys by bicycle for the journey to work.

Table 1 Percentage of journeys to work by bicycle 1981, 1991 and 2001

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<tr>
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<tbody>
<tr>
<td>England</td>
<td>4.11%</td>
<td>3.21%</td>
<td>3.11%</td>
</tr>
<tr>
<td>Wales</td>
<td>1.59%</td>
<td>1.41%</td>
<td>1.53%</td>
</tr>
<tr>
<td>Scotland</td>
<td>1.44%</td>
<td>1.36%</td>
<td>1.53%</td>
</tr>
<tr>
<td>Great Britain</td>
<td>3.76%</td>
<td>2.97%</td>
<td>2.89%</td>
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</table>

Note: All figures calculated by removing those who work or study mainly from home. Source: ONS (undated).

The decline in cycle use evident in the decade to 1991 has not been replicated to the same extent in the subsequent decade, suggesting that use of the bicycle for journeys to work may have reached its nadir. A full discussion of variation in cycling levels by region and district is provided by Parkin (2003); at a purely descriptive level, Parkin's study demonstrates the link between cycle use and topographical and climatic factors, with higher cycle use across the flatter, drier east of England and the warmer south of
England. The importance of topography and climate to levels of cycling will be explored in more detail below.

*Understanding why people do (not) cycle*

The derivation of relationships between an observable choice to cycle and the factors that influence that choice is a complex process. The starting point is the appropriate measurement of relevant influencing factors. Transport planning usually affords primacy to estimates of cost and time, but there is another area of difficulty in the modelling of cycling because a further significant resource that is consumed is effort expended by the cyclist, and this needs careful consideration. Other less tangible factors, such as self image, perceived ability and social norms also play a part.

Manufacturers of cars and public transport vehicles go to great lengths to create an appropriate indoor environment for travellers, and the nature of the vehicle is an important further consideration in transport demand modelling because the perceived quality of the in-vehicle environment on a journey will affect choices amongst modes. Similarly, the comfort, aesthetics, luggage handling and gearing of the bicycle are all important. In addition, the environment through which a cycle travels is the cycling equivalent of in-vehicle space, and so the characteristics of that cycling environment are equally significant. Important factors here are likely to be the comfort of the route as determined by surface condition, the general attractiveness of the route and the relative absence or presence of motor traffic, which may influence both perceptions of risk and levels of noise and air pollution.
The genesis of much cycle design guidance that is now adopted in the UK and elsewhere is the Dutch cycling design guidance (CROW 1993a; 1993b), which identifies the following fundamental infrastructure requirements for cycling:

- Coherent/comprehensive: a comprehensive network linked to where cyclists begin and end their journeys;
- Direct: a system of connections which is as direct as possible and avoids detours;
- Attractive: design and integration with surroundings should make it pleasant to cycle;
- Safe: facilities that guarantee safety from other road users and take account of personal security as well as road safety;
- Comfortable: facilities that allow a rapid and comfortable flow of bicycle traffic.

This list provides a valuable aid for designers when developing routes and designing routes in detail. The issues of network coherence, directness and comfort (surface condition) are all in some way related to effort, while the issues of attractiveness and safety are related to the environment surrounding the cyclist. Some cyclists may be content to trade a lack of directness for enhanced safety, whereas others may place a higher value on a direct route with a quicker journey time.

Mathematical models can be used to estimate the relative weights of different influencing factors. Such models may be built using data derived from groups of people, for example using census data for a given geographical area such as a ward or some other defined zone. Such so-called aggregate models group data using averages, proportions or totals. Transport variables relate to the characteristics of the transport system that connects the zones. For cycling, additional transport system variables are required in order to consider the effects of effort expended and the cycling environment.

An alternative approach derives relationships of choice to influencing factors at the 'disaggregate' level of an individual, either revealed through a survey of a person’s recent trip making activity (revealed preference data) or through statements about
hypothetical choices they would make given different system variables (stated preference data), such as time and distance. Disaggregate models of the cycling choices individuals make (so-called discrete choice models) can be developed using revealed and/or stated preference data. Traditionally, revealed preference data was used to model choices, but models based on stated preference data have been increasingly used to aid understanding of decision-making processes.

Discrete choice models that use stated preference data tend to concern either cyclist route choice ('as a cyclist, which route would I take?') or a mode choice that includes cycling ('would I cycle or use an alternative mode of transport?'). Route choice models assist in understanding the relative influences of features of routes, and are useful in developing appropriate infrastructure for cyclists. Mode choice models assist in understanding the relative influences of factors pertaining to the choice of the bicycle, and are useful in developing infrastructure and wider promotional measures to encourage cycle use. The main advantage of stated preference based techniques is that they allow the testing of hypothetical measures, such as the effect of cycling measures not yet implemented. However, this benefit needs to be balanced against the uncertainty as to whether respondents would actually make the decision. It is preferable, therefore, to incorporate both revealed and stated preference data into discrete choice models.

Both disaggregate and aggregate quantitative modelling, therefore, have a complementary contribution to make to our understanding of choice for the bicycle.

_Potential further developments in quantitative methods_

To improve on current understandings as to why people do or do not cycle, two main issues need to be addressed in quantitative research into cycling. First, the range
and type of data collected and analysed needs to be broader than what is deemed adequate for other modes of transport, to include factors relating to effort and environment. Second, the choice mechanisms that ought to be considered in relation to cycling may be more involved, and result from more complex responses involving the broader range of data. These may include personal, social and cultural factors, such as life stage, not often considered in transport modelling.

Given this choice complexity, there is growing interest in understanding transport choice for modes such as the bicycle in other ways. One approach is based on an understanding of decision making that is extended over time. Decision making is not a purely abstract, rational calculation but is related to a range of factors that can be characterised as 'personal attitude', 'the social norm' and 'control factors' (that is, those real and perceived factors that either facilitate or inhibit a person’s ability to perform the behaviour) (Ajzen 1985). This approach has been used in various European studies (for example, Bamberg and Schmidt 1994; Forward 1998) to show the significance of control factors. Other approaches include the adoption of a marketing paradigm called diffusion theory (after Rogers 1983), and a hierarchical model based on progression through a series of choice levels where successful progression to the next choice stage is dependent on a positive outcome at the previous level in the hierarchy (for example, Brög 1982). These different approaches may better account for the particularly strong physical, environmental and cultural factors involved in decisions to (not) cycle than do choice models which simply emphasise time and cost.

Findings from quantitative analyses
Utilising a range of quantitative analyses of cycling, we turn now to detailed exploration of the different factors involved in decisions to cycle, or not to cycle. We begin with an assessment of the role of demographic and personal factors, including the significance of car ownership, journey distance, journey purpose, bicycle ownership, class, age, and concerns for health and the environment. We then move onto consideration of the physical factors of climate and topography. Finally in this section, we explore the influence of factors related to the transport environment, such as prevailing traffic conditions, traffic risk and the qualities of cycling routes. All these factors are clearly of significance in influencing whether or not someone decides to cycle; our aim in this section is to use existing evidence, derived from quantitative research, to assess just how influential each of the factors might be.

*Car ownership and journey distance*

Rising car ownership and use has dramatically changed the nature of urban areas and patterns of travel over the last half century. People today make more trips and travel further than ever before, and this has resulted in changed patterns of land use and the entrenchment of car dependency. So, for example, out-of-town retail and leisure centres develop at locations remote from traditional urban centres, often clustering around nodes on the motorway network. Increasing traffic congestion within urban areas has exacerbated this trend for development in non-urban areas.

Two important features of travel by car are, firstly, the flexibility of both the journey destination and route choice and, secondly, the ability to choose start and end times free of public transport timetabling constraints. The bicycle also exhibits this flexibility and freedom, but only over shorter journey distances.
The 2001 census shows that just 8% of employees in England and Wales live in a household with no car or van available. In the past, it is these households which have been seen as potentially most receptive to cycling. However, in a study of the variation in cycle use for the journey to work at ward level for England and Wales, Parkin (2004) found that employees in households with one car are more likely to cycle than their counterparts in households with no car. It is only at the level of two cars or more that the propensity to cycle is reduced, or 'suppressed' in transport research terminology. The effect is different for London, where ownership of multiple cars in a household is lower than the rest of the country.

It may no longer be assumed, therefore, that greater propensity to cycle is linked with not owning a car. Promotion strategies for cycling should recognise that the greatest potential market for growth in cycling will in fact be drawn from car-owning households. The important point to promote is the greater flexibility of a bicycle compared with a car, particularly in congested urban conditions where car journey time reliability is worse than for a bicycle. Davies et al. (2001) demonstrate that beyond the 15% of the population that is positive towards cycling and already cycles regularly or quite often, the next 20% of the market 'closest' to adopting cycling are likely to own a car, but only between 67% and 80% own a bicycle. Thus there is clear potential to promote cycling among car-owning households and individuals who do not currently own bicycles.

Parkin (2004) analysed the effect of distance to work relative to propensity to use the bicycle. Distances in the census data are banded as 'less than 2 km', '2 km to less than 5 km', '5 km to less than 10 km', and four higher distance bands. Wards with a higher proportion of workers in the travel distance band '2 km to less than 5 km' show a
higher level of cycle journeys to work. Distances of less than 2 km are likely to be less popular for cycling because they are within walking distance. At distances over 5 km the time and effort required to cycle are likely to militate against bicycle use. The experience of the Danish city of Copenhagen shows time savings for journeys up to 5 km, but it is worth noting that distances up to 10 km remain well within the parameters of a half hour journey time, and the city authorities are aiming to increase cycling speeds in order to facilitate these longer journeys (City of Copenhagen 2002).

It is important for cycle planners to recognise that cycle journeys are most likely to take place between a home origin and destination located in an urban centre or at a public transport node, such as a railway station. When routes for cycle traffic are being considered, they should be planned for distances of at least 2 km from these destinations towards residential areas.

*Journey purpose and bicycle ownership*

The 1999/2001 National Travel Survey shows that 42\% of bicycle trips are for work and business, 32\% for leisure and 12\% for shopping. However, there are methodological problems with the collection of NTS data, which may not record home-based bicycle travel that is entirely for recreational purposes: for example, a car journey to access a mountain biking centre would be recorded as a leisure journey by car, but a purely recreational cycle ride from home may not be counted as a home-based cycle journey for recreation. Furthermore, the NTS does not record journeys that take place off the public highway. Thus there is under-reporting of the journeys taking place along newly created traffic-free paths and segregated roadside facilities.
The General Household Survey of 2002 found that cycling is the fourth most popular sport, game and physical activity (19% of adults had participated in the last 12 months, and 9% in the last four weeks). Although cycling was included irrespective of the purpose, there is evidence that many respondents will have participated in this activity for recreational purposes. For example, Cope et al. (2003) report that two thirds of those who access the National Cycle Network do so for recreational purposes, and that around one quarter of all users cite health and/or fitness reasons. Off-road trail riding (more commonly known as ‘mountain biking’) has particularly captured the minds of the British public, and has changed from an obscure hobby to a regular pastime for around 1.5 million Britons, with a further 1.9 million taking part in this activity on a less frequent basis (Mintel 2001).

One factor encouraging participation in recreational cycling is cycle technology and fashion. Trends in bicycle sales for the UK are difficult to ascertain because there is no reliable bicycle sales statistical service; this results in a reliance on anecdotal information from within the cycle industry. The Bicycle Association estimates that around two million cycles are sold annually in the UK, with mountain bikes accounting for 60% of all sales. Mintel (2005) suggests a higher figure of approximately 2.4 million cycles sold per year, with total spending on cycles in the UK currently running at around £300 million per annum. Such figures suggest the average price of a bicycle to be around £125, arguably making the practice of cycling more affordable than ever.

Anecdotal evidence from the cycle industry suggests that the mountain bike boom is over, and growth is instead now being witnessed in sales of ‘comfort bikes’ and ‘fast city bikes’ (also known as ‘trekking bikes’ or ‘hybrids’), adept on tarmac as well as rough trails. Market analysts also predict rising demand for cycles over the next
decade as various cycling promotion schemes take effect; these include ‘Bike Hub’, an industry wide initiative to support the future of cycling, and the ongoing development of the National Cycle Network.

In a study of over 500 cyclists, Gardner (1998) tried to establish why increased leisure cycling has not obviously led to more people cycling to work. He found a conflict between the image of leisure cycling as calm, peaceful and liberating, and of utility cycling as dangerous, demanding and stressful, and as requiring immense self-discipline. Despite this, Gardner suggests that leisure cycling has a part to play in fostering and/or preserving the cycling habit, and he notes how the mountain bike in particular has re-involved lapsed childhood cyclists. Gardner also notes that many people who currently cycle for utility purposes claim that leisure cycling did encourage them to try cycling to work. Thus leisure cycling is worth encouraging, and efforts should be made to extend to urban utility journeys the characteristics evident in the environment of leisure cycling journeys.

Socio-economic classification and age

At an aggregate level it may be possible to detect variation in use of the bicycle by socio-economic classification and age. Parkin (2004) found no clear pattern in the use of bicycles by socio-economic classification. This runs counter to earlier views (for example, Waldman 1977) that cycling, being relatively cheap, is the preserve of lower socio-economic classes. Parkin’s finding receives support from the high levels of cycling in some gentrified parts of London (for example, Hackney, with 7% cycling to work from the 2001 census). The impact of high proportions of students concentrated in city centres is undoubtedly one reason for greater cycle use in the two ancient university
cities (Cambridge at 28% of all journeys, and Oxford at 16%). However, in his study at ward level, Parkin (2004) found that the proportion of students in a ward was not a significant predictor of the proportion of the ward as a whole that would cycle for the journey to work.

Parkin also found that a higher proportion of people cycle to work in wards with a higher proportion of workers aged 34 and under. This finding could be linked with lower levels of car ownership, and also with younger people tending to live in more central urban locations. There is certainly potential for greater cycle use in the future if existing cohorts are encouraged to continue cycling as new younger cohorts are introduced to its pleasures and benefits.

Disaggregate stated preference studies from some parts of the world have detected variations in the propensity to cycle based on socio-economic classification and age. Discrete choice model estimation by Ortúzar et al. (2000), based on stated preference data from Santiago in Chile, found those respondents most willing to cycle to be young, on low incomes, without a car in the household and with a low educational level. The discontinuity with UK findings suggests that cross-cultural differences may be at play here.

*Health and environmental imperatives*

The link between cycling and good health is well established (British Medical Association 1992). However, the British Medical Association also reports that one of the major deterrents to cycling since the growth in availability of cars has been public attitudes to cyclists as ‘second class’ road users. These attitudes may change if the advantages of cycling as a means of gaining and maintaining fitness become more
widely accepted. The effects of a disregard for health, particularly in relation to the propensity to become obese, are more present in the minds of the public after the widespread recent media reporting of the so-called obesity epidemic in the UK.

Hillsdon and Thorogood (1996) show that activities that can become part of everyday life, such as walking or cycling to work, are more likely to be sustained than activities that require attendance at specific venues. Cope et al. (2003) claim that 70% of adult users of the National Cycle Network report that it has helped them increase their level of physical activity (although lack of evidence as to users’ previous activity levels makes such self-reported changes difficult to substantiate).

Exhortations to cycle for environmental reasons may appear persuasive and logical from a policy perspective, because of cycling’s clear environmental and traffic congestion reduction benefits. Nonetheless, it seems likely that the personal benefits of greater fitness and reduced potential ill health will tempt more people (back) into the saddle.

**Physical factors**

Cycling is distinct from other forms of vehicle transport in that it requires human effort to provide the locomotion. This is self-evidently true of walking, but the coupling of a rider with a machine appears to heighten awareness of the effort being made. The amount of effort required is the result of a combination of the mass of the rider and bicycle, the rotational mass of the wheels, the gradient, the rolling and air resistances and the mechanical efficiency of the bicycle. Over periods of between 20 minutes and an hour, a typical power output for a non-athlete cyclist is 75 watts; this may rise to 200-250 watts for healthy male touring cyclists, and to 350-400 watts for racing cyclists.
(Whitt and Wilson 1982). The non-policy sensitive variables of hilliness and wind speed will affect the power consumption requirements of a bicycle, as will the number of times a cyclist has to stop or slow down on a journey, and hence have to speed up again, which requires acceleration and hence additional effort. The number of stops and starts is related to the design of the infrastructure, and may be influenced by appropriate policy and design philosophy.

Let us assume a notional head wind and two stops and starts per kilometre. Under such conditions, a cyclist with a power output of 75 watts would be able to travel only 75% as far for the same total energy output on a route with gradients constantly varying between 3% up and 3% down, as compared with the same journey on a completely flat route. This demonstrates the significant physical impact of hills on the effort required to cycle.

Parkin (2004) confirms that hilliness in a district, measured as the proportion of kilometre squares in a district with an average gradient of 3% or more, has one of the largest influences on the proportion of people cycling to work at ward level. A 10% increase in the size of the variable for hilliness is linked with a 10% to 15% reduction in the proportion of people cycling to work.

The experience of the cyclist is partly determined by the environment through which he or she cycles, and this environment is very significantly influenced by climatic conditions, which in turn are influenced by the time of year and also time of day (lightness and darkness). Emmerson et al. (1998) analysed climate and cycling data for two locations, one on the Wirral, north west England, the other in Essex, south east England. They found that the month of the year and the day of the week explained more of the variation in cycle flows at the sites under consideration than did the weather
conditions. However, using data for all 8800 wards in England and Wales, Parkin (2004) found that a 10% lower rainfall and a 10% higher mean temperature were both linked with a 5% higher proportion of people cycling to work. Neither a measure for windiness nor number of hours of sunshine proved statistically significant.

At a more disaggregate level, Ryley (2005) analysed the types of individuals that might be affected by hilliness and rainfall in their decision as to whether or not to cycle. A household survey in west Edinburgh included the following two attitudinal statements: 'Edinburgh is too hilly to cycle' and 'Edinburgh is too wet to cycle'. Individuals agreeing with one statement also tended to agree with the other; approximately one fifth of respondents agreed with each statement. Testing by various socio-economic and transport variables (age, gender, household income, bicycle availability, motor car availability and frequency of driving, cycling and walking) showed gender to be the most significant factor, with women far more likely than men to find Edinburgh too hilly and too wet for cycling.

It is generally not possible or practical to adjust hilliness or climatic conditions through policy interventions. However, it is important to recognise the impact these factors have on cycling levels, and to realise that there is a lower upper bound to the quantity of cycling that may be attainable in hillier, wetter and cooler regions.

**Traffic conditions and perception of risk**

There exists a growing corpus of work evaluating the perception of risk of cycling in different conditions (for example, Landis et al. 1997; Harkey et al. 1998; Guthrie et al. 2001; Landis et al. 2003; Parkin et al. 2007). Early work considered sections of

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Interventions are possible; for example, a route with switchbacks up a steep gradient, large scale earth-moving, innovative schemes such as the cycle lift in Trondheim in Norway, and covered cycling corridors. They are, however, often costly or otherwise impractical within many contexts.
highway between junctions, later work included junctions, and the most recent work, by Parkin et al., has created a comprehensive model for the perception of risk for a whole journey. This models the acceptability of cycling based on perceived risk across the different components of a journey. The factors that influence the perception of risk include the volume, speed and composition of motor traffic, the number of parked vehicles in the highway along the route, and the types of junction and types of turn being made. Interestingly, the provision of facilities for cycle traffic on the highway (for example, cycle lanes approaching and through junctions) was found not to greatly influence the perception of risk. This may be because the presence of such facilities is alerting the cyclist to an assumed level of hazard that they may otherwise not have perceived. Conversely, it may simply be that such facilities within the highway have no value in altering the perceived level of hazard to which a cyclist is exposed.

One factor that may be supposed to encourage participation in recreational cycling is increased opportunity for traffic-free recreational cycling. There has been an increase in the number of traffic-free cycling routes, from the creation of technical forest trails to the restoration of disused railway lines and canal tow-paths for casual leisure riding. Local authorities, landowners (such as Forest Enterprise and British Waterways) and organisations that facilitate cycling such as Sustrans have all played a part in increasing leisure cycling routes and facilities. Planning authorities now recognise that the availability of good quality accessible open space for walking and cycling, linking home and work, potentially enables people to reduce their car use and also to carry out regular exercise as part of their daily routines. Traffic-free routes allow these journeys to take place in a more attractive and natural environment, without the stress of having to cope with motorised traffic.
Confirming these suppositions, Parkin found the only significant reduction in the perception of risk to be linked with cycling in traffic-free conditions. The significant value of segregated facilities has also been shown by others (Wardman et al. 1997; Wardman et al. 2000). However, Parkin found that the majority of respondents found cycling to be acceptable based on perceived risk whether or not the route was traffic-free.

Stated preference-based discrete choice modelling research (Bovy and Bradley 1985; Hopkinson and Wardman 1996; Abraham et al. 2002; Stinson and Bhat 2003) has shown time and safety to be the greatest determinants of a cyclist’s route choice. These studies also show the preference of cyclists for off-road and quieter routes. There is scope for extending research into cyclist route choice to incorporate more detailed analysis of cycle facilities, variation by socio-economic classification, and other variables such as topography and weather. A preference for off-road cycling has also been found in cyclist mode choice modelling of stated preference data. For example, the model of Ortúzar et al. (2000) shows that segregated cycleways could produce increases in bicycle use of as much as 10% mode share for certain sectors of Santiago.

The importance of facilities at the destination (for example, cycle parking, showers and changing facilities) is highlighted by both Wardman et al. (2000) and Ryley (2005) from mode choice stated preference experiments for journeys to work and education. Employers could therefore be encouraged to provide cyclists with facilities at workplaces, schools and colleges, although more work is recommended, in order to disentangle the relative impact of different facilities such as cycle parking and showers.

*Route characteristics*
Jones (2001) summarises a range of complaints about poor quality cycle infrastructure that recurred across a series of seminars organised by the National Cycling Forum for practitioners and activists. Some complaints concerned design within the carriageway, for example cycle lanes that are too narrow for the kinematic (moving) envelope of a cyclist, and junction design that places cyclists in danger. But most of the criticisms were in connection with traffic free routes, and included:

- conflict with pedestrians on shared-use paths, particularly those that take space away from existing footways;
- lack of continuity of routes, resulting, for example, from 'give way' and 'cyclist dismount' signs;
- street furniture that creates obstacles;
- poor surfaces on off-road routes; and
- off-road paths that take inconvenient routes.

Hence, while traffic-free routes may reduce one of the negative influencing factors in connection with cycling, namely the perceived hazard from traffic, such provision also has the potential to introduce a series of other problems for the cyclist.

In respect of stops and starts, assuming a notional head wind, a cyclist with a power output of 75 watts would be able to travel only 80% of the distance for the same total energy output on a flat route with six stops per kilometre as compared with a flat route with two stops per kilometre. Recognising the importance of hilliness due to its impact on the effort of cycling, it follows that a journey with frequent stops for a cyclist will have a commensurately high likelihood of reducing the propensity to cycle.

Rolling resistance is linked with the amount of effort required of a cyclist, and the perception of the state of the highway network surface could be linked with a reduced propensity to cycle. Testing this hypothesis, Parkin (2004) found that local authority scores for so-called 'best value' indicators for the proportion of highway in need of
repair were significant in explaining the variation at ward level in the proportion of people cycling to work. Poor riding surfaces put people off cycling. Another aspect of rolling resistance is relevant; novice cyclists are less likely to understand the potentially significant detrimental effect of high rolling resistance, especially on the common entry-level bicycle configuration that has large cross-section knobbly tyres that may perhaps only infrequently be inflated to the correct pressure. Inappropriate tyres, incorrectly inflated, will have a negative impact on ride comfort and will make cycling feel like harder work than it ought to be. Bicycle promotion activities should therefore include guidance on bicycle purchase decision making and maintenance.

Discussion

This chapter has reviewed some of the more recent and relevant quantitative studies into cycling mode and route choice. The significance of both the effort of cycling and the perception of the environment through which the cyclist travels have been shown to be as important as more traditional concerns with time and distance. To conclude, we consider the implications of our analysis for two areas; first, future methodological developments in cycling studies, and second, future cycling promotion strategies.

Recommendations on methodological developments

Quantitative models are able to infer statistically significant weights on the different influencing factors on cycle mode and route choice, and have the important ability to forecast future changes. Qualitative and quasi-quantitative methods (simple ratings scores associated to qualitative responses) are often required as a precursor to
the implementation of quantitative models and help determine the range of parameters that need to be analysed. As a stand-alone technique, qualitative analyses can also provide other useful insights that are not able to be tackled using quantitative models.

In attempting to evaluate the contribution of the wider transport environment on levels of cycling, a number of studies have concentrated particularly on perceptions of risk. But it is not completely clear the extent to which the presence of traffic is disliked because of the element of additional perceived risk, and the extent to which traffic adversely affects other features of journey ambience, such as noise and general attractiveness of a route.

Based on estimates of hilliness, it has been shown that expenditure of effort has a large impact on the volume of cycling for the journey to work. Extrapolating this major influence of effort, it becomes clear that other features of routes, such as road surface regularity and the number of stops required on a journey, are also very important to consider, as they too will have a large impact on the amount of effort required.

Cross-sectional aggregate statistical data (NRTE and NTS) have been shown to demonstrate mutually inconsistent trends. This is a direct consequence of the variation to be expected for counts of low numbers or proportions, and of shortcomings in what is counted as a bicycle trip. More emphasis therefore needs to be placed on collecting appropriate data sets in order to deduce trends using appropriate time series analysis techniques.

Finally, more work is required to further develop theory and practice in modelling choice mechanisms, for two reasons. First, to fully and properly include attributes such as risk and effort. Second, to encompass some of the wider, more cultural, issues that may affect choice for the bicycle.
Lessons for promoting cycling

Hilliness has been shown to have a very significant effect on the proportion of people cycling the journey to work. While it is not feasible to eradicate hills, careful consideration should be given to the alignment of cycle routes in hilly areas, in order to reduce the negative consequences of topography. Similarly, it has been shown that both surface roughness and the number of stops and starts have a strong impact on the amount of effort required to cycle. Correspondingly, infrastructure should comprise direct routes, with few stops and starts, and have well maintained riding surfaces.

The perception of the risk of cycling on a road with motorised traffic is unaffected by the provision of cycle lanes along routes, and approaching and through junctions. The relative importance of the perception of risk and other environment features remains fully to be explored, but it is possible to say that important features of network design involve not just safety, but also effort and positive features such as attractiveness and comfort. It is also important to understand that perceptions of the risk and effort involved in cycling practices are unlikely to relate directly to actual levels of risk and effort. For example, a reduction in perceived risk without a commensurate reduction in actual risk might lead to exposure of a larger number of people to hazard.

Networks for cycle traffic should extend from significant trip attractors, such as town centres, at least to 2 km and as far as 5 km, as over these distances the flexibility and freedoms of the bicycle are evident without undue exertion. It cannot be assumed that use of the bicycle for leisure purposes will follow through into use for utilitarian purposes, but promotion of the bicycle for utilitarian trips should recognise that the market comprises principally car-owning households.
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