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Shifting towards healthier transport?
From systematic review to primary research

Volume 1 of 2

David Bruce Ogilvie
MA MB BChir MPH MRCGP FFPH

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Medical Research Council Social and Public Health Sciences Unit
Division of Community Based Sciences
Faculty of Medicine
University of Glasgow
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Author's declaration

The material contained in the thesis has not previously been presented for a higher degree in this or any other university. The research reported is my own original work which I carried out in collaboration with others as follows:

I and Mark Petticrew had the original idea for the systematic review. I designed the study, carried out the pilot search and part of the definitive literature search, carried out all of the study selection, data extraction, critical appraisal, synthesis and secondary methodological analyses, and wrote the journal manuscripts arising from the systematic review. Matt Egan, Val Hamilton and Mark Petticrew contributed to and advised on the design of the study and the critical revision of the journal manuscripts. In addition, Val Hamilton carried out part of the definitive literature search and as co-reviewers, Matt Egan and Mark Petticrew validated (checked) the processes of study selection, data extraction and critical appraisal described in Chapter 3.

I had the original idea for the M74 study. I designed the study and the survey materials, applied for ethical approval, cleaned and coded the survey data, carried out all the geographical and statistical analyses and wrote the journal manuscript arising from the study. Richard Mitchell, Nanette Mutrie, Mark Petticrew and Steve Platt constituted the steering group for the study, contributed to and advised on the design of the study and the interpretation of the emerging findings, and contributed to the critical revision of the journal manuscript.

Mark Petticrew reviewed drafts of the thesis.

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The methods and substantive findings of the systematic review (Chapters 3, 4 and 5) have been published as:

> Ogilvie D, Egan M, Hamilton V, Petticrew M. Promoting walking and cycling as an alternative to using cars: systematic review. *BMJ* 2004; 329: 763-766.

The methodological background to and findings of the systematic review (Chapters 2, 4 and 5) have been published as:

> Ogilvie D, Hamilton V, Egan M, Petticrew M. Systematic reviews of health effects of social interventions: 1. Finding the evidence: how far should you go? *J Epidemiol Community Health* 2005; 59: 804-808.

> Ogilvie D, Egan M, Hamilton V, Petticrew M. Systematic reviews of health effects of social interventions: 2. Best available evidence: how low should you go? *J Epidemiol Community Health* 2005; 59: 886-892.

The design of the M74 study (Chapters 6 and 7) has been published as:

> Ogilvie D, Mitchell R, Mutrie N, Petticrew M, Platt S. Evaluating health effects of transport interventions: methodologic case study. *Am J Prev Med* 2006; 31: 118-126.

Further papers are in preparation (see Chapter 10).

Summary

Promoting a shift from using cars towards walking and cycling (a modal shift) has the potential to improve population health by reducing the adverse health effects associated with exposure to motor traffic and increasing the population level of physical activity through active travel. However, little is known about the effects of interventions which might achieve this by changing urban design, transport infrastructure or other putative determinants of population travel behaviour.

I conducted a systematic review of the best available evidence about the effects of interventions to promote a modal shift. I searched twenty electronic literature databases as well as websites, bibliographies and reference lists and invited experts to contribute additional references. I identified 69 relevant studies and devised a two-dimensional hierarchy of study utility based on study design and study population with which I selected a subset of studies for inclusion. I appraised the quality of these studies; extracted data on the effects of interventions on choice of mode of transport, how these effects were distributed in the population, and associated effects on measures of individual and population health and wellbeing; and produced a narrative synthesis of the findings.

Twenty-two studies were included. These comprised three randomised controlled trials, seven non-randomised controlled prospective studies, 11 uncontrolled prospective studies, and one controlled retrospective study of interventions applied to urban populations or areas in which outcomes were assessed in a sample of local people. I found some evidence that targeted behaviour change programmes could change the behaviour of motivated subgroups, resulting (in the largest study) in a modal shift of around 5% of all trips at a population level. Single studies of commuter subsidies and a new railway station also showed

positive effects. The balance of best available evidence about other types of intervention such as publicity campaigns, traffic calming and cycling infrastructure suggested that they had not been effective. Participants in trials of active commuting experienced short term improvements in certain measures of health and fitness, but I found no good evidence about health effects associated with any effective intervention at population level.

Most relevant studies were not found in mainstream health or social science literature databases. Further analysis of the 47 excluded studies did not change the overall conclusions about effectiveness, but did identify additional categories of intervention that merit further research and provided evidence to challenge assumptions about the actual effects of progressive urban transport policies. The contributions of internet publications, serendipitous discoveries and the initially-excluded studies to the total set of relevant evidence suggested that undertaking a comprehensive search may have provided unique evidence and insights that would not have been obtained using a more focused search.

I identified an evaluative bias whereby the effects of population-level interventions were less likely than those of individual-level interventions to have been studied using the most rigorous study designs. Understanding of how environmental and policy factors may influence active travel and physical activity currently relies heavily on evidence from cross-sectional studies of correlates rather than intervention studies. I therefore took advantage of the opportunity presented by a local ‘natural experiment’ — the construction of a new urban section of the M74 motorway in Glasgow — to design, develop and complete the cross-sectional (baseline) phase of a new primary study of the effects of a major environmental intervention.

Using a combination of census data, geographical data and field visits, I delineated an intervention study area close to the proposed route of the new motorway and two matched control areas elsewhere in Glasgow. I collected and described data from residents in the three study areas (n=1322) on socioeconomic status, the local environment, travel behaviour, physical activity and general health and wellbeing using a postal questionnaire incorporating two established instruments (the SF-8 and the short-form International Physical Activity Questionnaire), a travel diary and a new 14-item neighbourhood rating scale whose test–retest reliability I established in a subset of respondents (n=125). I then analysed the correlates of active travel and physical activity using logistic regression. Using travel diary data from Scottish Household Survey respondents (n=39067), I also compared the characteristics and travel behaviour of residents living close to the proposed route with those living in the rest of Scotland and analysed the correlates of active travel using logistic regression.

Overall data quality and the test–retest reliability of the new neighbourhood scale appeared acceptable. Local residents reported less car travel than expected from national data. In the local study area, active travel was associated with being younger, being an owner-occupier, not having to travel a long distance to work and not having access to a car, whereas overall physical activity was associated with living in social-rented accommodation and not being overweight. After adjusting for individual and household characteristics, neither perceptions of the local environment nor the objective proximity of respondents' homes to motorway or major road infrastructure appeared to explain much of the variance in active travel or overall physical activity, although I did find a significant positive association between active travel and perceived proximity to shops. Apart from access to local amenities, therefore, environmental characteristics may be of limited relevance as explanatory factors for active travel in this comparatively deprived urban population which has a low level of car ownership and may therefore have less capacity for making discretionary travel choices than the populations studied in most published research on the environmental correlates of physical activity.

The design and baseline data for the M74 study now provide the basis for a controlled longitudinal study, which could not otherwise have been carried out, of changes in perceptions of the local environment, active travel, physical activity, and general health and wellbeing associated with a major intervention in the built environment. This will, in time, contribute to addressing calls to produce better evidence about the health impacts of natural experiments in public policy.

1 General introduction

1.1 Overview of the thesis

This thesis addresses the following problem: how can evidence be produced and synthesised about the effects on population health of interventions made in an area of public policy whose primary aim is not to improve health, but which may nonetheless have important effects on health?

I explore this general problem in intervention research for public health by examining the specific example of transport. Transport is one area of public policy in which the decisions made may influence important determinants of population health. There is increasing recognition of the relationship between transport and health, but little is known about how interventions in the transport sector influence population health in practice beyond the effects of some measures to reduce injuries on the roads. In this thesis, I focus on one particular aspect of the relationship between transport and health: the potential to improve population health by promoting a shift from using cars towards walking and cycling (a *modal shift*).

The thesis comprises two linked, sequential, original research studies.

The first study is a **systematic review** of previous studies of the effects of interventions on choice of mode of transport, how these effects are distributed in the population, and associated effects on measures of individual and population health and wellbeing. This study makes an original contribution to the available evidence in its own right. It also makes a methodological contribution to the field of evidence synthesis by exploring some of the boundaries of accepted methods and examining the implications of decisions made at certain critical points in the process.

Many interventions in the transport sector could be described as 'natural experiments' in public policy, in the sense that researchers have no control over the nature or allocation of the interventions but may have an opportunity to observe their effects. My systematic review shows that more studies, using more rigorous methods, of the health effects of such natural experiments are required. Leading directly from the first study and drawing on other relevant literature, I developed a second study to address some of the identified gaps in knowledge. This second study, the **M74 study**, concerns the construction of a new urban section of the M74 motorway in Glasgow.

One of the challenges of studying this type of intervention is the long time scale involved. It will not be possible to complete the longitudinal part of the M74 study until 2011 at the earliest. In the second part of the thesis, I therefore show how I developed, piloted and carried out the cross-sectional phase of this study. This constitutes an original methodological case study of how the health effects of a major environmental intervention can be studied and prepares the ground for a future follow-up phase of the study. It also makes an original contribution to the available evidence about the associations between socioeconomic status, the physical environment, travel behaviour and physical activity.

The thesis is organised to reflect the logical progression from the first to the second study and comprises ten chapters: a general introduction (Chapter 1), followed by four chapters on the first study (introduction, methods, results and discussion: Chapters 2 to 5), followed by four analogous chapters on the second study (Chapters 6 to 9), followed by a concluding chapter (10).

Since the thesis addresses more than one sector of public policy (health and transport), more than one substantive topic area (travel behaviour, physical activity, and their associations both with environmental factors and with the effects of interventions), and more than one substantive methodological field in public health research (evidence synthesis and the design of intervention studies), I have not attempted a comprehensive review of the literature in all of these fields. In the introductory chapters specific to each of the two studies (Chapters 2 and 6), I mostly review selected literature which informs the choice of *methods* used in those studies. In the general introduction (this chapter), on the other hand, I justify the importance of the topic of the thesis for public health and review selected epidemiological and other evidence which informs the *focus* of the studies.

1.2 Overview of this chapter

In this chapter, I outline the background to the topic of the thesis.

I begin by outlining the significance for public health of transport in general and of a modal shift from using cars towards walking and cycling in particular.

I then review selected evidence from a range of disciplines which, taken together, summarises important aspects of what is known about how much people travel and by which modes of transport, and about the relationships between walking and cycling and the environmental or policy factors to which people are exposed. I show that, in contrast to the considerable body of evidence about cross-sectional associations, little is known about the actual effects in practice of interventions which might promote a modal shift by changing urban design, transport infrastructure or other putative determinants of population travel behaviour.

I go on to discuss selected recent developments in transport and health policy. I show that policy appears to run ahead of the evidence, in that many different interventions have been advocated without clear evidence of what their effects on populations are likely to be. I therefore conclude that the next logical step should be to examine what is known about the effects of interventions which might promote a modal shift by synthesising evidence from existing primary studies in a systematic review.

1.3 The significance of transport for public health

1.3.1 Introduction

Human beings have always moved from place to place: to interact with other people, to obtain food, or to work, among many other reasons. Movement over land was once limited by the speed and range of a human being or animal travelling on foot. The invention of the bicycle extended our capabilities by transforming human effort more efficiently into kinetic energy; motor vehicles now enable us to travel at much higher speeds and over much greater distances.

Since the middle of the twentieth century, the growth of motorised land transport in the United Kingdom (UK) and other developed countries has been dominated by the rise in the ownership and use of private cars. [1] This has made it possible for people to live, work, shop and pursue leisure activities in widely-dispersed locations, liberating them from the limitations of human-powered or public transport. Alternatively, according to Illich, the mobile, car-based society has created 'universal enslavement', compelling people to travel further and faster on their daily business 'at the expense of being able to drop in on an acquaintance or walk through the park on the way to work'. [2] More recently, Adams has proposed the concept of 'hypermobility', arguing that ever-increasing mobility imposes unacceptable social costs and that it is therefore possible for a society to have 'too much of a good thing'. [3]

The significance of transport for public health is reflected in its choice as the topic for one of the chapters in Marmot and Wilkinson's 1999 book *Social determinants of health*. [4] The dramatic increase in the use of motor vehicles in recent decades has the potential to influence the health both of individual people making journeys and of people around them. Public health interest in the relationship between transport and health has focused on two aspects: the adverse effects of motor traffic on health, and, more recently, the potential health benefits of physical activity through transport.

1.3.2 Adverse effects of motor traffic on health

There is a long history of research on adverse effects of motor traffic on health. Motor traffic produces noise, vibration, dirt and fumes which may cause disturbance to people living or working near roads. [5] Exposure to particulate air pollution in exhaust fumes is associated with an increased incidence of respiratory illness, [6] and road traffic is estimated to contribute about one-fifth of the UK's total emissions of carbon dioxide which are now the subject of increasing concern because of their contribution to global warming. [7] Motor vehicles also account for numerous injuries and deaths to road users, both inside and outside vehicles: 3201 deaths and 28954 serious injuries resulting from road traffic crashes were recorded in Great Britain in 2005. [8] In children, there is a steep social gradient in deaths from road traffic crashes, with a mortality rate in social class V five times greater than that in social class I. [9]

1.3.3 Physical activity

Health benefits

There is growing concern about the health consequences of sedentary lifestyles, to the extent that increasing the population level of physical activity has been described as the 'best buy' for improving public health. [10] Physical activity is associated with a reduced incidence of chronic disease and premature death. A recent report issued by the Chief Medical Officer for England found that evidence for the protective effect of physical activity was most convincing for cardiovascular disease, type 2 diabetes and carcinoma of the colon, but also found evidence of at least 'moderate' quality that physical activity protects against several other chronic diseases. [11] It is also recognised that the recent rise in the prevalence of obesity is likely to be partly attributable to insufficient physical activity. [12] Drawing on the available epidemiological evidence that moderate-intensity physical activity confers substantial health benefits if undertaken with sufficient frequency and in sufficient quantity, consensus guidelines issued by the Centers for Disease Control and Prevention and the American College of Sports Medicine in 1995 recommended that adults should aim to undertake at least thirty minutes of moderate-intensity physical activity on at least five days per week. [13] This advice was endorsed and reinforced by the Chief Medical Officer's report in 2004 and is the current advice for adults in the UK (a higher quantity is recommended for children). [11] Most adults surveyed for the 2003 waves of the Scottish Health Survey and the Health Survey for England did not report sufficient physical activity to meet this criterion. [14 15] For the purposes of this thesis, it is taken as understood that the health of the population would benefit from an increase in moderate-intensity physical activity; a critique of the aetiological evidence which underpins the authoritative recommendations cited above lies outside the scope of the thesis.

Social patterning

A detailed consideration of the descriptive epidemiology of physical activity also lies outside the scope of the thesis. However, one important insight from population surveillance data is that the social patterning of physical activity varies according to how physical activity is defined and between the different domains in which it occurs. For example, the physical activity strategy for Scotland highlights data from the Scottish Health Survey which show conflicting social gradients in the prevalence of 'high' and 'low' levels of physical activity: men in social class V are less likely than those in social class I to report a 'medium' level of activity and more likely to report either a 'high' or a 'low' level. [16] Similar findings from the Health Survey for England are encapsulated in the observation that men in higher socioeconomic groups are more likely to report *any* participation in physical activity, but men in lower socioeconomic groups are more likely to report a 'high' level of physical activity. [15] In both surveys, reporting a 'high' level of physical activity is equivalent to meeting the Chief Medical Officer's recommendation.

These patterns may reflect differences between more and less discretionary forms of physical activity. People in lower socioeconomic groups are more likely to be engaged in physically-active manual work (if they are men) and less likely to have access to a car (see Section 1.5.2 later in this chapter), either or both of which may require them to be more active in the course of day-to-day living; these factors may therefore help to expain the higher prevalence of a 'high' level of activity in social class V. On the other hand, people in lower socioeconomic groups are less likely to engage in physical activity through sport and recreation, which are discretionary activities requiring a higher level of motivation and the allocation of time and, sometimes, money; this may help to explain the higher prevalence of sedentariness (a 'low' level of activity) in social class V. [15]

Walking and cycling

The definition of moderate-intensity physical activity encompasses any activity involving energy expenditure of between three and six metabolic equivalents (METs), i.e. between three and six times the rate at which energy is expended at rest. [11] Walking and cycling are two activities which fall within this range of energy expenditure. Walking expends energy at an average of 3.3 METs at a moderate pace of 3 miles/hour (more if walking uphill or carrying a load), while cycling at 10–12 miles/hour expends energy at an average of 6.0 METs and is therefore at the upper end of the moderate-intensity range. [17] Since most people need to move from place to place in any case, one way in which people might be able to incorporate more physical activity into their lives is to walk or cycle more. In particular, walking — which has been described as 'the nearest activity to perfect exercise' [18] — is a popular, familiar, convenient and free form of exercise which can be sustained into old age, [19] and is increasingly seen as the key to promoting moderate-intensity physical activity at the population level. [20]

1.4 Active travel and modal shift

1.4.1 Definitions

The distinction between walking and cycling for transport and walking and cycling for other purposes is not always straightforward, and the terminology used varies between disciplines. In this thesis, I am concerned mainly with walking and cycling for transport, which I refer to as *active travel*, adopting Handy's definition of active travel as 'destination-oriented' physical activity: active travel 'is not simply a loop from starting point back to starting point' (such as going for a walk purely for recreation or to exercise a dog) 'but rather involves a destination, a place where the traveler stops for some activity'. [21] For most practical research purposes, the active modes of transport can be defined as walking and cycling; although it is possible to travel by other physically-active modes such as rollerblades, skateboards and non-motorised wheelchairs, these account for an extremely small proportion of trips.

A *prima facie* case can be made, based on the evidence cited above (Section 1.3), that the interests of population health would be served both by promoting walking and cycling as modes of transport (to increase physical activity in the population) and by reducing the use of motor vehicles (to reduce the exposure of the population to their harmful effects). The simultaneous achievement of both objectives can be conceptualised as a change in the distribution of people's choice of mode of transport. In this thesis, I use the terminology common in transport policy and research, in which people's choice of mode of transport is referred to as *mode choice*, the proportion of travel undertaken by a given mode of transport is referred to as *mode share*, and a change in the distribution of mode share is referred to as *modal shift*.

I am concerned with one particular definition of modal shift, namely a shift from using cars for personal transport towards walking and cycling. It is, of course, possible for other modal shifts to occur; these may or may not have beneficial implications for health. For example, some objectives of transport policy, such as reducing traffic congestion, could be met by a modal shift from cars towards public transport such as buses, trams and trains. However, it does not necessarily follow that this would be associated with any increase in physical activity; although using public transport typically involves some walking at either end of the trip, [22] this is not inevitable and may not be greater than that associated with, for example, parking a car in a city centre car park and walking to one's destination. Promoting public transport also has the potential directly to reduce physical activity; for example, it is conceivable that subsidised or free bus travel for senior citizens could discourage the target population from making some walking trips. I have chosen to focus on the promotion of a modal shift from using cars towards walking and cycling because this is the shift from which the greatest population health benefits appear most likely to accrue.

1.4.2 Importance of a population perspective

The case for promoting a modal shift in these terms may appear less convincing from the perspective of an individual making choices about their mode of transport than from the perspective of improving population health, for two reasons.

First, there may be strong disincentives for an individual to reduce or give up their use of a car. For some people, owning and driving cars contributes to their sense of autonomy and self-esteem. [23] At a more instrumental level, Adams has argued that in a 'hypermobile' society where access to opportunities increasingly depends on access to motor transport, an individual is always likely to benefit from having greater mobility than the average. [3] People need transport to avail themselves of goods, services and amenities, [24] either by travelling to obtain them or by having them delivered. If these are available near where people live, they may be able to obtain them without using motor transport themselves. In many parts of the UK, however, there has been a tendency in recent years for some local amenities such as shops and hospitals to be withdrawn; their replacements are increasingly concentrated in fewer, larger sites which are often on the edges of towns or cities and may be many miles from the population they serve and from which they draw their workforce. [25 26] Access to motor transport may therefore be increasingly necessary as a means of ensuring social inclusion in general and access to food, employment and health care in particular. This access may sometimes be possible by public transport, but if routes are not well served by public transport there may be no realistic alternative to using a car.

Second, there may also be strong disincentives for an individual to take up walking or cycling. One person's choice of mode of transport is not independent of the behaviour of others. For example, a child's decision to walk or cycle to school instead of travelling by car (or a parent's decision to allow them to do so) may depend not only on individual factors such as access to a bicycle and on environmental factors such as the weather and the convenience of the route for cycling, but also on the mode choices made by other road users: the danger posed by motor traffic, whether real or perceived, is a disincentive to walk or cycle. [27]

These disincentives illustrate the potential limitations of an individually-focused approach to health improvement in the area of transport. On the one hand, many people are constrained in their mode choices by structural aspects of the society in which they find themselves: they cannot choose to walk to the shops if the nearest shops are not within walking distance. On the other hand, one person's modal shift (say, from driving to work to cycling to work) does not merely benefit their own health (by increasing their physical activity): it may also constitute a social good with positive externalities. These externalities include reducing the danger they pose to other road users, which may help to encourage others to perceive cycling as less dangerous and therefore contemplate making the same modal shift themselves, producing a virtuous spiral; this could, in theory, eventually lead to a 'critical mass' effect whereby walking and cycling become much more popular. [27 28]

Since the potential for modal shift is likely to be either limited or enhanced by the behaviour of other road users and by structural aspects of society, it seems doubtful that an individually-targeted approach to promoting modal shift would be sufficient to bring about large-scale changes in the population. Rose contrasted individually-targeted and population-wide strategies to improving population health using the example of blood pressure. He argued that although the health of an individual person with high blood pressure might benefit considerably from a preventive strategy targeted at high-risk individuals, the interests of the population as a whole would be better served not by targeting a small number of high-risk individuals but by a comparatively small decrease (left shift) in the mean population blood pressure. [29] A loose analogy can be drawn between Rose's population strategy and the analysis of modal shift as a putative means of improving population health. Unlike blood pressure, the variable of interest (mode share) is categorical rather than continuous. Nonetheless, if it is accepted that the health of the population as a whole might be improved by a change in the distribution of mode share, then modal shift can be seen as a change in the population distribution of a putative determinant of health which could best be achieved through intervention at population level.

1.5 Evidence from existing research

1.5.1 Introduction

In this thesis, I focus on the quantitative analysis of modal shift from the perspective of public health, with a particular interest in modal shift as a means of promoting active travel and physical activity. This has two implications for the scope of the literature reviewed in this chapter. First, although qualitative research offers a complementary perspective on why people choose to use particular modes of transport and on the factors which may facilitate or hinder the decision to change modes, this lies outside the scope of the thesis. Second, current understanding of mode choice, mode share and modal shift as quantitative phenomena is reflected in a variety of types of evidence and bodies of literature, each of which could form the basis for a complete literature review in its own right. For example, there is an entire field of travel behaviour research, all of which is potentially relevant. I have therefore chosen to review what I consider to be the three most important bodies of evidence which form the background to this thesis, bearing in mind the perspective of the particular research paradigm within which I am operating (intervention research for public health) and the focus on promoting active travel rather than, for example, managing traffic congestion. This means, for example, that I have not reviewed the literature on topics such as the psychology of driver behaviour or the modelling of traffic flows.

The first body of evidence comprises **descriptive evidence** from the transport literature about current mode shares, and recent trends in mode shares, within the UK and between cities and countries. The second body of evidence comprises **correlational evidence** from studies in the physical activity, planning and other literature of the associations between characteristics of individuals and their surroundings (the 'environment'), mode choice, and physical activity. The third body of evidence comprises **intervention evidence** from systematic reviews of studies, mostly from the physical activity literature, of the effects of interventions which might change travel behaviour or promote physical activity through transport.

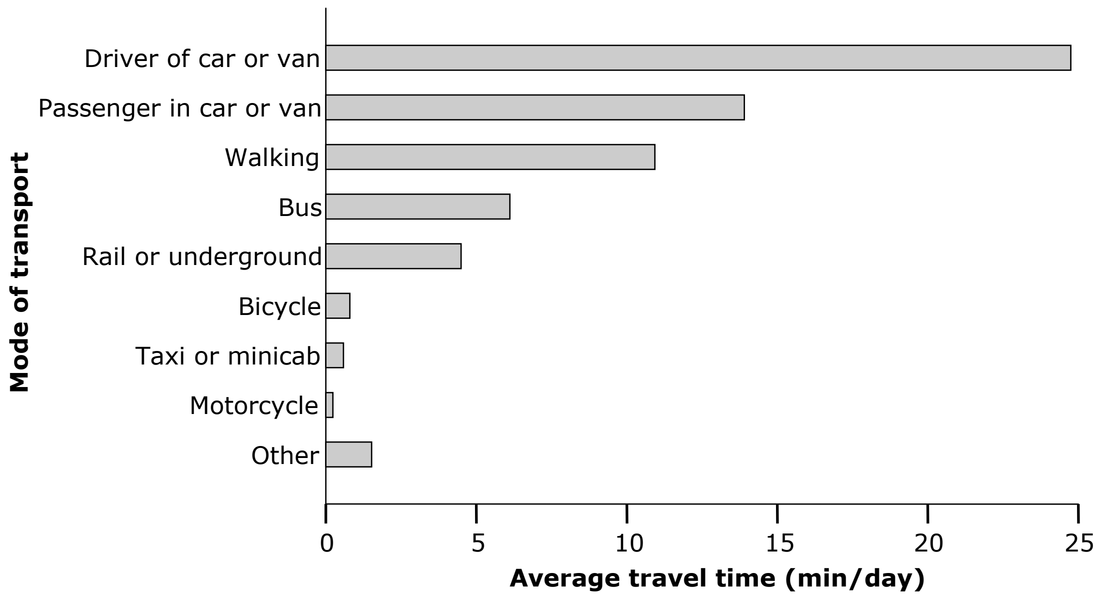
Although I have not attempted a comprehensive account of the field of travel behaviour research, two important theoretical concepts from that field have informed my thinking. The first is the concept of a *travel time budget*: it is widely held that people are prepared to spend a relatively stable average daily quantity of time travelling, irrespective of the mode of transport. [30] National Travel Survey data suggest that in the UK, the average travel time budget is about an hour. [31] The second is the concept that people's demand for personal transport is a *derived demand*: most of the time, people travel not for the sake of travelling itself but to buy goods or participate in activities at the destination. [32] A caveat to be considered is that until recently, most travel behaviour research was concerned with the use of motor vehicles. Leading authors in the field have acknowledged that walking and cycling are the least well understood aspects of travel behaviour [33] and, more specifically, that travel surveys capture walking less well than other modes of transport and that derived-demand models 'explain' walking less well than other modes. [32] Nonetheless, one implication of these general principles is that if the population as a whole were to make more walking or cycling trips, it is likely that most of these would be existing trips previously made by other modes of transport, since these already have a purpose and an allocation of the travel time budget. This is not to deny that some people may decide to make completely new walking or cycling trips, but overall, as Tolley has argued, 'without increasing the number of trips per person per day, increasing walking and cycling can only happen if some other mode declines.' [34] In other words, these concepts from travel behaviour research support a 'modal shift' perspective on the promotion of walking and cycling: it is necessary not only to encourage people to walk or cycle but also, simultaneously, to discourage the use of motor vehicles and emphasise the possibility of shifting the mode of existing trips.

1.5.2 Descriptive evidence

National data

The main source of data on travel behaviour in the UK is the National Travel Survey (NTS), a continuous cross-sectional survey of a random sample of private households in which a randomly-selected adult in each household is asked to record a seven-day travel diary. [31] In the second part of the thesis, I turn my attention to an alternative source, the Scottish Household Survey (SHS), but NTS provides a more useful overview of the background to the thesis because it provides trend data going back much further in time.

Between 1972 and 2005, the estimated average annual distance travelled by NTS respondents increased by 61%, from 4476 miles to 7208 miles. This increase was largely accounted for by people making longer trips rather than more trips: the average annual number of trips increased by only 8%, from 956 to 1044, whereas the average length of each trip increased by 47%, from 4.7 miles to 6.9 miles. The average annual time spent travelling increased by 9%, from 353 hours (58 minutes per day) to 385 hours (63 minutes per day). Of the average 63 minutes per day in 2005, 39 minutes were spent travelling by car or van, 11 minutes walking and 0.8 minutes cycling (Figure 1). The small overall quantity of cycling conceals a large difference between the majority who do not cycle and the minority who do: the average cyclist reported five cycling trips and 107 minutes of cycling per week. [31]



Source: National Travel Survey 2005 [31]
Times recalculated from hours per year and some small categories merged

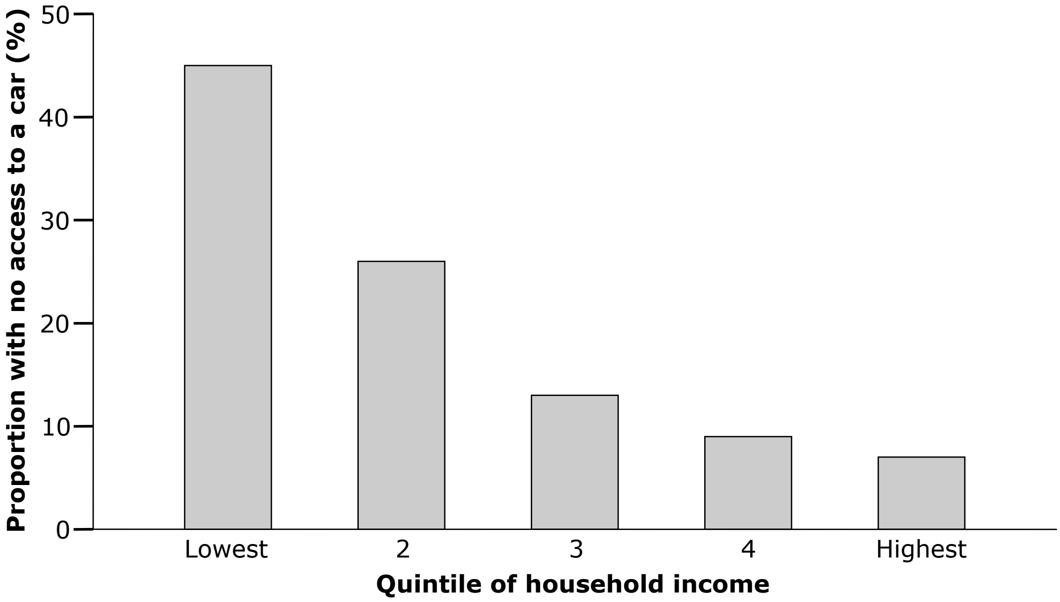
Figure 1. Average daily travel time by mode of transport

Mobility and mode share vary between population subgroups: women, younger people, people living in households without access to a car, and people in lower socioeconomic groups spend a greater proportion of their travel time using active modes and public transport and a lower proportion using cars. In 2005, for example, people living in households without access to a car made fewer trips, spent less time travelling and covered less distance than those living in households with access to a car (Table 1), but travelled an average of 273 miles per year on foot compared with 180 miles for those with access to a car; [31] a similar relationship between walking and access to a car has been shown for children using 2003 NTS data. [27] Between 1972 and 2005, the proportion of NTS respondents living in households without a car decreased from 41% to 19%; access to a car is strongly associated with household income (Figure 2). [31]

	Average total travel per person per year		
Cars available to household	Trips	Distance (miles)	Time (hours)
None	764	2954	310
One	1068	6696	379
Two or more	1143	9584	424

Source: National Travel Survey 2005 [31]

Table 1. Average total annual travel by number of cars available to household



Source: National Travel Survey 2005 [31]

Figure 2. Access to a car by quintile of household income

Most published analyses of mode share using NTS data are based on the concept of the *main mode* of each trip, i.e. the mode of transport used for the greatest proportion of the total distance of a given trip. For example, a trip in which most of the distance was covered on a bus is coded as a bus trip, even though it may also have included a substantial quantity of walking at one or both ends. Between 1995 and 2005, the average annual number of trips decreased slightly, from 1086 to 1044. Breaking trips down by main mode, the largest absolute decrease was in walking trips (from 292 to 245); there was also a decrease in cycling trips which, although small in absolute terms (from 18 to 14) was substantial in relative terms (a 22% decrease). Analysis of trips to and from school by main mode has shown an increase in car trips over the same period (from 29% of trips to 32%); among primary schoolchildren, this corresponded to a decrease in walking trips (from 53% to 49%), whereas among secondary schoolchildren it corresponded to a decrease in local bus trips (from 15% to 12%), reflecting the greater average distance travelled to secondary school. [31]

NTS data are continuously collected from large, representative population samples using consistent methods. The trends reported are therefore likely to be real. However, important limitations in these data have been recognised. NTS may not capture walking and cycling trips as comprehensively as it captures trips using motor vehicles, for two reasons. First, respondents are instructed not to report 'short' walking trips (less than one mile) except on the seventh day of the travel diary. Second, respondents are instructed not to record trips made 'off-road'; survey data therefore exclude trips on footpaths or off-road cycle paths, both of which may be used for walking and cycling as transport and not solely for recreation. It is therefore possible that some of the decline in walking and cycling trips captured in NTS could be accounted for by some of those trips having been shifted from public highways to off-road facilities. Nonetheless, it appears reasonable to conclude that the small increase in average total daily travel time since the 1970s conceals a large increase in longer trips made in motor vehicles and a decrease in shorter trips by active modes; that these trends occurred in parallel with increasing access to private cars; that the increase in motorised mobility has been concentrated among those with access to a private car, who are less likely to travel on foot than those who have no car; and that cycling makes a marginal contribution to overall travel.

Comparisons between cities and countries

It is a matter of common observation that walking and, particularly, cycling are more popular as modes of transport in some places than in others. Comparisons between cities or countries show large differences in the absolute quantities of walking or cycling or in the proportions of trips attributable to these modes of transport. The UK Commission for Integrated Transport (CfIT) reports Eurostat data for the then fifteen countries of the European Union (the EU15) in 1995: the average distance walked per person per year ranged from 387 km (Greece) through 415 km (UK) to 500 km (Denmark), and the average distance cycled per person per year ranged from 20 km (Spain) through 77 km (UK) to 901 km (Denmark). For both walking and cycling, most EU15 countries reported both a higher absolute average distance in 1995 and a larger relative increase (or smaller relative decrease) since 1990 than the UK. [35] Pucher and Dijkstra report mode shares for urban trips in 11 countries in Europe and North America, also in 1995: the mode share for walking ranged from 6% (United States) through 12% (England and Wales) to 29% (Sweden), and the mode share for cycling ranged from 1% (United States) through 4% (England and Wales) to 28% (Netherlands). [36] The European Union report on the Analysis and Development Of New Insight into Substitution of short car trips by cycling and walking (ADONIS) compares mode shares in selected cities in Belgium, Denmark, the Netherlands and Spain (time period not stated): the mode share for walking ranged from 4% (Brugge, Belgium) to 69% (Vitoria, Spain), and the mode share for cycling ranged from less than 1% (Barcelona and several other cities in Spain) to 35% (Groningen, Netherlands). [37] These differences are not limited to comparisons between the UK and other countries, or between cities outside the UK. The CfIT report also cites large differences in the active mode share (walking and cycling combined) between cities in the UK in 1991, for example between Newcastle (higher) and Leeds (lower) and between Cambridge (higher) and Brighton (lower). [35]

Although these differences are widely acknowledged and remarked upon in the transport literature, it appears difficult to explain the differences other than by appeal to 'commonsense' explanations or plausible but unproven hypotheses. For example, Pucher and Dijkstra cite the large differences in urban mode shares between selected countries at a single point in time as support for certain transport policy measures which apply in the countries with the highest mode shares for walking and cycling, but no analysis is shown to justify the implication that the policies are the cause of the observed mode shares. [36] Specifically, they do not address the possibility of reverse causality, i.e. that those countries have 'progressive' transport policies because they have historically high mode shares for walking and cycling; this possibility is admitted in the ADONIS report, which concludes 'It has not been possible to clear out what comes first: if many cyclists infrastructures [sic] give a higher share of cycling or if it is the other way around: many cyclists result in actuations to improve their conditions.' [37] Furthermore, the reports cited do not show that the methods for calculating mode shares in the different cities or countries under consideration were comparable; it is sometimes explicitly stated that the data are not strictly comparable. It is also not always clear precisely what group of trips constitutes the denominator for the stated mode shares. Nonetheless, it appears reasonable to conclude that there are substantial differences in mode shares for walking and cycling between cities and countries; that the UK has one of the lowest active mode shares in Europe; and that other countries, as well as certain cities within the UK, provide a precedent for claiming that it might be possible to achieve a higher active mode share.

All three reports identify numerous features of transport policy and infrastructure which characterise countries and cities with high mode shares for walking and, particularly, cycling, summarised as follows:

> … better facilities for walking and cycling, traffic calming of residential neighborhoods, urban design sensitive to the needs of nonmotorists, restrictions on motor vehicle use in cities, rigorous traffic education of both motorists and nonmotorists, and strict enforcement of traffic regulations protecting pedestrians and bicyclists. [36]

> … the regional and city-wide approaches to planning and operations which facilitate greater levels of co-ordination; the area-wide coverage of low (30 kph) speed limits and cycle networks that improve road safety and encourage take-up of walking and cycling; the scale of investment in transport infrastructure and revenue support for services; and the commitment to encouraging new

> mobility initiatives [such as car pooling and car sharing]. [38]
>
> … the effort and investment put into cyclists measures [sic] results in an important percentage of bicycle trips… in order to promote e.g. cycling in towns with no tradition for cycling and with a low share of bicycle trips, important road layout measures have to be implemented, in order to reserve space for these specific road users, and especially to protect them from the motorised road-users, who are not used to take [sic] them into account… What seems to be important is a continued network, such as some special attention in crossing points between different types of road users. [37]

These reports all make an explicit or implicit claim for a causal relationship between transport policy and mode share. In particular, there is a common theme concerning the importance of a transport infrastructure which favours active modes (e.g. 'cycle networks') and inconveniences car drivers (e.g. 'road layout measures'). Although this body of descriptive evidence does not provide satisfactory evidence of a statistical relationship, let alone a causal relationship, there is another body of evidence which goes somewhat further towards examining the plausibility of such claims.

1.5.3 Correlational evidence

There is a long history of research on factors which may explain why some people are more physically active than others. Until recently, this field was dominated by studies of individual demographic and psychosocial characteristics associated with physical activity, [39] reflecting the fact that efforts to promote physical activity often focused on sport, recreation or health-directed exercise and drew on techniques to encourage individual behaviour change. [40] However, as Owen and colleagues have argued, 'it is too easily assumed, given the focus of social cognitive models on constructs such as attitudes [and] self-efficacy… that conscious individual decision making is the primary determinant of behavioural choice'. [20] A recent systematic review of interventions in this field has also highlighted a lack of evidence that this type of intervention brings about sustained, long-term change and questioned whether the effects observed in the volunteers participating in randomised controlled trials of such interventions are generalisable to the wider population. [41]

The acknowledgment of the limitations of individual-level techniques of behaviour change has been accompanied by a growing interest in environmental factors, driven by a view that habitual patterns of behaviour are likely to be environmentally-cued and that sustained change depends on having a supportive environment in which people can be active. [20 42] Most research in this field has been cross-sectional, exploring the associations between physical activity and characteristics of the local environment such as patterns of urban land use, the design of residential neighbourhoods, perceived aesthetic quality, and the convenience of local amenities. [32] Terminology varies, but in view of the predominance of cross-sectional rather than longitudinal studies, Bauman and colleagues have recommended that the term 'environmental correlates' be used in preference to 'environmental determinants' in order to emphasise the limited causal inferences which can be drawn from such studies; this is the terminology I have chosen to use. [43]

It has not been possible to review all the primary studies in this rapidly-growing field. Instead, I have reviewed the ten most relevant and rigorous reviews of primary studies in this field published between 2002 and 2006 which I have been able to identify. Selected methodological characteristics of these reviews are summarised in Table 2, which shows that most adopted at least some characteristics of a systematic approach: typically, they reported their search strategy in at least moderate detail, made a limited attempt to take the internal validity of studies into account, and used a tabular rather than a statistical method to synthesise the strength of the evidence for each putative environmental correlate; one review included a meta-analysis.

These reviews also reflect a variety of perspectives on the research problem. Some reviewed literature in a single research field, such as physical activity or transport, while others drew on studies from more than one discipline, such as planning and public health. One was exclusively concerned with the perceived characteristics of the environment, while most considered both perceived and 'objective' characteristics (in this context, 'objective' is usually taken to mean ascertained by direct observation by a researcher or from spatially referenced routine data, rather than reported by survey respondents). Some drew on other reviews as sources of studies or sought to update previous reviews.

Some of these reviews examined the evidence for an association between characteristics of the physical environment and physical activity in general. The review by Trost and colleagues dealt mostly with individual and social correlates of physical activity, but also found 'sufficient' evidence for several environmental correlates including access to facilities, satisfaction with recreational facilities, neighbourhood safety, and enjoyable scenery. [39] Humpel and colleagues found that accessibility, opportunities for physical activity, and aesthetic attributes were all associated with physical activity, [44] while Wendel-Vos and colleagues found that the availability of physical activity equipment was 'convincingly' associated with vigorous physical activity and that accessibility and convenience of recreational facilities and availability of trails were 'possibly' associated with overall physical activity. [45] A more recent meta-analysis of the influence of perceived environmental characteristics concluded that after adjustment for individual characteristics, perceptions about the presence of physical activity facilities, pavements, shops and services, and the perception that heavy traffic was not a problem, were all significantly associated with physical activity. [46]

Other reviews examined the evidence for an association between characteristics of the physical environment and walking or cycling in particular. Saelens and colleagues reviewed evidence from the transport, urban design and planning literature and concluded that people living in communities with higher density, greater connectivity, and a greater mix of land uses reported higher rates of walking and cycling for transport than those living in low-density or poorly connected communities or those with a limited mix of land uses. [47] In this context, density refers to population density (residents per unit area); connectivity refers to the directness with which local journeys can be made, such that a neighbourhood with streets laid out in a grid system has greater connectivity than one based on cul-de-sacs which are not directly connected with each other; and mixed land use refers to the intermingling of different types of land use such as residential, commercial and public space in close proximity to each other, as opposed to their being deliberately separated, for example in a purely residential suburban development. Badland and Schofield came to similar conclusions, placing particular emphasis on mixed land use as the most important characteristic of urban design because of its influence on the accessibility and convenience of destinations. [48] Connectivity was also found to be 'convincingly' associated with active commuting by Wendel-Vos and colleagues. [45]

Owen and colleagues examined the association between environmental characteristics and walking: not just walking for transport, but also walking for exercise or recreation and walking in general. [20] They found that the environmental characteristics most strongly or consistently associated with walking varied according to the type of walking under consideration. For example, the aesthetic quality of the surroundings was associated with walking for exercise or recreation and with walking in general, but not with walking for transport; access to and convenience of facilities and destinations for walking were associated with all three categories of walking; and perceptions of traffic were associated with walking for transport and walking in general but not with walking for exercise or recreation. They described the overall body of evidence as 'modest but consistent', acknowledging that in many individual studies, the associations were not statistically significant. Also with respect to walking, Wendel-Vos and colleagues found 'possible' associations with availability of pavements and environmental aesthetics, but only among men. [45]

Handy found 'convincing' evidence of an association between the built environment in general and physical activity, but 'less convincing' evidence of which specific characteristics were most strongly associated. [21] However, she reported that almost all studies comparing 'traditional' or 'walkable' neighbourhoods with 'suburban' neighbourhoods found higher levels of active travel in the traditional neighbourhoods, and that the perceived aesthetic quality of neighbourhoods and the reported presence of pavements were strongly associated with walking.

The findings of Davison and Lawson with respect to children were broadly in agreement with those of the other reviews, which were mostly concerned with adults. [49] They found that children's physical activity was associated with the presence of pavements and of destinations within walking distance, access to public transport, low traffic density, and not needing to cross roads at uncontrolled junctions. They also found that the likelihood of walking and cycling to school decreased as the distance from home to school increased. Ferreira and colleagues, on the other hand, described heavy traffic and the need to cross roads as 'consistently unrelated' to children's physical activity. [50]

In summary, a growing (although still limited) body of evidence suggests that certain characteristics of the physical environment — some ascertained using 'objective' measures and others ascertained in terms of people's perceptions — may be associated with patterns of physical activity in general and walking and cycling in particular. Among the correlates most frequently identified in these reviews are the aesthetic quality of the surroundings, the presence of pavements, the convenience of facilities for being active, the availability of green space, access to amenities (destinations) within walking or cycling distance, safety from traffic and personal attack, and the lack of heavy traffic. Some of these local characteristics reflect higher-order aspects of urban design and policy such as density, connectivity and mixed land use.

However, the claims currently made in the scientific literature for the importance of environmental correlates are generally circumspect, exemplified by the conclusion of Giles-Corti and Donovan that access to a supportive physical environment may be a necessary, but insufficient, condition for an increase in physical activity in the population [51] and by the ecological model proposed by Saelens and colleagues on the basis of their review, in which individual socio-demographic characteristics, psychosocial factors and characteristics of the neighbourhood environment interact to influence walking and cycling both as modes of transport and as recreational activities. [47] This model is preliminary, and it is recognised that better models are needed of how the environment influences behaviours such as walking and cycling. [20]

Several other caveats should also be considered. First, instruments for measuring the perceived characteristics of the local environment are considered still to be in a comparatively early stage of development. [20 52 53] Second, most research in this field has been conducted in North America and Australia. [45] The urban and suburban settings of these studies are often different from those in the UK, as illustrated by the interest of researchers in those countries in the presence of pavements; it is unusual for streets in the UK not to have a pavement or footpath alongside them. Third, very few studies have satisfactorily addressed the possibility of reverse causality concealed by selection bias, i.e. the possibility that people who prefer to be more active choose to live in areas where the built environment already supports those preferences, although one recent study from California has found that the association between environment and behaviour persists after adjustment for individual attitudes and preferences. [54] Fourth, and perhaps most importantly, it has long been recognised in this field that finding a strong relationship between, for example, urban form and travel behaviour is only the first stage in analysis for public health purposes; identifying such relationships is not the same thing as showing that *changing* the built environment will lead to a change in travel behaviour, let alone a population increase in physical activity. [55 56]

Reference	Aim of review*	Identification of studies for inclusion	Reporting and handling of validity of studies	Synthesis and reporting of findings
Trost [39]	To review and update the research base on factors associated with physical activity in adults	Searched a small number of databases (databases, years of publication and search terms listed) and reference lists	Not reported	Tabulated the number of studies reporting a positive, negative or no statistically significant relationship for each environmental variable
Humpel [44]	To review the findings of quantitative studies of adults examining the associations of particular environmental attributes with physical activity behaviours	Searched a small number of databases (databases and search terms listed) for publications in English	Details of sample, measures, adjustment for confounders and results tabulated for all included studies (n=19)	Tabulated the number of studies reporting a positive, negative or no statistically significant relationship for each environmental variable
Saelens [47]	To provide a brief review of findings from transportation studies that have examined the relationship between neighbourhood environment and non-motorised transport	Searched one named database and 'other biblographic sources' including reference lists (three examples of search terms listed)	Studies divided into 'correlational' studies using multivariate regression models (n=4) and 'neighbourhood comparison' studies which did not adjust for confounders (n=10)	Tabulated summary outcome data for each study
Owen [20]	To review studies from the public health literature specifically addressing the environmental correlates of walking	Studies identified from a previous review (named), by searching databases (three examples listed, but not search terms). Unpublished studies also obtained from colleagues	Details of sample, study design, measures, adjustment for confounders and results tabulated for all included studies (n=18)	Tabulated the number of studies reporting a positive, negative or no statistically significant relationship for each environmental variable

* Some reviews also had other aims.

Table 2. Reviews of environmental correlates of physical activity

Review	Aim of review*	Identification of studies	Reporting and handling of validity of studies	Synthesis and reporting of findings
Handy [21]	To review and evaluate empirical evidence regarding the relationship between the built environment and physical activity behaviours	Studies identified from recently published reviews (listed), others published more recently (method of finding these not reported), reference lists and expert recommendations	Details of sample, measures, adjustment for confounders and results tabulated for all included studies (n=50), which were divided into higher and lower methodological tiers	Tabulated the number of studies reporting a positive, negative or no statistically significant relationship for each environmental variable, with greater weight given to higher–tier studies
Badland & Schofield [48]	To build upon previous reviews (listed) and other relevant academic literature to systematically draw together the evidence surrounding various urban design factors and physical activity behaviours	Not reported	Details of sample, setting, measures, adjustment for confounders and results tabulated for all included studies addressing neighbourhood effects (n=13)	Narrative, i.e. text only
Duncan [46]	To identify the strength and direction of relationships between characteristics of the perceived environment and physical activity	Searched a small number of databases (databases, years of publication and search terms listed) for publications in English. Studies also identified from reference lists and expert recommendations and by hand-searching relevant journals (listed)	Studies included only if they assessed the association between the perceived environment and physical activity using logistic regression and reported odds ratios and confidence intervals	Meta-analysis and estimation of pooled odds ratios
Davison & Lawson [49]	To examine the association between children's physical activity and environmental attributes (perceived and objectively measured)	Searched a small number of databases (databases, years of publication and search terms listed), reference lists and the internet for publications in English	Details of sample, study design, measures, adjustment for confounders and results tabulated for all included studies addressing neighbourhood effects (n=33)	Tabulated the number of studies reporting a positive, negative or no statistically significant relationship for each environmental variable

* Some reviews also had other aims.

Table 2. Reviews of environmental correlates of physical activity (continued)

Review	Aim of review*	Identification of studies	Reporting and handling of validity of studies	Synthesis and reporting of findings
Ferreira [50]	To review and update the evidence provided by a previous review, characterising in more detail the environmental correlates of physical activity in children and adolescents	Searched a small number of databases (databases, years of publication and search terms listed) for publications in English. Studies also identified from reference lists and authors' files	Details of sample, setting, study design and measures tabulated for all included studies (n=150). Results from multivariate models, where available, extracted in favour of those from univariate models	Tabulated the number of studies reporting a positive, negative or no statistically significant relationship for each environmental variable
Wendel-Vos [45]	To gain insight into which environmental factors have been identified in the scientific literature as potential determinants of various types and intensity of physical activity (excluding occupational physical activity) among adult men and women	Searched a small number of databases (databases, years of publication and exact search syntax listed) for publications in English, Dutch or German	Details of sample, setting, study design and outcomes tabulated for all included studies (n=47). Results from multivariate models, where available, extracted in favour of those from univariate models	Tabulated the number of studies reporting a positive, negative or no statistically significant relationship for each environmental variable

* Some reviews also had other aims.

Table 2. Reviews of environmental correlates of physical activity (continued)

1.5.4 Intervention evidence

The descriptive and correlational evidence cited above suggests a variety of characteristics of the built environment (including transport infrastructure) and transport policy which may be associated at the population level with higher mode shares for walking and cycling in towns, cities or countries and at the individual level with walking, cycling, or overall physical activity. These types of evidence do not, however, provide convincing evidence on their own to support any assumption that interventions intended to change those characteristics will necessarily bring about a modal shift.

A further step towards providing such evidence has been taken by the cumulation of collections of case studies of 'successful' intervention projects. When I began the work reported in the thesis, several such collections had recently been published or were in progress, typically concerned with one particular aspect or technique of influencing modal shift such as personalised journey planning, workplace travel plans, or the journey to school. These exercises in the cumulation of evidence range from the apparently uncritical repetition of the 'headline' achievements of projects held to represent best practice to a more detailed critique and comparison of the results from different projects. [57-61] However, none of these collections involved a clear endeavour to be systematic, either in the identification of case studies for inclusion or in the critiques made of the methods used in the case studies. The approach adopted perhaps reflects a primary aim of assembling examples of optimal results in order to estimate the theoretical potential of different approaches and influence policy — often based on projects at comparatively small scale, such as at a single workplace or school — rather than a primary aim of critically examining the evidence for the effects of interventions at the level of the population.

From the perspective of public health research, it is increasingly recognised that the most robust evidence for the effects of interventions may be derived from systematic reviews of intervention studies. This theme will be developed fully in Chapter 2. When I began the work reported in this thesis, Morrison and colleagues had recently completed a systematic review of existing systematic reviews of the health effects of interventions in the transport sector. [62] They found 28 systematic reviews which met their inclusion criteria, all but four of which were concerned with interventions to improve the safety of motor vehicles. The predominance of injury reduction as a theme within this body of evidence reflects the history of research on transport and health to which I referred above (Section 1.3). Despite searching widely, Morrison and colleagues did not identify any systematic review which had examined the effects of interventions on mode choice or physical activity.

Systematic reviews of interventions in the field of physical activity research did not appear to have addressed this question either. When I began the work reported in this thesis, the Task Force for Community Preventive Services in the United States (US) had recently published its now widely-cited systematic review of the effects of interventions to promote physical activity. [63] Although this systematic review was restricted to studies published in English, it had comparatively generous inclusion criteria and sought to cover a wide range of approaches to promoting physical activity, including environmental and policy approaches. However, the main report of this systematic review (published in 2002) included no evidence about the effects of transport interventions. An extension to this systematic review was established to investigate the effectiveness of policies and practices in urban design, land use and transport, but this was not published until 2006. [64] Another systematic review in this field, published in 2004, examined the effects of 'changing the environment'. [65] Of the 17 studies included in this review, 14 assessed the effectiveness of prompts such as posters to encourage people to climb stairs; only three involved physical modification of the environment as such, of which only one was directly concerned with the promotion of active travel. [66] In the following year, another systematic review of 'environmental interventions' confirmed the field to be dominated by studies of prompts [67] and a systematic review of systematic reviews for the Health Development Agency reported that 'At present, no review-level evidence of the effectiveness of interventions aimed at changing policy or the built environment on physical activity is available', despite having included 16 systematic reviews published between 1996 and 2003. [68] The most recent systematic review in this field, undertaken for the National Institute for Health and Clinical Excellence (NICE) to support the development of intervention guidance, examined the effectiveness of community-based walking and cycling programmes: for cycling programmes, no studies were deemed suitable for inclusion, and for walking programmes, only four studies were included, none of which was directly concerned with promoting walking as a mode of transport. [69]

1.6 The need for evidence to inform policy

In 1999, ministers responsible for health, transport and the environment in European member states of the World Health Organization (WHO) signed a charter in which they recognised that 'cycling and walking… offer significant positive health gains; however, these transport modes have often been overlooked in planning and decision-making.' In a critique published by WHO a year later, Dora and Phillips also noted that 'health issues are not sufficiently included in… governments' decisions about the way cities are organized and transport infrastructure is constructed.' [70] However, the 1999 charter did appear to signal something of a change in policy. The charter included specific undertakings to:

> … promote safe and environmentally friendly cycling and walking by providing safe infrastructure and networks, implementing measures for traffic management, enforcing speed controls and speed limits that are appropriate to local circumstances, and designing roads and settlements taking into account the needs of pedestrians and cyclists.
>
> Reduce the need for motorized transport by adapting land use policies and urban and regional development plans to enable people to have easy access to settlements, housing and working areas, and shopping and leisure facilities by cycling, walking and public transport. [71]

These policy commitments clearly reflect the evidence from descriptive and correlational studies discussed in this chapter and are mirrored in transport policy at national level. Despite the lack of evidence from intervention studies, at the time when I began the work reported in this thesis the assumption that interventions such as those outlined in the charter would bring about a modal shift appeared widespread in transport policy circles. This is exemplified by the summary of the Department for Transport's white paper *A new deal for transport: better for everyone,* published in 1998:

> Local transport plans will set targets for increasing walking and cycling. These *will be achieved by* such things as giving priority at junctions to reduce waiting times, maintaining cycle lanes and footpaths properly and reallocating road space to cyclists and pedestrians where appropriate. Safe crossings and secure cycle parking at shops and stations can all help make a significant shift in local travel patterns. [Emphasis added] [72]

No evidence was cited in the white paper to justify the assertions made in this paragraph. Admittedly, as Killoran and colleagues have pointed out in a recent evidence briefing for NICE, policy documents tend not to spell out the putative causal links between interventions and outcomes; nonetheless, they described the transport field as one in which 'development of policy has outpaced development of the evidence base'. [73] This critique mirrors the more general observation made by Wanless in his 2004 report *Securing good health for the whole population*, namely that relatively little is known about the likely health impact of interventions to influence any of the wider determinants of population health. [74] Wanless recommended that 'every opportunity to generate evidence from current policy and practice needs to be realised' — a theme which will be developed in Chapter 6.

The lack of evidence about the effects of interventions is not the only barrier to achieving modal shift through changes in transport policy and infrastructure. Dora and Phillips' concerns about the limited attention given to walking, cycling and health impacts in transport planning are neither new — they were, for example, highlighted by Hillman and colleagues in their study of everyday travel in the UK in 1976 [75] — nor yet satisfactorily addressed, because health improvement is not, and is unlikely to become, the primary aim of transport policy. The potentially conflicting aims of transport policy are illustrated by the new national transport strategy for Scotland published in 2006, in which the 'number one priority' is unambiguously identified as the promotion of economic growth; achieving this aim is seen to depend primarily on improving the strategic transport network, especially the motorway and trunk road network. [76]

The potential contribution of the promotion of active travel to increasing physical activity in the population has also become a major theme of recent policy and strategy documents such as the physical activity strategy for Scotland *Let's make Scotland more active*, published in 2003, [16] and the physical activity action plan to support the 2005 public health white paper for England, *Choosing Health*. [77] For example, *Let's make Scotland more active* identifies as a strategic objective 'To develop and maintain long-lasting, high-quality physical environments to support inactive people to become active', going on to explain that 'Environmental policies are essential... A good example of this is the current use of ring-fenced resources... in the public transport fund to support development that helps people to walk and cycle.' The physical activity action plan for England promises that:

> Opportunities will be created by changing the physical and cultural landscape — and building an environment that supports people in more active lifestyles. We need to provide choice and a range of options so that people can be active on a daily basis. Choices to build everyday activity into daily routines such as walking to the shops and cycling to school… [77]

Although these strategic commitments in health policy appear to mirror parallel commitments being made in transport policy, a recent examination of 'joined up policy and practice' between the transport and health sectors in Scotland has found that significant progress remains to be made, both in convincing transport planners of the importance of considering the health impacts of transport policy and practice and in generating evidence about the cross-sectoral costs and benefits of interventions. [78] The publication of *Choosing Health* in 2004 also highlights another unresolved tension in this cross-sectoral policy field. Much of the emphasis of the WHO charter was on the responsibility of governments to exercise control by intervening in the transport sector, for example by restricting the use of motor vehicles or reallocating road space for use by pedestrians and cyclists, whereas *Choosing Health* exemplifies a more recent emphasis of health policy, particularly in England, on the responsibility of individuals to exercise healthy choices — an emphasis which is mirrored, to some extent, by the interest taken by the Department for Transport in promoting 'smarter choices' in travel behaviour through 'soft measures' rather than the 'hard measures' of, for example, traffic calming. [61] These alternative approaches not only reflect differences in ideology but may also depend on different theories of how behaviour change can be brought about. It remains to be seen whether the pursuit of the 'choice agenda', which has been criticised as having 'little or no place in public health', [79] is a more or less effective means of promoting a modal shift than the previous emphasis on the responsibility of the state to intervene to change the social determinants of health, as outlined at the beginning of this chapter.

1.7 Conclusions

Changes to transport policy and infrastructure which may promote a modal shift from using cars towards walking and cycling have the potential to change the population distribution of a putative determinant of health and therefore constitute at least putative public health interventions. The potential health benefits of such a modal shift include those associated with a reduction in the adverse health effects associated with motor traffic. A particular causal association can be hypothesised which links a modal shift to an increase in the population level of physical activity and thereby an improvement in health on account of the reduction in risk of many chronic diseases.

Promoting such a modal shift would help to meet policy objectives in both the health and the transport sectors and is mentioned as a desirable goal in recent policy documents in both sectors. Many different interventions have been advocated to achieve this end. However, the putative causal chain linking interventions in the transport sector to modal shift and a consequent increase in physical activity and improvement in health has not been clearly established. Examples can be identified of cities and countries which have high mode shares for walking and cycling and also have certain types of transport policy and infrastructure, and there is a growing body of cross-sectional evidence of associations between environmental characteristics and patterns of walking and cycling and of physical activity in general. However, the evidence about the effects of interventions that might promote a modal shift has not previously been systematically examined. In the absence of such an examination, it is possible that measures have been advocated based largely on the unproven assumption that because they are intended to produce the desired outcome, they will do so and should therefore be introduced. As Petticrew and Macintyre have argued, it may be unwise to base public policy on ‘good intentions and received wisdom’ of this kind; they cite several examples of well-meaning policy interventions which had unexpected undesirable effects. [80]

I therefore began my investigation by systematically reviewing the available evidence to address the question: what are the effects of interventions to promote a modal shift from using cars towards walking and cycling?

2 Systematic review: introduction

2.1 Overview of this chapter

In Chapter 1, I outlined the background to the topic area for the thesis to establish its significance for public health and demonstrate the need for a systematic review of the effects of interventions. In this chapter, I begin by reviewing the general rationale for the systematic review as a research method. I go on to outline key methodological principles currently advocated for the conduct of systematic reviews of the effects of interventions in the health sector. These principles are not necessarily readily transferable to systematic reviews addressing broader questions about the effects of interventions which may influence the wider determinants of health. I therefore review these principles in the light of critiques made by authors in a variety of disciplines in order to form a more balanced overview of current thinking about how such 'public health' systematic reviews might best be done. I conclude by outlining the aims for my own systematic review, which forms the first study of this thesis. These aims address both substantive research questions about the effects of interventions in the chosen topic area and methodological research questions about the systematic review process.

2.2 Rationale for a systematic review

2.2.1 The value of cumulating research evidence

No individual piece of scientific research either stands or should be regarded in isolation. There is a well-established academic tradition of reviewing the available literature in a given field, for which several rationales may be proposed. [81] One is as a precursor to a new piece of research: to draw on the methods and findings of others, place one's own research in context and avoid duplication. Another is to establish a more general research agenda by identifying what research has and has not been done. However, it has also been argued that as well as providing context and direction for a new piece of research, reviewing the existing literature can make a more directly scientific contribution in its own right: in other words, that science should be understood as a fundamentally cumulative activity and that new scientific knowledge can be created by cumulating existing literature. [82]

Various approaches have been taken to the cumulative review of scientific literature, of which Badger and colleagues have described three: reviews written by experts in a given field, which may rely heavily on the judgment and preferences of that expert as to what evidence should be included; 'trawls' of literature (for which the authors may be 'secretive about their fishing grounds') which may identify literature that is interesting but not necessarily representative; or accounts of an individual researcher's intellectual journey. [81] Some authors use the term *narrative review* to refer to literature reviews of these kinds.

2.2.2 The need for a systematic approach

While each of these approaches has its merit, it is increasingly recognised that — at least in some circumstances — a more systematic approach may have greater merit. Particularly when addressing questions about the effects of interventions, both pragmatic and ethical reasons have been advanced in favour of a systematic approach. [81] The pragmatic reasons stem from the 'information explosion' by which more and more information, such as the results of individual research studies, is available with greater and greater ease. This has two main implications. First, individuals find it more difficult to keep up with the research in a given field and therefore come to rely more heavily on reviews to make sense of and apply that research; it is argued that single 'atomized' and 'unsynthesized' research studies are of little use on their own for these purposes [82] and that it is more efficient for decision-makers to rely on syntheses of such studies produced by others. [83] Second, in the face of a potentially overwhelming quantity of available evidence, those conducting reviews need to be more selective about which pieces of evidence they choose to include. The ethical reason stems from a recognition of the potential limitations of either relying on the findings of single, high-profile studies, which are potentially misleading, [83] or relying on a 'narrative' approach to cumulating evidence, as itemised (for example) by Slavin: 'narrative' reviews may be dominated by literature which happens to be easily accessible to the author (the so-called 'file-drawer problem') rather than based on an exhaustive search for all relevant literature; decisions about which pieces of evidence to include may be susceptible to bias related to the prejudices of the author; and the weight or credibility which particular findings are deemed to contribute to the overall balance of evidence may not be related to the strength of the research from which those findings were obtained. [84]

In order to address these concerns, an approach to literature review known as the *systematic review* has developed. Particularly in the health sector, the systematic review is now increasingly seen as the most robust way of synthesising evidence about the effects of interventions; it is seen as potentially valuable not only as a precursor to a new piece of research, but also as well as or, sometimes, instead of undertaking more primary research studies. This is illustrated in the CONSORT statement, to which many leading medical journals subscribe, which recommends that the report of any new randomised controlled trial should ideally include justification of the need for the trial by reference either to an existing systematic review of previous trials or to the absence of previous trials. [85] The recognition of the value of systematic reviews is not limited to the arena of clinical or health service interventions; in recent years, there have also been frequent calls for more and better systematic reviews of evidence about the effects of interventions to improve population health. [74 86-88]

2.3 The nature of a systematic review

2.3.1 Definition and purpose

Reviewing the history of the field in general, Chalmers, Hedges and Cooper identify several examples of work done before the twentieth century which might retrospectively be described as systematic reviews, but go on to show that the approach was mainly developed in the twentieth century, particularly in the years following World War II. [82] They note that the use of terminology has not been consistent over time or between disciplines: *research synthesis* was favoured by some early pioneers in the social sciences, whereas *systematic review* has became popular more recently, particularly in the health sector. An alternative term, *evidence synthesis*, also has currency in some circles. In this thesis, I use the term *systematic review* because that is the term with greatest currency in intervention research in health in general and in public health in particular. From this point onwards, I use the term exclusively to refer to the systematic review of evidence derived from quantitative, outcome-oriented, evaluative studies of the effects of interventions. The systematic review of other types of research evidence — such as aetiological epidemiology or qualitative research — lies outside the scope of the thesis, as does the integration of diverse types of evidence, for example using the methods of realist synthesis described by Pawson and colleagues, [89] or those of the Evidence for Policy and Practice Information and Coordinating Centre (EPPI-Centre) at the University of London for the integration of quantitative and qualitative evidence. [90]

The systematic review has been described as 'a method of locating, appraising and synthesising evidence' [91] which 'facilitates the management of increasing amounts of information by separating redundant and irrelevant information from the rest in a critical, replicable fashion'. [92] From an epidemiological perspective, the systematic review can be understood as an observational study, not of a population of human beings but of a population of individual research studies. [93] When applied to evidence about the effects of interventions, a systematic review may help to address a variety of objectives: to produce general statements about the effects of interventions; to resolve uncertainties about effects (such as the balance between beneficial and harmful effects); or to answer questions which cannot be addressed within a single research study but depend on examining differences between studies. [94 95]

A more instrumental view of the purpose of a systematic review is that it should 'gather, summarize and integrate empirical research so as to help people understand the evidence' and 'help people make practical decisions about... interventions and public policy'. [94] A frequently-cited example is the case of treatment for myocardial infarction. In a retrospective analysis, Antman and colleagues compared the evidence of effectiveness which could have been obtained from a cumulative meta-analysis of the data from all completed randomised controlled trials (had such trials been systematically reviewed) with the advice published in contemporary general medical textbooks and review articles. They showed that experts had continued to recommend treatments which a systematic review would have shown to be ineffective or potentially harmful, and that they had not begun to recommend treatments which a systematic review would have shown to be effective. [96]

2.3.2 A research activity

Kleijnen has pointed out the congruence between definitions of a systematic review and a typical dictionary definition of research, which refers to studying sources, collating 'old facts', systematic and critical investigation, and reaching new conclusions. [97] In contrast to the 'narrative' approach to literature review described earlier in this chapter, therefore, advocates and practitioners of the systematic review see it as constituting original research in its own right. A systematic review involves a series of activities analogous to those of any other scientific investigation. These include formulating a research problem, collecting relevant data, analysing and interpreting the data, and reporting the findings, endeavouring to use transparent and replicable scientific methods throughout the process. [82 98]

2.4 Methods for a systematic review

Chalmers and colleagues identify an important distinction between two streams of methodological development in the field. [82] One is the development of methods to reduce the imprecision of results by pooling the outcome data from multiple studies, of which the most frequently-used example is the technique of *meta-analysis* first described by Glass in the mid-1970s. [99] The other is the development of methods to reduce bias in the cumulation of evidence. It has been suggested that because the development of methods to reduce imprecision (particularly meta-analysis) preceded the development of methods to reduce bias, 'meta-analysis' is sometimes used to refer to the whole process of a systematic review. However, Chalmers and colleagues recommend reserving this term for the statistical pooling of outcome data, recognising that it is only one possible method of handling the data generated in a systematic review; the same distinction is also made clear in the definitions given in Last's dictionary of epidemiology. [100] Chalmers and colleagues note that the systematic review involves many more methodological issues than the choice of method for pooling outcome data, and identify a growing recognition of a need for methodological rigour in the other parts of the process, just as for any other type of research; [82] this recognition is illustrated by the work of the Task Force on Community Preventive Services, which summarised its objectives in developing methods for the Community Guide suite of systematic reviews of public health interventions in terms of reducing bias, increasing reliability and maintaining objectivity, rather than in terms of reducing imprecision. [101]

Although health is now one of the sectors in which the systematic review has achieved the greatest impact, the synthesis of evidence of effectiveness developed later in the biomedical sciences than in some of the social sciences. Chalmers and colleagues trace the serious development of the systematic review in health to Cochrane, who drew attention to the lack of a 'critical summary' of randomised controlled trials in 1979. [82 102] Since then, and especially since the 1990s, the systematic review enterprise in health (particularly in health care) has grown rapidly, both in terms of the number of systematic reviews and in terms of the development of methods, methodological guidance and organisational frameworks to support the production of systematic reviews. This is epitomised by the Cochrane Collaboration, which was begun in 1993 and under whose auspices over 2500 systematic reviews have now been published. [103] The Cochrane Collaboration and the Centre for Reviews and Dissemination (CRD), among others, have published detailed and authoritative guidelines on how to undertake systematic reviews of the effects of interventions. [104 105] (In social policy, the Campbell Collaboration — a 'sibling' organisation to the Cochrane Collaboration — now also promotes systematic reviews of the effects of interventions, [98] but has not yet published detailed methodological guidance.) These guidelines address all components of the systematic review process. I have not attempted an exhaustive account of these, but I have considered four particular components which are particularly relevant to this thesis:

1. Defining admissible evidence
2. Searching for the evidence
3. Appraising the evidence
4. Synthesising the evidence.

In each of the sections which follow, I outline what may be considered 'conventional' methods for the systematic review of studies of the effects of interventions, as reflected in current Cochrane and CRD guidelines, and then reflect on the application of those methods in public health. After I had completed the systematic review reported in this thesis, the Cochrane Health Promotion and Public Health Field published additional guidance to which I also refer in places. [106 107] Some areas of public health practice, such as immunisation or screening, involve comparatively discrete and replicable interventions whose effectiveness can readily be studied using 'conventional' methods developed for the assessment of clinical interventions. However, systematic reviews of more complex public health interventions are more methodologically challenging, [108] and if the research question concerns the health effects of interventions in the broader area of social policy, these challenges become greater. First, the 'conventional' methods — and the positivist epistemological position that underlies them — are less widely accepted as a means of generating evidence in the social sciences than in the biomedical sciences. [109 110] Second, even if the principles of the 'conventional' approach are accepted, it can be difficult to apply them to studies of interventions that are often complex, highly contextual, or not amenable to the types of study design usually accorded high status in the health research community. [109 111]

2.5 Defining admissible evidence

In this section I consider selected aspects of how the research question for a systematic review is framed and how evidence is selected for inclusion.

2.5.1 Breadth of research question

Researchers designing systematic reviews of intervention studies are typically advised to specify their research questions in terms of four or five facets: the interventions, the populations receiving the interventions, the outcomes of interest, the comparisons to be made, and the study designs deemed worthy of inclusion. [106 112] For example, the CRD guidelines offer the following example:

> Population: Patients undergoing hip replacement
> Interventions: Antimicrobial prophylaxis versus placebo
> Outcomes: Post-operative infection and cost per infection prevented
> Study designs: Placebo-controlled randomised controlled trials and relevant economic evaluations. [113]

The Cochrane handbook characterises some (perhaps most) systematic reviews as addressing comparatively narrow research questions in which each of these facets may be tightly defined, as in this example. However, it also acknowledges that each facet need not necessarily be defined with equal precision, that a systematic review may legitimately address a much broader research question, and that this may be preferable to a 'narrow' review in some circumstances: for example, a narrowly-focused systematic review may produce findings which are not generalisable to multiple settings or populations, or may be at risk of bias if the question is framed in such a way as to exclude studies of a particular class of intervention whose results are already known to conflict with the reviewer's personal beliefs or prejudices. [112] The handbook for Cochrane reviewers examining health promotion or public health interventions also suggests that a review addressing a broad question ('lumping') may be more useful to those making policy decisions than a review addressing a narrow question ('splitting'). [106] On the other hand, it is acknowledged that searching for, synthesising and interpreting the data for a broad review may be more time-consuming and challenging than for a narrow review. [112]

2.5.2 Hierarchy of study design

Many systematic reviews, particularly among those published in the Cochrane Library, only consider evidence from randomised controlled trials (RCTs) to be admissible. [112] The privileged status accorded to the randomised controlled trial reflects a hierarchy of study design or methodology (often referred to as a 'hierarchy of evidence') [81 114] which has become strongly established as a means of discriminating between intervention study designs on the basis of their internal validity, i.e. their resilience to bias in estimating the effect of an intervention. Many versions of this hierarchy have been formulated. A typical example appears in the CRD guidance:

1. Experimental studies (e.g. RCT with concealed allocation)
2. Quasi-experimental studies (e.g. experimental study without randomisation)
3. Controlled observational studies
4. Observational studies without control groups
5. Expert opinion based on pathophysiology, bench research or consensus. [115]

In this version, the third level — 'controlled observational studies' — is subdivided into cohort studies and case-control studies, the former taking precedence; however, even including this distinction may not go far enough in discriminating between the wide range of potential study designs usually subsumed under 'quasi-experimental' or 'observational' headings. [111] Other versions of the hierarchy include a higher level for systematic reviews; prioritise randomised controlled trials with 'definitive' results over those without; or include a lower level for 'anecdotal' evidence. [116]

The principle of admitting only randomised controlled trials into a systematic review therefore reflects a desire to minimise bias and is based on theoretical, empirical and pragmatic arguments. The theoretical argument is that randomisation is the only (or, at least, the best) way to control for potential confounding factors which are not known to and measured by the investigators in an intervention study. [117] The empirical argument is based on the findings of comparative analyses such as that of Kunz and Oxman [118] showing that, on average, non-randomised or observational studies tend to produce larger estimates for the size of the effect of an intervention than randomised studies do. [119] The pragmatic argument is that more effort is required to identify non-randomised studies. [117]

However, the Cochrane handbook also recognises that adopting this approach can compromise the relevance of a review, and asks (but does not answer) the question 'How far is it possible to achieve a higher level of relevance by including evidence other than that derived from RCTs without violating the central principle: minimising bias?' [119] There is comparatively little dissent from the theoretical argument in favour of the randomised controlled trial design as a means of minimising bias. With respect to the empirical argument, however, the Cochrane handbook acknowledges that the conclusions of comparative studies vary; [119] many of the comparative studies have themselves been criticised for significant methodological weaknesses, [111] and some, such as those of Benson and Hartz [120] and Concato and colleagues, [121] have found little difference in the estimated effect sizes from RCTs and observational studies. [122] The pragmatic argument that finding non-randomised studies requires more effort is somewhat circular, in that the Cochrane Collaboration has always prioritised the identification of controlled trials and has therefore invested great effort in compiling a central register (CENTRAL) of these, but not of other types of study. [123]

2.5.3 Flexibility of inclusion criteria

It is increasingly recognised that an approach to selecting studies based on the 'hierarchy of evidence' may rely too heavily on study design as a marker of the overall validity or utility of individual research studies. [124 125] This is of particular concern from a public health perspective because, it is argued, excessive deference to such a hierarchy may tend to favour interventions most amenable to certain types of study design, particularly those with a medical rather than a social focus and those that target individuals rather than populations. [111] Concern has been voiced that those interventions which are most likely to influence the wider determinants of health, and thereby influence the greatest number of people, are those about whose effectiveness the least is known — a phenomenon for which the term 'inverse evidence law' has been coined. [126 127] Applying the additional filter of insisting on certain types of study design has the potential to introduce additional bias: this has been described as 'methodological imperialism' that could distort, rather than strengthen, the evidence base by focusing attention on certain approaches to health improvement which happen to be more amenable to randomised or controlled study designs and dismissing other approaches which may be equally, or more, effective simply on the grounds that other study designs have been used to evaluate their effectiveness. [109 128] In a systematic review of interventions to reduce serum cholesterol, Peersman and colleagues showed how admitting a wider range of study designs resulted in a greater range of interventions which could be recommended as 'effective' than those which would have been identified in a systematic review of randomised controlled trials. [129]

These concerns do not, however, necessarily reflect dissent from the propositions that well-conducted randomised controlled trials may have fewer threats to internal validity than other study designs and that it may be feasible to study the effects of many 'public health' interventions using randomised controlled trials. On the contrary, it is possible — at least in theory — to allocate many types of 'public health' intervention randomly between different schools, neighbourhoods, cities or jurisdictions, and it has been argued that randomised controlled trials of such interventions should be conducted where possible. [111] However, in conducting systematic reviews of currently-available evidence, it has to be recognised that many interventions of interest to public health have not been studied, and in some cases cannot realistically be studied, in this way for a variety of reasons (discussed further in Chapter 6). [130 131] There are precedents within the Cochrane Library for varying the inclusion criteria for study design according to the nature of the available evidence. For example, although some reviews conducted and published under the auspices of the Cochrane Tobacco Addiction Group are restricted to RCTs, those concerned with interventions at community or population level include other study designs including, in some cases, observational studies without control groups. [132 133] The decision to include a wider range of study designs may be interpreted or justified in different ways, even within the same organisation. For example, the *handbook* of the Cochrane Health Promotion and Public Health Field reflects the orthodox Cochrane position, recommending that 'Where RCTs are lacking… other study designs… should also be considered for inclusion'. [106] As Pawson has observed, this position implies a *post hoc* lowering of the usual high 'quality hurdle' of the randomised controlled design to enable the 'systematic review aeroplane' to take off at all, albeit with 'quite a few nuts and bolts untightened'. [134] On the other hand, the *guidelines* issued by the same organisation in the same year cite Glasziou and colleagues [125] in recommending that 'The criteria used to select studies should primarily reflect the question/s being answered in the review, rather than any predetermined hierarchy.' [107] This position implies the possibility that one might decide *a priori* to include a wide range of study designs, rather than only doing so because one has no choice.

The tension between the stringency of inclusion criteria based on study design and the relevance of the evidence thereby admitted to a systematic review raises a further question as to whether it is necessary or desirable to specify the inclusion criteria in full at the outset. Both Cochrane and CRD guidance lay strong emphasis on the importance of preparing (and, in the case of the Cochrane Collaboration, submitting for peer review) a detailed protocol for a systematic review which sets out in detail the procedures that will be followed — another example of the way in which the systematic review is approached in the same way as any other piece of scientific research. [113 135] However, others have acknowledged that it may not always be possible to specify inclusion criteria in advance [93] and that a more appropriate definition of what studies are 'relevant' for a particular systematic review may emerge through a time-consuming, extended and iterative process of searching, scanning, refining criteria, and further searching. [89 136] Hammersley has critiqued the use of fixed and standard criteria on the ground that it ignores the need to make a contextually-sensitive judgment about the validity of the findings of particular studies; while he acknowledges that different study designs have different advantages and disadvantages, he notes that no study design is better than the others in all respects, since stronger internal validity is often achieved at the cost of weaker external validity. [137] Drawing an analogy with a legal principle, Slavin has argued that 'the same evidence that would be essential in one case might be disregarded in another because in the second case there is better evidence available'. [84] In other words, one might choose to exclude evidence from certain types of study if there were sufficient evidence from preferred study designs to address the research questions, but in the absence of sufficient evidence from higher levels of the 'hierarchy of evidence' one might then consider admitting evidence from other study designs. Slavin argues for a 'best evidence' approach in which the most important criterion for including studies should be their relevance to the research question; although he still regards methodological adequacy as important, he does not regard study design as the overriding concern in this regard. [84]

2.6 Searching for the evidence

In this section I consider selected aspects of how the search for evidence is conducted, focusing on the use of electronic literature databases and on methods for identifying 'grey' or 'fugitive' literature.

Designing the search strategy for a systematic review involves a trade-off between the breadth of coverage (reflecting the sensitivity of the search) and the efficiency of searching (reflecting its specificity). [93 138 139] The aim is generally understood as being to identify as many research studies as possible that may be relevant for inclusion in the review (ideally *all* relevant studies, since this is a characteristic which is held to distinguish a systematic review from a 'narrative' review [100 105]) by searching as comprehensively as time and other resources permit. The particular importance of finding and including 'difficult-to-locate' intervention studies in public health has been acknowledged [140] and reflects a recognition that failure to do so increases the susceptibility of a review to *publication bias*. Publication bias may take a number of forms, enumerated (for example) by Howes and colleagues as database bias, language bias and grey literature bias, arising from decisions to restrict the search to journals indexed in particular databases or published in particular languages or from a failure to search for material not published in academic journals. [140]

2.6.1 Searching electronic literature databases

The main source of evidence for most systematic reviews is electronic literature databases. In practice, the number of databases searched varies widely between reviews; in an analysis of a sample of Cochrane reviews, Royle and Milne found that between one and 27 databases had been searched for each review. [141] This analysis, which was limited to systematic reviews of clinical trials, found that most trials had been found by searching one of four key databases (the Cochrane Controlled Trials Register, Medline, EMBASE, and the Science and Social Science Citation Index) and that searching an additional 26 databases contributed only 2.4% of the total number of trials identified. This suggests that the optimal trade-off between sensitivity and specificity may be obtained by thoroughly searching only a few databases, coupled with other strategies to identify additional unpublished studies (discussed below).

However, the fact that some systematic reviews had involved a search of many databases suggests at least a perceived need to search more widely than the 'big four' databases identified by Royle and Milne. This may be driven by the recognition that there is substantial non-overlap between databases in their coverage, even of important journals within biomedical research. [123] Even where a database such as Medline does yield many of the relevant studies for a review on a clinical topic, the value of searching a wider range of databases has been acknowledged: the authors of systematic reviews on topics including risk communication in primary care, [138] exercise therapy in cancer, [139] acupuncture, [142] lipid-lowering agents [142] and nutritional supplementation following hip fracture [143] have all reported the importance for their reviews of studies found only by searching other specialist databases. The limitations of major biomedical databases are likely to be even greater when searching for evidence about 'public health' interventions. A substantial minority of journals relevant to public health are known not to be indexed in Medline; [140] in a cross-disciplinary topic area, it may be particularly important to search a large number of databases. [138 139 144]

Searching multiple databases does not simply involve applying the same search terms in the same way in each database, and is acknowledged to be time-consuming. [144] One problem is the variety of interfaces by which databases may be searched; although some biomedical databases such as Medline and EMBASE can be searched simultaneously using a common interface such as Ovid, this is not true across the range of databases of literature in other disciplines, each of which may have to be interrogated using interfaces with different technical configurations and syntactical requirements. Another problem is that terminology and the quality of indexing and abstracting vary widely between databases and disciplines. [145-147] This problem is exemplified by the case of Transport, the largest and most widely-used database of transport literature. Wentz and colleagues found it impossible to construct a satisfactory search strategy to find controlled evaluation studies in Transport, [148] a finding which reflects the fact that terms for study design are not consistently indexed in that database. However, the problems with searching for terms for study design are not limited to non-biomedical databases or topics. In their systematic review of interventions to reduce serum cholesterol, Peersman and colleagues showed that a search which included a wide range of terms to define the topic, but did not include any terms for study design, was the most effective in identifying relevant studies; [129] the Cochrane Health Promotion and Public Health Field recommends against using terms for study design to limit searches. [106]

2.6.2 Searching other sources

In order not to be unduly influenced by the most easily-accessible examples of the 'published' academic literature, reviewers are also typically advised to search more widely using reference lists, conference proceedings and other sources of 'grey' or 'fugitive' literature. [84 142] In a relatively new or emerging field, it may also be particularly valuable to contact experts for help in identifying relevant studies. [149] However, there is little consensus about how to make the most efficient use these additional sources of evidence. For example, excluding 'grey' literature from meta-analyses of clinical trials has been shown in one study to result in an overestimation of effect size by an average of 12%, [150] but another study has suggested that a comprehensive search strategy may have little effect on the overall result and may introduce bias by including trials of lower validity; [151] Howes and colleagues warn that 'difficult-to-locate' studies relevant to public health are often of lower methodological quality than those published more prominently. [140] On the other hand, Slavin argues that some types of 'fugitive' literature may be less prone to bias than the evidence available through journals — for example dissertations, which he suggests are likely to be written up irrespective of whether the results of the study are 'favourable'; [84] this is in contrast to the widely-acknowledged problem that studies with 'positive' results may be more likely to be written up for, submitted to and published in journals (especially well-respected journals) than those with inconclusive or 'negative' results. [152]

Internet search engines offer one alternative way of finding 'fugitive' literature, but current guidance on how to search the internet systematically is largely limited to warnings about how difficult this might be, [144 146] and some reviewers who have included internet searches have reported finding few or no useful studies by searching the internet. [136 142]

The Cochrane handbook specifically suggests that reviewers send interim lists of references to authors and experts in the field and ask if they know of any other relevant studies, but warns that asking researchers for information on 'unpublished' studies can be unrewarding. [123] However, a previous systematic review of the health effects of new roads, of which I was a co-author, included several important unpublished studies that could only have been found in this way; [5] in another systematic review in a comparatively new field, near-patient testing, McManus and colleagues found that 24% of eligible references were recommended by experts; [149] and in another on the diffusion of innovation in health care organisations, Greenhalgh and colleagues found that most relevant studies were found by 'snowballing' (following up reference lists and citation tracking), personal contacts and serendipity rather than by the search strategy for databases and specific journals specified in the original protocol. [153] These findings suggest that, particularly where a systematic review is likely to involve complex types of evidence or a comparatively new field, less formal approaches to searching may not only be necessary but may even be more productive than more formal approaches.

2.6.3 Trade-off between sensitivity and specificity

Current guidelines offers little concrete assistance in deciding how comprehensive a search strategy ought to be. At the end of a review on access to health care for people with learning disabilities in which a large number of databases had been searched, McNally and colleagues reflected that their time might have been better spent assessing the value of each database more critically at the outset before including it in their definitive search. [136] On the other hand, it is impossible to know what relevant evidence might be omitted in a search strategy that is too ruthlessly focused. Reflecting on their experience of searching for evidence for a review on the transfer of patient information, Hawker and colleagues commented on the importance of serendipity in finding relevant evidence [154] and also identified a possible unique advantage of a comprehensive search strategy: that eventually, references to the same study begin to appear repeatedly and one gains the impression of having reached adequate saturation in the search, in much the same way that a qualitative researcher may continue sampling until no new conceptual categories are generated. [155] Achieving saturation in this sense is not necessarily synonymous with achieving comprehensiveness in the sense of identifying all relevant studies, [156] but the latter objective may be unrealistic in a systematic review of a complex field dominated by difficult-to-locate, 'fugitive' literature. An unresolved tension between the objectives of comprehensiveness and saturation is apparent in a recent paper from the Cochrane Health Promotion and Public Health Field, which refers in adjacent sentences to the importance of *considering* 'all relevant studies' and *including* 'an unbiased sample of studies'. [157]

2.7 Appraising the evidence

Irrespective of the criteria by which studies are selected for inclusion in a systematic review, it is then necessary to appraise the included studies. Terms used to describe this process include *critical appraisal*, *quality assessment* and *validity assessment*. Cochrane and CRD guidelines advance several reasons for asssessing the quality of individual studies: to limit bias; to select a subset of studies which meet a minimum quality threshold to be included in the analysis; to weight the results of individual studies when combined in a meta-analysis; to investigate the relationship between the quality of studies and their results; to guide the interpretation of the findings; and to guide the making of recommendations for future research. [115 117]

2.7.1 Internal and external validity

Systematic reviews often include the use of 'objective' methods of appraising study quality to minimise bias, for example by using checklists or scoring systems for methodological criteria. These may be used either to divide studies into those to be included and excluded, or to weight or rank those studies which are included. Most established methods for grading study validity mainly address internal validity (the extent to which the design and conduct of the study are likely to minimise bias) [158] rather than external validity (the extent to which the results of the study are likely to be applicable outside the context of that study, also referred to as applicability, generalisability or transferability). [117] However, as Slavin, Hammersley and others have argued, the external validity of a study may be at least as important as its internal validity in determining how its findings should be interpreted. [84 137] Most methods also draw on the 'hierarchy of evidence' and accord greater worth to studies whose designs are closer to the top of the hierarchy.

Glasziou and colleagues have observed that using such hierarchies as part of quality assessment has had both beneficial and undesirable effects. On the one hand, there is an obvious benefit in raising awareness that some forms of evidence may be more trustworthy than others. On the other hand, they identify 'misconceptions and abuses' that have arisen as a result of an unthinking or over-simplified application of the principle and make five propositions concerning efforts to grade the quality of research evidence, from which two principles emerge as particularly important in this context. [125] The first is that different types of research question require different types of evidence to answer them, and that a 'balanced' assessment ought to draw on a variety of types of evidence. The second is that, although using a hierarchy can lead to misleading simplifications, it can be helpful in directing attention to the best available evidence in a field containing studies of diverse quality. These principles are to some extent compatible with the principle of 'best evidence' synthesis previously advanced by Slavin and discussed above (Section 2.5.3). [84] One way to interpret and harmonise these principles, particularly when attempting to address a broadly-specified research question, would be deliberately to seek out a variety of evidence contained in a diverse range of studies and then use a hierarchical, or partly-hierarchical, method to identify the best available evidence in light of what is now known to constitute all the available evidence. Petticrew and Roberts warn that quality assessment should not be seen as an exercise to find 'perfect' studies. Rather, they recommend that the aim should be to identify studies which are 'fit for purpose' or 'evidentially adequate'. [159]

2.7.2 Appraisal checklists

Problems with quality assessment are not limited to the use or abuse of a 'hierarchy of evidence'. The validity of the instruments used to appraise the quality of studies has also been called into question. For example, although the Cochrane handbook recommends summarising the performance of individual studies against a list of explicit methodological criteria to derive an overall assessment of validity, it goes on to warn that no particular scale or scoring system can be recommended without reservation, even for randomised controlled trials, and that the computation of a summary validity score 'is not supported by empirical evidence'. [117] The empirical basis for assessing the quality of non-randomised studies is less well developed than that for randomised controlled trials; a monograph on the subject identifies a range of 'tools' (scales and scoring systems) which may be helpful, but stops short of recommending that any of them should be used without further modification. [160] A further limitation of methods for assessing study quality is that they inevitably rely, at least to some extent, on what the authors of the study have written about their methods; in other words, they are assessing the quality of reporting as much as the quality of the research conducted. [117]

A more fundamental critique of the use of checklists or scoring systems questions whether it is either possible or desirable to reduce the judgment involved in assessing the quality of research to the terms of a set of uniform, usually categorical criteria. Pawson and colleagues suggest that a checklist 'does little more than assign structure and credibility to what are actually highly subjective judgments'; [89] in public health circles, the value (but also the difficulty) of adopting a more flexible approach has been acknowledged, particularly in the case of reviews which include a variety of study designs, in publications from the Health Development Agency and the Task Force for Community Preventive Services. [161 162]

2.8 Synthesising the evidence

2.8.1 Beyond meta-analysis

The aim of synthesising evidence from all the primary studies included in a systematic review is typically expressed in terms of attempting to reach an overall conclusion about effectiveness. This intention might be expressed in categorical terms — for example, 'Is intervention X effective?' or 'Is intervention X more effective than intervention Y?' — or in terms of estimating the size of effect attributable to a particular intervention. However, guidelines indicate that systematic reviews can and should also investigate other related questions. CRD guidelines describe the aim of data synthesis as not only to generate a summary of the effects of interventions, but also to investigate whether the effects are consistent across studies and to investigate reasons for apparent differences, [163] and the Cochrane handbook proposes a framework of four questions:

1. What is the direction of effect?
2. What is the size of effect?
3. Is the effect consistent across studies?
4. What is the strength of evidence for the effect? [164]

These guidelines also distinguish between ‘quantitative’ methods of synthesis and ‘descriptive’, ‘non-quantitative’ or ‘narrative’ methods of synthesis. It is implicit in the way these guidelines are written that ‘quantitative’ methods (specifically, meta-analysis) are inherently preferable. For example, the Cochrane handbook describes the use of narrative synthesis to address the four questions enumerated above ‘where meta-analysis is either not feasible or not sensible’, [164] and the CRD guidelines refer to the possibility that ‘a non-quantitative synthesis may informally explore how the differences in study characteristics affect their results’ if meta-analysis is deemed unfeasible. [163] However — perhaps as a result of the historical precedence of the development of methods for meta-analysis over methods for other components of the systematic review process — contemporary authors are often careful to point out that a systematic review need not necessarily involve the quantitative pooling of outcome data in a meta-analysis, [125 165] and guidelines are clear about the statistical hazards of attempting a meta-analysis of the results of a group of studies which are not suitable for such analysis. A detailed consideration of the methods of meta-analysis is beyond the scope of the thesis, but guidelines acknowledge, for example, that the validity of meta-analysis depends on a degree of homogeneity among the studies to be included, not just in terms of study design but also in other characteristics such as the populations studied, the duration of follow-up and the outcome metrics used. [163 164]

Statistical considerations are not the only argument against the use of meta-analysis. The guidelines of the Cochrane Health Promotion and Public Health Field appear to contradict the implicit preference for meta-analysis in the ‘core’ Cochrane handbook by warning that even if data are statistically suitable for meta-analysis, this may still not be an appropriate method of synthesis. [107] These guidelines recommend that the author ‘needs to make the case for meta-analysis before proceeding', which implies that meta-analysis should not be the default or preferred method but rather that it should only be used when a positive case can be made for doing do. There is concern that the technique may sometimes be used in a way which does not make the best use of the available evidence. For example, Slavin contends that 'meta-analysis is typically mechanistic, driven more by concerns about reliability and replicability than about adding to understanding of phenomena of interest'. [84] In other words, the attraction of a compact, visually assimilable 'result' such as a forest plot (the favoured graphical method of summarising the results of a meta-analysis), derived from a subset of homogeneous studies, may sometimes be seen as more compelling than the potential to understand what lies behind the findings of all relevant studies; the risk is that primacy may be accorded to the application of a particular statistical method rather than to the most useful method of exploring what the available evidence may show. Slavin questions the assumption that studies should be excluded from analysis solely on the grounds that an effect size suitable for entry into a meta-analysis cannot be calculated: 'Even if their findings cannot be pooled statistically they can and should be discussed on an equal footing with studies of similar quality that do yield effect sizes.' [84]

2.8.2 Methods for narrative synthesis

The alternative to 'quantitative' methods of synthesis such as meta-analysis is an approach typically referred to as *narrative synthesis*. This term is not synonymous with *narrative review*, which is usually taken to mean a non-systematic approach to an entire literature review. Instead, it refers to an approach to synthesising the findings of a systematic review which relies mainly on text to 'tell the story' of the findings. [166] The language used to distinguish meta-analysis from narrative synthesis sometimes implies a lack of rigour in the latter; this is apparent, for example, in the use of the adjective 'subjective' in the Cochrane handbook to contrast narrative synthesis with the 'statistical' approach of meta-analysis. [164]

The findings of a recent project which aimed to produce guidance on narrative synthesis — published after I had completed the systematic review reported in this thesis — suggest that a degree of scepticism may be appropriate. [166] The authors note that although narrative approaches to synthesis are common, these do not rest on an authoritative body of knowledge and sometimes lack transparency and reproducibility, both of which are generally considered important characteristics of the scientific method. The authors concluded that it was not appropriate to recommend a prescriptive approach, preferring to outline a general framework and a selection of methods which could be used to address the following issues identified in the framework:

1. Developing a theory of how the intervention works, why and for whom
2. Developing a preliminary synthesis of findings of included studies
3. Exploring relationships in the data
4. Assessing the robustness of the synthesis. [166]

Despite the primacy of text in the definition of narrative synthesis, the specific methods identified by Popay and colleagues range from those mainly associated with qualitative research (such as thematic analysis) to those involving quantitative analysis and graphical plots of quantities such as odds ratios and confidence intervals; the use of tables, which perhaps fall somewhere between the extremes of qualitative and quantitative approaches to data, is particularly common in systematic reviews using narrative methods of synthesis. The authors offer their 'toolbox' of methods as ways which may be used in order to increase the transparency and trustworthiness of systematic reviews. This aspiration is consistent with the Cochrane handbook, which recommends that 'In a narrative synthesis the method used for each stage should be pre-specified, justified and followed systematically. Bias may be introduced if the results of one study are inappropriately stressed over those of another.' [164]

2.8.3 Purpose of synthesising evidence

The objectives enumerated by Popay and colleagues and quoted above suggest that the purpose of synthesis may be considerably wider than that implied by Cochrane and CRD guidance. This may reflect the influence of critiques of 'conventional' systematic review methods made by social scientists such as Pawson, who has argued for a realist approach to evaluation and synthesis concerned more with understanding how and why interventions work, for whom and in what circumstances than with the 'one-dimensional' question of whether interventions are 'effective' or not. [134 167] Deciding how to synthesise the data in a systematic review may therefore ultimately depend on a more fundamental issue than statistical considerations about the data: what is the purpose of synthesising the evidence anyway? Hammersley has argued that 'synthesis' may mean different things to different people, identifying one particular use of the word common among qualitative researchers but less common among those conducting systematic reviews: producing a mosaic or map in which the distinctive, complementary contributions from different studies are combined in order to produce a 'bigger picture'. [110] This meaning is in sharp contrast to the reduction of imprecision by pooling effect sizes from homogeneous studies in a meta-analysis, but may be a useful way of conceptualising the potential value of a systematic review making an initial, broadly-specified foray into a complex field.

One aspect of the 'bigger picture' to which Hammersley refers may be the articulation of uncertainty. The primary purpose of meta-analysis is to *reduce* uncertainty about the effects of interventions by pooling the results of multiple studies to produce a more precise estimate of effect size than any single study can provide. However, it is not necessarily either possible or desirable to specify this as the only, or primary, objective of synthesis, particularly in a field about which relatively little is known; in this situation, the most important findings to emerge may reflect uncertainty about the effects of interventions, about the research undertaken on them, or about their potential for unexpected or inequitable effects. Alderson and Roberts have argued that researchers and journals should not be embarrassed to admit uncertainty, but should articulate and admit it so that the evidence base can then be strengthened. [168]

2.9 Conclusions

A systematic review of the available evidence about the effects of interventions incorporates all the characteristics of scientific research, and therefore constitutes original research in its own right.

The rationale and methods for systematic reviews of this kind are now comparatively well accepted in biomedical research, but it is increasingly acknowledged that these 'conventional' methods may not be entirely suitable for addressing questions about the effects of interventions relevant to public health. This reflects two main underlying tensions. First, 'conventional' methods of cumulating evidence, designed to minimise bias, have tended to favour study designs which may not always be feasible in this field. Second, 'conventional' methods of synthesising the cumulated data, designed to reduce imprecision in the estimation of an overall effect size, may be neither statistically appropriate nor meaningful as a means of understanding the effects of the complex types of intervention which characterise the field.

There is therefore a clear need for a approach which is more inclusive and thoughtful, but which also incorporates the rigour and transparency of the scientific method. Methods for achieving this are still evolving, and there is currently no consensus on how best to go about this. However, the most promising approach may be that described by Slavin as 'best evidence synthesis', in other words, not allowing a desire for the 'best' evidence to stand in the way of using the best available evidence. [84] The 'input' phase of this approach has been described as requiring the researcher as to review and evaluate 'such research as is available', making informed judgments about the utility of different studies in the light of the whole range of studies available; [81] the 'output' phase has been described as 'designed to incorporate many of the important contributions of meta-analysis but also to retain many of the features of intelligent and insightful narrative reviews'. [84]

2.10 Aims of the systematic review

In light of the unresolved methodological issues identified in this chapter, I expressed the aims of the systematic review in terms of both primary (substantive) and secondary (methodological) research questions. The primary (substantive) research questions were intended to explore both intended and unintended effects of interventions and, where possible, factors which might underlie differences in outcomes, such as the theoretical basis of the interventions. I selected only two of the many possible secondary (methodological) research questions to be addressed.

The **aims** of the systematic review were:

1. To synthesise the best available evidence about the effects of interventions which may promote a population modal shift from using cars towards walking and cycling

2. To examine the implications of methodological decisions made at selected critical points in the systematic review.

The **objectives** of the systematic review were:

1. To locate, select, appraise, interpret and synthesise the best available evidence to answer the following specific research questions:

   (a) What interventions are effective in promoting a modal shift?
   (b) What is the size of their effect?
   (c) What is the theoretical basis of effective interventions?
   (d) How are the effects of interventions distributed in the population?
   (e) What effects do interventions have on health?
   (f) Do the interventions have any adverse effects?
   (g) What interventions are not effective?

2. To identify the relative and distinct contributions of different sources of evidence

3. To analyse the utility of the different types of study designs identified and investigate how the findings may be influenced by decisions to include and exclude evidence on the basis of study design.

3 Systematic review: methods

3.1 Overview of this chapter

Chapter 2 concluded with a statement of the aims of the systematic review, expressed in terms of primary (substantive) and secondary (methodological) research questions. In this chapter, I describe the methods used to address these research questions.

The systematic review was carried out in seven phases. The first five phases were necessary, primary components of any systematic review:

1. The pilot search for evidence
2. The definitive search for evidence
3. The selection of studies for inclusion
4. The extraction of data from and appraisal of those studies
5. The synthesis of evidence from those studies.

The final two phases were secondary analyses intended to contribute to methodological development:

6. An analysis of the utility of different sources of evidence
7. A sensitivity analysis of the implications of the inclusion thresholds chosen.

The methods for each phase of the review were developed iteratively in the light of the results of the previous phase. At certain points, therefore, this chapter contains cross-references to relevant sections of the results chapter (Chapter 4) which may help to explain the methodological decisions taken.

3.2 Pilot search for evidence

Before embarking on the definitive search for evidence about the effects of interventions, I needed to design a search strategy that struck an appropriate balance between sensitivity and specificity, and I needed to validate my initial assumptions about the nature and scope of the evidence that I was likely to find.

I therefore began by carrying out a pilot search using a limited number of search terms applied to a limited number of electronic databases. I chose three databases for the pilot study: Medline, Web of Science (including the Science and Social Science Citation Indices, and now part of Web of Knowledge) and Transport Research Information Services (TRIS). I chose these databases because they cover a variety of disciplinary areas and can be searched relatively easily using web-based interfaces.

I devised an initial search syntax for the pilot study by combining text terms to reflect three key aspects of the outcome of interest: the use of cars, the use of other modes of transport, and a change in mode of transport. The pilot search was conducted in October 2002 using the search terms summarised in Table 3.

I sifted these citations by hand and identified those for which an abstract was available that suggested the article could be relevant to the primary aim of the systematic review. I read all the abstracts in detail and categorised them according to their likely utility for answering this research question. I then selected the most useful subset of citations, i.e. those which appeared to describe intervention studies with relevant outcome measures. For these citations, I then identified additional potential search terms from the text of their abstracts and the terms used to index them in the relevant database, the year of publication, the setting of the study, the publication in which the article appeared and the name or descriptor applied to the intervention.

The results of this pilot exercise are summarised in Chapter 4, Section 4.2.

Concept	Search terms used
Use of cars	automobile* car cars commut* driv* motor* traffic vehic* *MeSH terms*:† transportation/ motor vehicles/
Use of other modes of transport	active commut* bicycl* bike* bus cycl* (light OR mass OR public OR rapid) AND transit metro pedestrian* public transport rail* subway train trains tram* underground walk*
Change in mode of transport	increas* promot* decreas* discourag* reduc* travel behavior (modal OR mode) AND (chang* OR choice* OR distribution OR shift* OR split*)

* Indicates a truncation wildcard: for example, a search for driv* retrieves records containing the words driver, driving or drivers in databases which offer this function. The actual symbol used for the truncation wildcard varied between database interfaces.
† Medical subject headings (MeSH) — taxonomic categories unique to the Medline database.

Table 3. Search terms used in pilot search

3.3 Definitive search for evidence

The definitive search for evidence about the effects of interventions comprised the purposive use of five types of sources of citations:

1. Electronic literature databases
2. Websites
3. Bibliographies and reference lists
4. Existing collections of references on transport and health
5. Consultation with experts.

Where relevant, I also made specific follow-up searches for additional information about studies reported in documents obtained by these methods. I also found some citations by chance, for example by undirected web browsing (surfing).

Although handsearching journals (defined in the Cochrane handbook as 'a manual page-by-page examination of the entire contents of a journal issue') is recommended as an adjunct to searching electronic literature databases for reports of trials, [123] I did not consider it feasible to identify a manageable list of relevant journals spanning all disciplinary and topic areas which were capable of contributing studies relevant to such a broadly-specified systematic review. I considered it more useful to search more widely and comprehensively for both 'published' and 'grey' literature by searching a comparatively large number of databases with a comparatively sensitive set of search terms and by examining a comparatively large number of websites, bibliographies and reference lists, as detailed below.

3.3.1 Electronic literature databases

I expected to find relevant evidence in primary research and evaluation literature, including conference proceedings, produced in a range of academic and practical disciplines. A large number of electronic literature databases are now available in the biomedical, social and engineering sciences. Many of these might have been useful for the review, but it was not feasible to search all of them.

I drew on previous experience in the systematic review of the health effects of new roads referred to in Chapter 2. [5] Thirty-eight electronic databases had been searched for that review, but the large majority of relevant references had been found in about half of those databases. For this review, therefore, I chose to search this shorter list of 20 databases, broken down into broad categories according to the order in which they were searched: for this purpose, I distinguished the more general, 'first-line' databases often searched in systematic reviews for public health — both those concerned with the health sciences (such as Medline) and those oriented towards the social sciences or science in general (such as the Science Citation Index) — from those focused on more specialised fields (such as geographical sciences, sports sciences or transport) or on more specialised types of document (such as conference proceedings and theses) (Table 4). Each database was searched from its inception date to January 2003.

Category	Database
First-line health databases	Cumulative Index to Nursing and Allied Health Literature (CINAHL) Cochrane Controlled Trials Register (CCTR) Cochrane Database of Systematic Reviews (CDSR) Excerpta Medica Database (EMBASE) Medline (including PreMedline) PsycInfo
First-line science databases	Applied Social Sciences Index and Abstracts (ASSIA) International Bibliography of the Social Sciences (IBSS) Science Citation Index (Web of Science) Social Science Citation Index (Web of Science) Sociological Abstracts
Other specialist databases	Dissertation Abstracts GEOBASE Health Management Information Consortium (HMIC) Health Management Information Service (HELMIS) Index to Theses PapersFirst* REGARD† SportDiscus
Transport database	Transport (including TRIS)

* Database of conference proceedings held by the British Library.
† Database of research projects funded by the Economic and Social Research Council.

Table 4. Databases searched

The search syntax for the definitive search was based on that used for the pilot search, but with some terms removed (particularly those related to public transport, in light of the results of the pilot search) and others added to optimise the sensitivity and specificity of the search (Table 5).

Syntax
(automobile* OR auto use* OR car OR cars OR commut* OR congested OR congestion OR driver* OR mechanised transport* OR mechanized transport* OR motoring OR motorist OR motor* transport OR personal transport OR road use* OR traffic OR vehic*)†
AND
(active commut* OR active transport* OR bicycl* OR bike* OR biking OR cycle hire OR cycling OR cyclist* OR ecological commut* OR ecological transport* OR green* commut* OR green* transport* OR green travel* OR non-auto* OR non-motorised OR non-motorized OR pedestrian* OR physical* activ* OR walk*)‡
AND
(((modal OR mode) AND (analys* OR analyz* OR choice* OR distribution OR effect* OR selection* OR shift* OR split* OR substitut* OR switch* OR transfer* OR transport* OR use*)) OR ((transport* OR travel) AND (behavior OR behaviour OR chang* OR demand* OR habit* OR impact* OR pattern* OR shift* OR substitut*)) OR (decreas* OR discourag* OR disincentiv* OR encourag* OR incentiv* OR increas* OR intermodal distribution OR mode of transport OR promot* OR reduc* OR restrain* OR restrict*))

† In Medline the MeSH headings *transportation*/ and *motor vehicles*/ were added.
‡ In non-biomedical databases the word *cycle* was added. In biomedical databases, this term proved unhelpful in the pilot search because it retrieved large numbers of articles related to biochemical cycles.

Table 5. Definitive search syntax

3.3.2 Websites

I searched quality-assured internet gateways in medicine (www.omni.ac.uk), social sciences (www.sosig.ac.uk) and engineering (www.eevl.ac.uk), and also drew on my existing knowledge of available resources, to identify a provisional list of 63 websites that were likely to contain relevant evidence (Table 6). I then examined each website in detail and selected a purposive sample of 16 of the most useful websites. All of these contained bibliographies or searchable databases of documents, and the sample as a whole represented a range of types of organisation (governmental, academic and voluntary), countries of origin, and languages of publication (Table 7). I then searched these bibliographies and databases in detail in March 2003, using search techniques appropriate to each website (for example, scanning the titles of a simple bibliography, or entering selected key words into the search engine of a database of documents).

Uniform resource locator (URL)	URL (continued)
www.carfree.com	www.metropolis.org/metropolis/fr/home.nsf
www.cebe.cf.ac.uk	www.mobility-unit.dft.gov.uk
www.certu.fr	www.mva-group.com
www.cfit.gov.uk/research/ebp/key	www.nas.edu/trb
www.cittamobile.it	www.ncl.ac.uk/torg
www.cordis.lu/transport/src/public.htm	www.nhtsa.dot.gov
www.crow.nl/engels	www.nottingham.ac.uk/sbe/planbiblios
www.dft.gov.uk	www.ntl.bts.gov
www.eltis.org/en	www.oecd.org
www.energie-cities.org	www.ppsw.rug.nl/vsc/index.htm
www.engj.ulst.ac.uk/scobe	www.pubs.asce.org/cedbsrch.html
www.epommweb.org	www.reclaimthestreets.net
www.europa.eu.int/comm/dgs/ energy_transport	www.scotland.gov.uk
	www.sustainable.doe.gov
www.fhwa.dot.gov	www.sustrans.org
www.geocities.com/transport_and_society	www.tc.gc.ca/en/menu.htm
www.geocities.com/transport_research	www.tfhrc.gov
www.gridlock.york.ac.uk	www.toi.no
www.ibike.org/bibliography/bike-policy.htm	www.transguide.org
www.ice.org.uk	www.transportweb.com
www.inrets.fr/index.e.html	www.trg.soton.ac.uk
www.irfnet.org	www.tri.napier.ac.uk
www.ish-lyon.cnrs.fr/let/wctrs/wctr.htm	www.trl.co.uk
www.ite.org	www.trm.dk
www.itre.ncsu.edu/cte/cte.html	www.ucl.ac.uk/transport-studies
www.its.leeds.ac.uk	www.ulb.ac.be/ceese
www.jiscmail.ac.uk/lists/utsg.html	www.umweltbundesamt.de
www.londontransport.co.uk	www.urban.odpm.gov.uk
www.lrta.org	www.users.quista.net/dhalden
www.lse.ac.uk/depts/london/papers.htm	www.vd.dk
www.ltcon.fi/propolis	www.vti.se
www.predit.prd.fr	www.www-tec.open.ac.uk/eeru

Table 6. Provisional list of websites to be searched

Uniform resource locator (URL)	Host organisation
www.certu.fr	French Centre for the Study of Urban Planning Transportation and Public Facilities
www.eltis.org/en	European Local Transport Information Service
www.energie-cites.org	Energie-Cités association of European local authorities
www.epommweb.org	European Platform on Mobility Management
www.ibike.org/bibliography/ bike-policy.htm	International Bicycle Fund
www.nas.edu/trb	United States Transportation Research Board
www.nottingham.ac.uk/sbe/ planbiblios	Nottingham School of the Built Environment
www.ntl.bts.gov	United States National Transportation Library
www.scotland.gov.uk	Scottish Executive
www.sustrans.org	Sustrans (United Kingdom)
www.toi.no	Norwegian Institute for Transport Economics
www.transguide.org	Swedish Road and Transport Research Institute
www.trl.co.uk	United Kingdom Transport Research Laboratory
www.trm.dk and www.vd.dk	Danish Ministry of Transport
www.ucl.ac.uk/transport-studies	Centre for Transport Studies, University College London
www.vtpi.org/tdm	Victoria Transport Policy Institute, Canada

Table 7. Websites selected for definitive search

3.3.3 Bibliographies and reference lists

Some of the documents found in the search of electronic databases were general bibliographies or literature reviews rather than reports of primary research studies. I searched the reference lists of these documents, as well as the reference lists of all the other documents retrieved in full text, to find additional references.

3.3.4 Existing collections of references

I searched, by hand, the collections of references which had been obtained for previous systematic reviews conducted in the Medical Research Council (MRC) Social and Public Health Sciences Unit in the field of transport and health. [5 62]

3.3.5 Consultation with experts

In January 2003 I sent a draft protocol for the review to a number of experts in the field of transport and health, both in the UK and overseas, inviting them to comment and to identify any references which might be relevant. In May 2003, when most of the definitive search was complete, I posted on the internet an interim list of references (n=229) which I had already obtained in full text. I then wrote again to a number of experts, and posted messages on five relevant email groups (evidence-based-health@jiscmail.ac.uk, public-health@jiscmail.ac.uk, transport-health@groups.yahoo.com, utsg@jiscmail.ac.uk, and the health impact assessment distribution list maintained by the WHO Regional Office for Europe), inviting colleagues to review and add to this list.

3.4 Selection of studies

3.4.1 Criteria for initial selection

I specified criteria for including studies in terms of the types of publication and the four facets of the primary research question: the participants, the interventions, the study designs and the outcome measures.

Types of publication

I included studies reported in written documents of any type and in any language, including conference papers and technical reports, irrespective of whether they had been peer-reviewed and irrespective of whether any academic publication had arisen from the study.

Participants

I included studies of interventions applied to any identifiable urban population or area, such as a city, town, London borough or neighbourhood, in any developed country (defined for this purpose as a member state of the Organisation for Economic Co-operation and Development). Participants in these studies could have included men, women or children of any age, ethnic group or socioeconomic status. I chose to focus on towns and cities rather than rural settings because of the greater potential for, and potential gains from, a modal shift from using cars towards walking and cycling for the short trips which characterise travel in urban areas. I chose to exclude studies from less-developed countries because I considered it unlikely that evidence from intervention studies would be transferable to countries such as the UK from countries with a markedly different pattern of motor vehicle ownership and use.

Interventions

I included studies of any type of intervention (defined for this purpose as a policy, programme or project) applied to a population or area that was intended to promote, or could have been expected to promote, or was associated with, a shift from using cars towards walking or cycling.

I excluded studies of the following types of intervention:

1. Those given to individuals in clinical settings (such as exercise prescription), since I was primarily concerned with interventions applied at a higher (population) level

2. Those concerned with shifts between cars and public transport, unless they presented data relating directly to walking or cycling at one or both ends of the trip

3. Workplace or school travel plans or 'safer routes to school' schemes at single sites, since these were the subject of some of the other recent reviews or collections of case studies referred to in Chapter 1, [57-61] and I was primarily concerned with interventions applied at a higher (population) level. However, I did not exclude interventions applied to whole urban populations or areas which included travel plans or schemes at specific workplaces or schools as part of their overall content, neither did I exclude individual case studies found within these collections which did fulfil the inclusion criteria.

Study designs

I initially included empirical intervention studies of any design that reported data comparing people's choice of mode of transport before and during or after an intervention.

I excluded the following types of study:

1. Predictive or modelling studies

2. Stated preference studies (studies of what people say they would do under given conditions, typically concerned with investigating the influence of economic incentives on behaviour)

3. Studies of trends in or correlates of transport choices in the absence of a clear intervention to be evaluated.

The reason for excluding these types of study was that the systematic review was intended to focus on the actual effects of interventions in practice — the most significant gap in the available evidence identified in Chapter 1.

Outcome measures

The primary outcome of interest for the review was a change in the distribution of mode choice in the population. I included studies that reported data relevant to this outcome, irrespective of the metric used.

I excluded studies of changes in people's attitudes to or perceptions of the interventions, or changes in people's use of specific facilities or routes (e.g. changes in the distribution of cycle traffic between different routes) unless these studies also reported changes in the distribution of mode choice.

I also sought evidence related to the following secondary outcomes:

1. The distribution of the effects of the intervention between groups in the study population

2. Positive or negative effects on any direct measure of human health, fitness, health-related behaviour or wellbeing among participants or populations affected.

I did not include effects on businesses, or on environmental measures such as vehicle emissions or air quality, except where these were associated with changes in direct measures of effects on human beings.

3.4.2 Process of initial selection

The results of the definitive search of electronic literature databases were saved in a shared electronic reference management library (EndNote 6). I sifted the initial results to exclude obviously irrelevant references. I and two other reviewers then independently screened the remaining titles and abstracts for possible inclusion. I analysed the inter-rater reliability of these binary screening decisions by calculating Cohen's kappa (κ) for each pair of reviewers. [169] In light of the results of this analysis (Section 4.3.1), I then ordered the full text of any reference identified by at least one reviewer as potentially relevant. An analogous process was carried out for references identified through the web and other searches.

I then assessed the full text of all the documents obtained against the inclusion criteria. A second reviewer checked a 10% sample of these assessments and found no significant points of disagreement.

Studies which initially appeared capable of meeting the inclusion criteria were designated *relevant studies*. The results of the analysis of relevant studies are reported in Section 4.4.

3.4.3 Process of final selection

In light of the analysis of relevant studies (Section 4.4.1), I selected studies for final inclusion (*included studies*) if they met the following criteria.

Study design

I finally included studies with any type of prospective design or any type of controlled design, treating these characteristics as a marker of internal validity. The studies included under this criterion comprised experimental studies, controlled prospective or retrospective observational studies, and uncontrolled prospective observational studies. I excluded uncontrolled retrospective studies and *post hoc* case studies in which no clear link was established between the interventions and the effects described.

Study population

I finally included studies in which effects had been studied in a sample of local households or residents, or in a sample of an identifiable subset of a local population such as commuters, drivers or school pupils. I also included studies of people who had participated directly in a targeted intervention. I excluded studies whose study populations did not clearly reflect any local denominator population, treating the absence of this characteristic as a marker of external validity. These were studies whose outcome measures were based solely on passers-by at a study location (such as shoppers visiting a city centre) or on traffic counts.

Sufficiency of information

At this stage I also excluded studies which met the criteria for study design and study population, but which contained inadequate information about methods or results for the purposes of detailed critical appraisal.

3.5 Data extraction and critical appraisal

3.5.1 Data extraction

I extracted data from the reports of all relevant studies into a shared database (Microsoft Access 1997) and linked spreadsheet (Microsoft Excel 1997). The data for each study were checked by one of the two other reviewers, and we resolved any disagreements by discussion and re-examination of the original documents. The nature of the data extracted from each included study is summarised in Table 8.

Field
Bibliographic details
Context of the intervention
Theoretical basis (if any) of the intervention
Content of the intervention
Time periods of the intervention and the evaluation
Study design
Size, selection and representativeness of study populations or samples
Sources of data
Details of any control population or area and adjustment for any concurrent interventions, underlying trends or other potential confounding factors
Primary and secondary outcome measures
Length of follow-up and sustainability of effects

Table 8. Data extracted from relevant studies

Where critical details of methods or results were unclear or missing in the reports, I tried to contact the first author or the agency responsible for the report and sought clarification. Where relevant, I also searched the websites for particular interventions or studies to identify additional information.

3.5.2 Critical appraisal

Despite the reservations concerning the application of checklists expressed by some authors and referred to in Chapter 2, I found it useful to have a method of distinguishing in at least broad terms between more and less rigorous studies. Drawing on published checklists for critical appraisal [115] and on the criteria developed for the systematic review of the health effects of new roads, [5] I therefore formulated a list of ten binary criteria and summarised the 'validity' of each included study as a score equal to the number of these binary criteria which were satisfied (Table 9).

I had two rationales for selecting these particular criteria. First, they had to be capable of being applied to all included studies, irrespective of study design. Second, the criteria had to reflect not only the main potential biases in epidemiological studies in general but also more specific issues concerning the assessment of changes in travel behaviour from the perspective of seeking evidence relevant to population health improvement. Therefore, although studies did gain credit for the random allocation of the intervention, this aspect of study design was not paramount in the assessment of validity, reflecting an assumption that from a public health perspective a randomised controlled trial with a small, unrepresentative sample and a short follow-up period might be of less overall utility than, say, a larger, longer, population-based cohort study. More specifically, I accorded lower validity to studies that had only assessed the outcome of mode choice for a single trip on a single day rather than on the basis of a more inclusive assessment of travel behaviour; to uncontrolled studies that had compared travel choices at times of the year that were not seasonally comparable; and to studies in which the assessment of changes in travel behaviour had been limited to a follow-up period of less than three months.

Aspect of methods	Criterion
Comparability	Were 'before' and 'after' data obtained from the same, or comparable, groups or areas?
	Were 'before' and 'after' data collected at seasonally comparable times of the year, or if not, was the study a controlled study?
	Were outcomes compared with an appropriate control group or area, and if so, were control data collected in a comparable way?
Allocation	Were participants, groups or areas randomly allocated to receive the intervention or act as the control?
Response	Was the study sample randomly recruited from the study population with a response rate of at least 40%, or otherwise shown to be representative of the study population?
	Were the results based on a minimum sample size of at least 100 people in each group or survey wave?
	Were outcomes studied in a cohort or panel of respondents with an attrition rate of less than 30%?
Outcome	Were confidence intervals or the results of significance tests reported?
	Did the assessment of travel behaviour consider more than one type of trip, or trips made over a period longer than one day or a 'typical' day?
	Were the effects of the intervention assessed at least three months after the start of the intervention?

Table 9. Validity criteria for included studies

3.6 Data synthesis

I found that studies had used a variety of metrics for expressing data relevant to the primary outcome measure for the review. I could not identify a single common metric with which to synthesise the results of all relevant studies. For this reason, as well as the heterogeneity of the interventions and study designs, it was not appropriate to synthesise the results using a formal statistical method such as meta-analysis. In general, therefore, I synthesised the results of the review using narrative methods (text and a series of tables), but where possible I did summarise the effects of individual studies on the overall distribution of amode choice using a common derived modal shift metric *M*: the absolute percentage share of all trips that were shifted from cars to walking and cycling combined.

I derived *M* as follows. I calculated the absolute change in the percentage share of all trips made by walking and cycling combined and compared this with the absolute change in the percentage share of all trips made by car. If the two changes were in opposite directions, I took the smaller of the two changes and used this to summarise the absolute modal shift from the car to the active modes. For example, if the percentage share of car trips decreased from 50% to 40% of all trips, and the percentage share of walking and cycling trips combined increased from 20% to 25%, I summarised this as a positive modal shift of 5% of all trips from a baseline share of 20%. If the two changes were in the same direction (if, for example, the public transport share of all trips increased at the expense of car, walking and cycling trips), I summarised this as a modal shift of zero.

Following the convention of the Cochrane Library, I summarised data about the included studies using three tables: one summarising the key characteristics of each study (intervention, study design, study population, and primary outcome measures), one summarising more detailed descriptive and outcome data, and one summarising which validity criteria were met.

I categorised studies according to the main focus of the intervention assessed. Within each category, I summarised the observed effects of interventions on the primary outcome measure in decreasing order of overall study validity. I reported the results of authors' statistical tests as confidence intervals (if authors reported these), or as P-values (if authors did not report confidence intervals). Where authors did not report the results of statistical tests, it was sometimes possible for me to use their reported data to estimate 95% confidence intervals for the difference between two independent proportions using the formula given by Bland. [170] These results are described in the table of detailed descriptive and outcome data using the phrase 'likely [or 'unlikely'] to have been significant', or 'likely to have been of borderline significance' if my estimate of the 95% confidence interval barely included zero. For other studies, I could not do this either because authors did not report denominators, or because they presented and compared data from non-independent samples (such as 'before' and 'after' data from the same respondents) as if they came from independent samples. These results are described using the phrase 'of uncertain significance'.

In order to explore the heterogeneity of the outcome data and potential explanations for that heterogeneity, I plotted *M* against baseline active mode share and against study validity and calculated the Spearman rank correlation coefficients (r_s) for these bivariate relationships.

I then summarised the overall distribution of evidence using a summary table in which each study was categorised as showing evidence of a significant positive (or negative) effect, a positive (or negative) effect of uncertain significance, or a result which was inconclusive or suggested no effect. In this table, studies were only categorised as having found a 'significant' positive effect on the strength of a test of statistical significance published in the original study, not on the basis of my own estimates of likely significance which were based on limited access to the original data.

I synthesised data related to health effects and the social distribution of effects using a combination of tables and text, and synthesised data related to the theoretical basis of interventions using text.

3.7 Secondary analysis of sources of evidence

When the review was complete, I identified retrospectively where the references for all the relevant studies had been obtained. The purpose of this analysis was to explore the utility of the different sources of evidence and the implications of adopting such a comprehensive search strategy for the efficiency and findings of the review.

I based this analysis on a notional hierarchy of sources ranging from first-line health databases such as Medline to stumbling upon studies by chance (Table 10). This hierarchy reflected the order in which the search had been conducted. For each study, I identified the highest-order source from which a reference to that study had been identified — either a primary report of the study, or a secondary source such as a bibliography, literature review or book chapter that included an appropriate reference to a primary report.

Source
First-line health databases
First-line science databases
Other specialist databases
Transport database
Purposive search of websites
Own archives
Recommended by expert
Found by chance

Table 10. Hierarchy of sources

3.8 Sensitivity analysis of thresholds for inclusion

When the review was complete, I also conducted a sensitivity analysis to explore how the findings of the systematic review would have been influenced by a decision to set one of two alternative thresholds for inclusion:

1. Restricting the review to randomised controlled trials
2. Including all available relevant studies.

The purpose of this analysis was to investigate the influence of the choice of inclusion threshold on the scope, content and findings of the primary synthesis.

First, I compared the characteristics and findings of the randomised controlled trials with those of the overall body of included studies. Second, I tabulated key characteristics and outcome data from all the excluded studies, grouped these studies by category of intervention, and systematically compared the findings of the excluded studies with those of the included studies, category by category.

3.9 Ethical approval and data protection

No ethical approval was required for this study and no personal data relating to participants in the primary studies were obtained or stored.

4 Systematic review: results

4.1 Overview of this chapter

In this chapter, I present the results of the systematic review, by which I mean data arising from both the process of the review and the outcomes of that process, in the following order:

1. The findings of the pilot search for evidence

2. The process of the input phases for the review — the definitive search for evidence and the selection of studies for inclusion

3. The findings of the appraisal of, and synthesis of evidence from, the studies selected for inclusion (the main 'results' as such)

4. The findings of the secondary analyses of the utility of different sources and the implications of the inclusion thresholds.

As explained in the methods chapter (Chapter 3), I developed the methods for each phase of the review iteratively in the light of the results of the previous phase. At certain points in this chapter, therefore, I have summarised the interim conclusions from the process data in order to show how those findings influenced the subsequent methodological decisions.

4.2 Pilot search for evidence

4.2.1 Results

The pilot search generated a total of 851 citations. After I had sifted these to exclude obviously irrelevant citations and duplicates, 172 citations remained for which the abstract suggested the article could be relevant to the research question (Table 11).

Category	Number
Definite or possible intervention studies with relevant outcome measures	102
Descriptive studies of correlates of, or trends in, travel behaviour	26
Modelling studies based on correlates of, or trends in, travel behaviour	10
Review articles not obviously offering direct evidence of intervention effects	29
Simple descriptions of interventions offering no evidence of effects	5

Table 11. Abstracts of potentially-relevant articles identified in pilot search

I focused on the abstracts that appeared to describe intervention studies with relevant outcome measures (n=102). The text of these abstracts and the terms used to index them contained many potential search terms that I had not used in the pilot search strategy (Table 12), but most abstracts did not give a clear indication of the type of study design. About half of the articles had been published since 1995, but about a quarter of relevant articles had been published as long ago as the 1970s (Table 13). More studies had been conducted in the United States than in any other country; studies conducted in continental and Nordic Europe also made an important contribution, as did articles about interventions in more than one country or continent (Table 14). 40% of the citations were in books, conference proceedings or other 'grey' literature. Among the journal citations, the six most frequently represented periodicals were all transport or engineering journals rather than those published in health-related disciplines: *Transportation Research Record* (n=13), *Proceedings of the Institute of Civil Engineers* (n=9), *Transportation* (n=8), *Transportation Quarterly* (n=5), *Transport Reviews* (n=3) *and Traffic Quarterly* (n=2).

These abstracts referred to a wide range of types of intervention. The names or descriptors applied to these interventions are listed in Table 15, organised into a provisional taxonomy. Only a minority of abstracts (n=15) mentioned walking or cycling; most of the remainder clearly dealt only with shifts between the car and public transport, and it appeared unlikely from the abstracts that this latter group of studies would have reported data on walking or cycling as part of trips made by public transport.

Concept	Additional terms identified
Use of cars	auto use* car AND dependen* congestion journey* mechanised transport* mechanized transport* mobility personal transport* relian* AND (automobile* OR car*) road use*
Use of other modes of transport	biking cycle hire ecological transport kiss and ride (variously punctuated) multimodal non-auto non-motorised* non-motorized* park and ride (variously punctuated) patronage physical activity public transit ridership streetcar*
Change in mode of transport	(modal or mode) AND (analys* OR effect* OR selection OR switch OR transfer* OR transport OR use*) behavior change behaviour change disincentive* intermodal distribution restrain* restrict* shift AND travel substitut* transport pattern* travel AND (behaviour OR demand* OR habits OR impact* OR pattern*) traveler* traveller* trip tripmaking

Table 12. Additional text words and indexing terms identified in pilot search

Year of publication	Number
1960-69	1
1970-79	25
1980-89	11
1990-94	16
1995-99	29
2000-02	20
Total	102

Table 13. Year of publication of intervention studies identified in pilot search

Country of origin	Number
United States	34
European countries (excluding United Kingdom)	27
United Kingdom	13
Canada	2
Australia	1
Other*	25
Total	102

* Studies that spanned more than one country or continent or whose setting was not stated in the abstract.

Table 14. Country of origin of intervention studies identified in pilot search

Category	Sub-category	Intervention descriptors
Individual behaviour change		‘Car drivers test public transport’ campaign ‘Curb your car’ education and incentive program Information and feedback on effects of car use Travel awareness scheme TravelSmart behaviour change programme
Workplace interventions		Companies’ bicycle measures Compulsory city centre staggered work hours program Employer based demand management strategies Physically active commuting to work
Interventions to reduce car use	Access or parking restrictions	Auto restricted zone Car restraint Closing city centre car park Parking controls Parking policies Parking pricing and supply
	Road user charging	Road pricing Road tolling Road user charging
	Car pooling	Bus and car pool system project Carpool and bus lane Freeway high occupancy vehicle lanes and ramp metering Ridesharing project

Table 15. Taxonomy of interventions identified in pilot search

Category	Sub-category	Intervention descriptors
Public transport systems	Whole public transport systems	Integrated public transport system Intermodal transit facility Mass transit systems Mass transportation programs Public transport system Rapid transit system Transit innovations
	Information technology (IT)	Advanced transit information systems IT and telematics solutions for public transport Smart commuter intelligent transportation system
	Fare subsidies	Federal transit aid program Federal transit fare subsidies Free fare programs Integrated bus fare and ticket policies Subsidised bus tickets

Table 15. Taxonomy of interventions identified in pilot search (continued)

Category	Sub-category	Intervention descriptors
Public transport systems (continued)	Bus systems	Bus system Express bus system Local bus service development and marketing
	Bus priority schemes	Bus infrastructure improvements Bus priority network and red routes Bus priority scheme Red routes
	Rail, light rail or tram systems	Extension of rail system Extension of rapid transit rail Light rail Light rail system Light rail transit New high speed rail line New rail line New railway station Passenger train design Publicity about new tram system Rail system improvements
	Park-and-ride	Park-and-ride
	Public transport plus car restraint	Capital rail investment and transport demand management Car disincentives and transit improvements Light rail, streetcars and traffic restraint Transit co-operatives, parking restrictions and park-and-ride

Table 15. Taxonomy of interventions identified in pilot search (continued)

Category	Sub-category	Intervention descriptors
Urban planning and land use		Housing and employment clustered around transit
		Neo-traditional neighbourhood design
		Neo-traditional neighbourhood development
		Office relocation to public transport nodal points
		Suburban mixed-use centres
		Transit-focused office developments
Modification of the socioeconomic environment		Modification of the socioeconomic environment
Complex or high-level policies and strategies		Comprehensive traffic policy
		Conurbation transport policy
		Co-ordinated urban transport strategies
		Economic interventions
		Integrated approach to transport strategy formulation
		Pricing, regulatory policies and investment decisions
		Public policy differences
		Public transport and traffic management measures
		Traffic planning and pedestrianisation
		Transport Act 1985 (bus deregulation)
		Transport policies
		Transport white paper
		Urban transport policies
Miscellaneous		Pedestrian and bicycle transportation system
		Station electric car project

Table 15. Taxonomy of interventions identified in pilot search (continued)

4.2.2 Interim conclusions

I drew three interim conclusions from the findings of the pilot search.

First, although I had found some relevant primary studies, many of the abstracts were inadequate for judging the types of study design or the use of relevant outcome measures. This suggested that it would not be feasible to limit the search using filters or search terms for study design or outcome measures; instead, a highly sensitive and relatively unspecific search would be required.

Second, relevant studies were likely to be distributed widely in time and place throughout the developed world. This suggested that it would be important for the search to be able to capture evidence from European studies, some of which might have been published in languages other than English, and for the search not to be limited to recent years of publication.

Third, although numerous additional potential search terms were identified, the large majority of abstracts referred to studies of modal shifts between cars and public transport and did not refer to walking or cycling. This suggested that the search strategy should be augmented with the most frequently-used and specific terms, but also restricted in order to focus on walking and cycling rather than on all non-car modes of transport.

These observations informed the design of the definitive search strategy (Chapter 3, Section 3.3).

4.3 Definitive search for evidence

4.3.1 Results

Electronic literature databases

The search of electronic literature databases generated a total of 5206 citations. I sifted these citations and excluded those which were obviously irrelevant either from their titles (n=3102) or from their abstracts (n=1551). I also removed 52 bibliographies and other lists of publications which were kept back for the next phase of the search. After removing duplicates, this left 462 potentially-relevant citations which I and two other reviewers then independently assessed for inclusion. Inter-rater agreement was fair, [171] with values of Cohen's κ for each pair ranging from 0.24 to 0.29 (Table 16).

Websites, bibliographies and reference lists

After examining and sifting these sources of 'grey' literature I identified a further 269 potentially-relevant citations. I and one other reviewer independently assessed these citations for inclusion. Again, inter-rater agreement was fair (Cohen's κ = 0.30) (Table 17).

Other sources

I identified a further 56 potentially-relevant documents in other ways:

1. From existing collections of references
2. From the recommendation of an expert
3. Found by chance
4. Specific follow-up searches to find additional evidence about the effects of interventions reported in documents already retrieved.

		Rater 2			
		Include	Exclude	Total	
Rater 1	Include	70	47	117	Cohen's κ = 0.28
	Exclude	97	248	345	
	Total	167	295	462	
		Rater 3			
		Include	Exclude	Total	
Rater 2	Include	76	91	167	Cohen's κ = 0.29
	Exclude	52	243	295	
	Total	128	334	462	
		Rater 3			
		Include	Exclude	Total	
Rater 1	Include	54	63	117	Cohen's κ = 0.24
	Exclude	74	271	345	
	Total	128	334	462	

Table 16. Inter-rater agreement: electronic literature databases

		Rater 2			
		Include	Exclude	Total	
	Include	28	36	64	Cohen's κ = 0.30
Rater 1	Exclude	30	175	205	
	Total	58	211	269	

Table 17. Inter-rater agreement: websites, bibliographies and reference lists

4.3.2 Interim conclusions

The relatively low level of inter-rater agreement suggested either that the titles and abstracts were inadequate to enable reviewers to make replicable judgments about which studies to include, or that I and my co-reviewers were unable to apply the inclusion criteria consistently. In order to minimise the risk of inadvertently excluding relevant studies, I therefore decided to order the full text of any document selected for inclusion by at least one reviewer in the rating exercises for electronic literature databases (n=249) or websites, bibliographies and reference lists (n=94). I also ordered the full text of all the potentially-relevant documents identified from other sources (n=56). 399 full-text documents were obtained in total.

4.4 Selection of studies

4.4.1 Initial selection

From the 399 full-text documents, I identified 69 *relevant studies* (studies that initially appeared capable of meeting the inclusion criteria), reported in a total of 144 documents. After extracting data from these 69 relevant studies, I found that authors had used a wide range of study designs and had measured outcomes in a wide range of human study populations as well as by counting the movements of vehicles. For example, some studies had used relatively robust methods to measure changes in vehicle flows along certain roads, but these studies provided no information about the people using those vehicles or about their non-vehicular (walking) trips. Similarly, I found studies involving surveys of shoppers visiting a city centre at the weekend which showed how the distribution of mode choice had changed among shoppers, but provided no information about where the shoppers had come from, or how their overall travel patterns had changed. From these observations I developed a simple matrix, or two-dimensional hierarchy, of study utility with which to select studies for inclusion. The first dimension of the matrix was a hierarchy of study design: this was based on the degree of confidence with which observed effects were likely to be attributable to the intervention being studied, and was intended as a marker of internal validity. The second was a hierarchy of study population: this was based on the degree to which a study population related to an identifiable local denominator population, and was intended as a marker of external validity, i.e. the degree to which observed effects were likely to be generalisable to the local population or more widely (Table 18).

4.4.2 Interim conclusions

I noted during data extraction that studies at the lower ends of these design and population hierarchies tended to contain less detail of methods, results, or both. This suggested that the effort of including all relevant studies in the review might not be justified by the value of the evidence obtained. On the other hand, restricting inclusion to studies at the highest end of the design hierarchy (randomised controlled trials) would have resulted in a very small set of included studies. Having examined the distribution of studies in a two-dimensional matrix of study utility (Figure 3), I therefore chose final thresholds for inclusion that lay roughly midway between the extremes of each hierarchy.

4.4.3 Final selection

I first excluded studies whose design was neither prospective nor controlled (n=28). I then excluded studies whose populations did not represent a local population or subset of a local population (n=10). This left 31 studies (represented by the dark columns in Figure 3). I subsequently excluded nine of these on the grounds that they contained inadequate information about methods or results for the purposes of detailed critical appraisal, leaving 22 studies which were finally included in the review.

For most of the 47 studies eventually excluded, it was possible to make the decision to exclude them on the basis of the documents already obtained, but I tried (unsuccessfully) to obtain more information about six of these studies before excluding them. Further details of the excluded studies and the reasons for excluding them are given later in this chapter (Section 4.7.2).

On the other hand, I judged that additional information would be useful for most of the 22 included studies, and was successful in acquiring it for seven studies (Table 19).

The overall process by which studies were selected for inclusion is summarised in a flowchart (Figure 4).

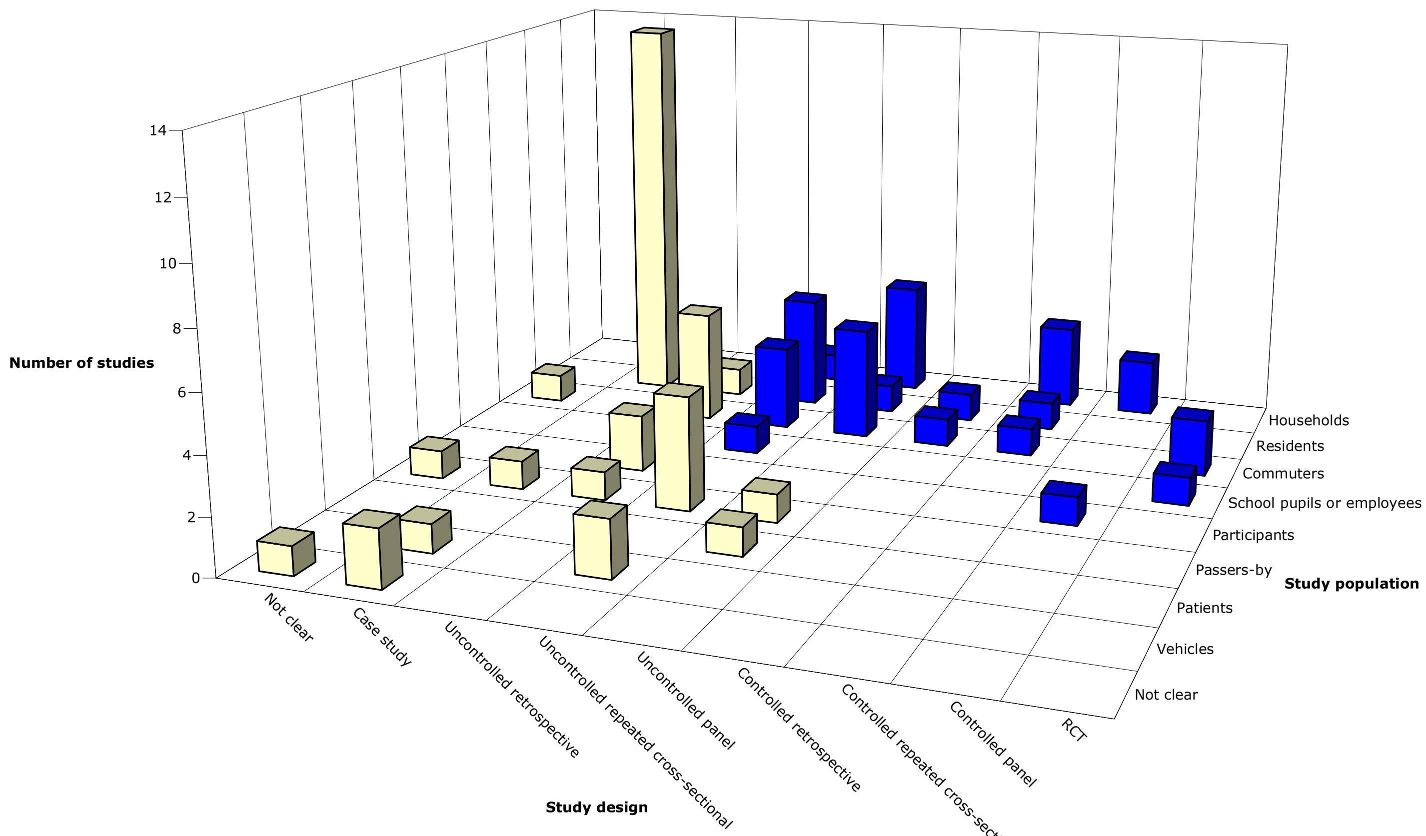
Study design	Study population
Randomised controlled trial Controlled panel* Controlled repeated cross-sectional Controlled retrospective Uncontrolled panel* Uncontrolled repeated cross-sectional	Households or local residents Commuters, employees or school pupils Participants in a targeted intervention selected from one of the groups above
———————————————— *Final threshold for inclusion* ————————————————	
Uncontrolled retrospective Case study of trends in mode share Design not clear	Passers-by at a study location Patients receiving an intervention in a clinical setting Vehicles Population not clear

* Repeated measures on the same participants.

Table 18. Two-dimensional hierarchy of study utility

Contact with author or agency	Final disposition of study	
	Included	Excluded
Did not attempt to contact	6	41
Could not be traced	—	3
Traced but did not respond	7	3
Promised more information which never arrived	2	—
Answered queries	7	—
Total	22	47

Table 19. Contact with authors or agencies responsible for studies



Dark columns represent studies that met the final inclusion criteria for study design and study population (n=31). RCT: randomised controlled trial.

Figure 3. Distribution of studies by design and population

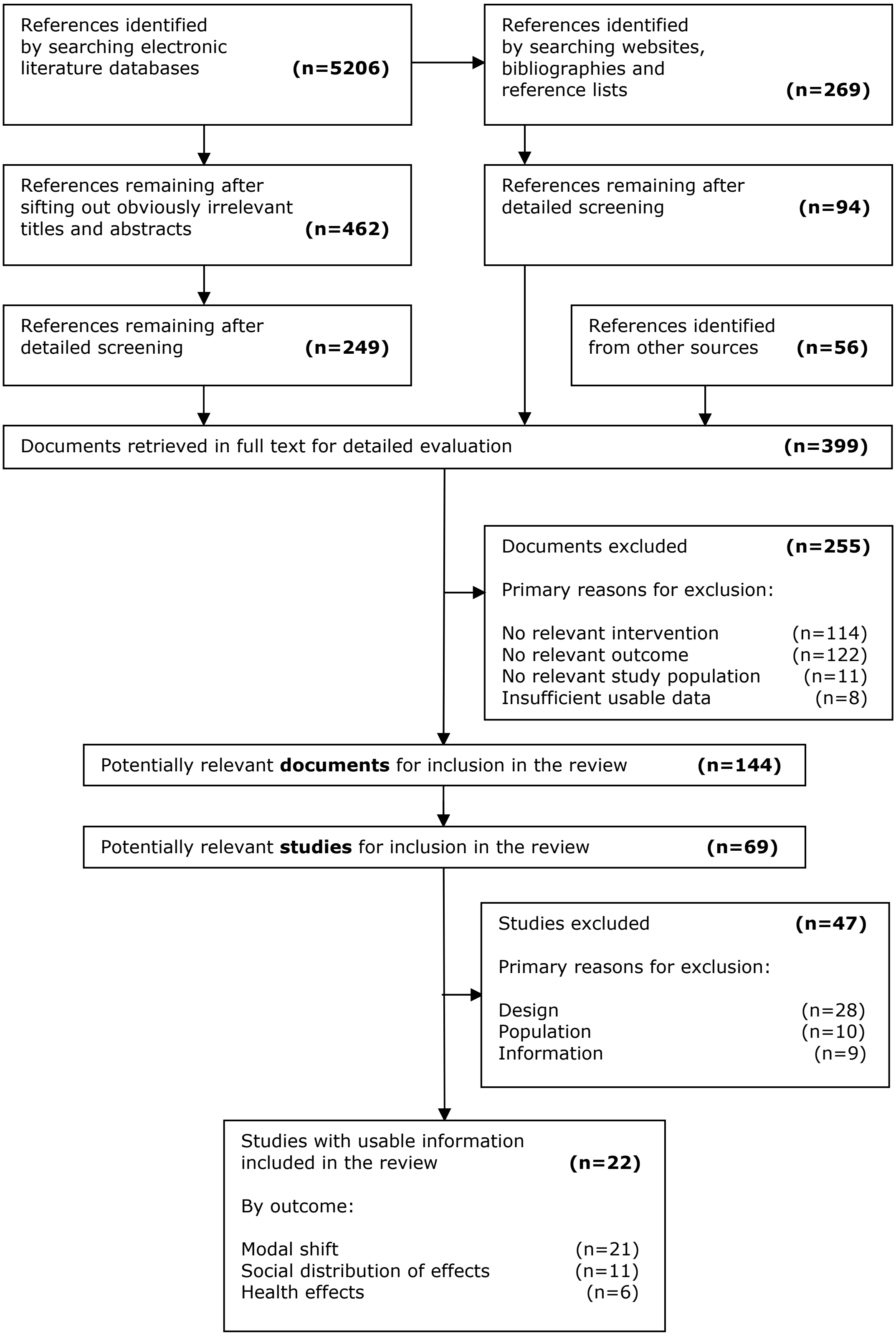


Figure 4. Overview of selection of studies for inclusion

4.5 Evidence from included studies

4.5.1 Basic characteristics of studies

The 22 studies that met the final inclusion criteria comprised three randomised controlled trials, seven non-randomised controlled prospective studies, 11 uncontrolled prospective studies, and one controlled retrospective study. Most of these studies were published since the mid-1990s (Table 20). The UK, the rest of Europe and the US were roughly equally represented as countries of origin (Table 21). Eight studies did not appear to have been published in an academic journal, [172-179] but all had been published, or at least referred to in some detail, in an English-language document identified in the literature search.

Year of publication	Number
1980-89	3
1990-94	2
1995-99	9
2000-02	8
Total	22

Table 20. Year of publication of included studies

Country of origin	Number
United Kingdom	8
European countries (excluding United Kingdom)	6
United States	6
Australia	2
Total	22

Table 21. Country of origin of included studies

4.5.2 Organisation and presentation of findings

Study names and citations

There was more than one reference for most studies. For the sake of clarity, in this chapter I have followed the convention of the Cochrane Library, referring to each study by a short name (based on the place where the study was conducted) and a single primary reference (the most important citation). Where studies are listed in alphabetical order, this order takes account of Danish and Swedish characters such as Å (also spelt Aa) which conventionally follow Z. The full names of the studies or interventions, and a full list of citations, are shown in Table 22.

Short name and primary reference	Full name, location and all references
Adelaide [180]	Travel Blending, Adelaide (Australia) [180-187]
Boston [188]	Downtown Crossing automobile restricted zone, Boston, Massachusetts (United States) [188-191]
California (cashing out) [192]	Cashing out employer-paid parking, California (United States) [192 193]
California (telecommuting) [194]	Neighbourhood Telecenters, California (United States) [194]
Delft [195]	Delft bicycle network (Netherlands) [195-207]
Detmold-Rosenheim [173]	Bicycle-friendly towns demonstration project, Detmold and Rosenheim (Germany) [173 208-212]
England (bypasses) [213]	Bypass demonstration project (England) [213 214]
England (20 mph zones) [179]	Twenty miles per hour zones (England) [179 215 216]
Eugene [174]	Curb Your Car, Eugene, Oregon (United States) [174]
Frome [175]	TravelSmart, Frome (England) [175 217]
Glasgow [218]	Walk in to Work Out, Glasgow (Scotland) [218 219]
Gloucester [176]	TravelSmart, Gloucester (England) [176 220]
Camden-Islington [221]	School travel co-ordinators, Camden and Islington, London (England) [221]
Maidstone [222]	MIST, Maidstone (England) [222]
Perth [223]	TravelSmart, Perth (Australia) [184-186 223-238]
Phoenix [239]	Clean Air Force, Phoenix, Arizona (United States) [239]
San Francisco [177]	City CarShare, San Francisco, California (United States) [177 240 241]
Stockton [178]	Cycle route, Stockton (England) [178]
Tampere [66]	Physically active commuting to work, Tampere (Finland) [66 242 243]
Trondheim [244]	Toll ring, Trondheim (Norway) [244-248]
Voorhout [249]	New railway station, Voorhout (Netherlands) [249]
Århus [172]	BikeBus'ters, Århus (Denmark) [172 250-254]

Table 22. List of included studies

Tables and figures

Following the convention of the Cochrane Library, data about the included studies are summarised using three tables:

1. A table summarising the key characteristics of each study: the intervention (including the costs, where these were identified), study design, study population, and primary outcome measures for each study (Table 23)

2. A table summarising more detailed descriptive and primary outcome data for each study (Table 24)

3. A table summarising which of the ten summary validity criteria were met by each study (Table 25).

The evidence of effectiveness across all categories of intervention is then summarised in Table 26, grouped and ordered in the same way as in the text (see below). For the studies whose primary outcome could be summarised using the common metric *M* (n=16), the estimated effect sizes are summarised in Table 27. There was a weak negative correlation between *M* and baseline active mode share (r_s=–0.37) and a stronger positive correlation between *M* and study validity (r_s=0.57); the estimates of these correlation coefficients were not substantially influenced by the inclusion or exclusion of the outlier representing the results from Århus (Figure 5).

The available data about the social distribution of the effects of interventions, and about any associated health effects, are summarised in Table 28 and Table 29.

Text

The studies are grouped into five categories according to the main focus of the intervention assessed:

1. Targeted behaviour change programmes
2. Agents of change and publicity campaigns
3. Engineering measures
4. Financial incentives
5. Providing alternative services.

Within each category, data related to the primary outcome of interest (modal shift) are synthesised narratively, the studies being written about in descending order of validity (except for the pilot studies from Frome and Gloucester, which are listed after the definitive study from Perth to which they are related).

Where sample sizes are given, these refer to the number followed up in the intervention group in a controlled study, or the number responding to the 'before' or 'after' survey wave (whichever was the smaller) in an uncontrolled study. Where response rates are given, these refer to the response rate to the 'before' wave of a panel study, or the response rate for the 'before' or 'after' survey wave (whichever was the smaller) in a repeated cross-sectional study.

I have followed the convention of the *British Medical Journal* in using 'significance' to stand for 'statistical significance' in reporting results. Unless otherwise stated, where I have described an association or a difference as 'significant' this should be taken to mean statistically significant at the conventional level of α=0.05 (two-sided).

Study	Year*	Intervention	Study population	Study design	Primary outcome
Adelaide [180]	1998	Tailored feedback on travel diaries with suggestions on changing travel patterns, supported with customised information (Travel Blending) Identified costs: A$44 per household A$15 per person	Households living in, working in, or visiting two neighbourhoods of Adelaide (Dulwich and Christies Beach)	Uncontrolled prospective panel	Reported frequency of, and time spent on, all trips in a seven-day travel diary by mode
Boston [188]	1978	Car restriction, subsidised bus services and pedestrianisation in central business district Identified costs: US$5,000,000	Employees in city centre office buildings in Boston	Uncontrolled repeated cross-sectional	Reported mode of journey to work on day before survey
California (cashing out) [192]	1992	State legislation requiring employers with at least 50 staff to 'cash-out' the cost of rented parking spaces Identified costs: mean additional subsidy of US$2 per employee per month	Employees at workplaces in urban South California	Controlled repeated cross-sectional	Reported mode of all journeys to work over five consecutive days
California (telecommuting) [194]	1993	Voluntary use of neighbourhood telecommuting centres as an alternative to commuting to usual workplace	Registered users of telecommuting centres in California	Retrospective, using participants as their own controls	Reported mode of all trips recorded over two periods of three consecutive days

* Year in which the intervention started. A$: Australian dollars. ECU: European Currency Unit. NLG: Dutch guilders. NOK: Norwegian kroner. NR: not reported. US$: US dollars.

Table 23. Characteristics of included studies

Study	Year*	Intervention	Study population	Study design	Primary outcome
Camden-Islington [221]	NR	Site-specific advice to participating schools from a school travel co-ordinator	Pupils in primary schools in two London boroughs	Cluster randomised controlled trial	Reported mode of journey to school on one day
Delft [195]	1982	Upgrading and increased connectivity (+3.3 km) of cycle route network Identified costs: NLG 30,000,000	Households in suburbs of Delft	Controlled repeated cross-sectional, with nested panel of a subset of respondents in both survey waves	Reported mode of all trips of residents aged 10 and over on one of a number of specified days covering all the days of the week
Detmold-Rosenheim [173]	1981	Bicycle-friendly demonstration project in two towns, mainly consisting of planning and building improvements to cycle route network (+31 km and +13 km respectively)	Households in both towns	Uncontrolled repeated cross-sectional	Reported mode of all trips of residents aged 10 and over on one of a number of specified days covering all the days of the week
England (bypasses) [213]	1992	Construction of bypasses, followed by a variety of traffic calming measures and enhanced walking or cycling facilities in each town centre	Residents of six small towns in England	Uncontrolled repeated cross-sectional	Reported main mode of residents' trips to town centres
England (20 mph zones) [179]	1996	Construction of 20 mph (30 km/h) zones, enforced using a range of engineering measures	Residents of neighbourhoods in six towns in northern England	Uncontrolled repeated cross-sectional	Stated change in travel patterns

* Year in which the intervention started. A$: Australian dollars. ECU: European Currency Unit. NLG: Dutch guilders. NOK: Norwegian kroner. NR: not reported. US$: US dollars.

Table 23. Characteristics of included studies (continued)

Study	Year*	Intervention	Study population	Study design	Primary outcome
Eugene [174]	1994	Promotion of alternative modes through workplace transport co-ordinators and transport fairs, free bus passes, and rewards for staff using alternative modes	State employees in Oregon	Uncontrolled repeated cross-sectional	Reported most commonly used mode for commuting
Frome [175]	2001	Individualised marketing of alternative modes to households showing an interest in using them (TravelSmart: see Perth) Identified costs: £72,000	Households in Frome	Controlled prospective panel with common baseline dataset	Reported main mode of all household trips, expressed in terms of estimated trips per person per year by mode extrapolated from a one-day travel survey
Glasgow [218]	1998	Self-help pack to promote active commuting (Walk In to Work Out) containing written interactive materials based on transtheoretical model of behaviour change, e.g. advice on choosing routes, personal safety, safe cycle storage, activity diary, map Identified costs: £1 per pack	Employees at three public sector organisations in Glasgow	Randomised controlled trial	Reported time spent walking to work in seven-day recall physical activity diary, progression to higher stage of change, and prevalence of cycling

* Year in which the intervention started. A$: Australian dollars. ECU: European Currency Unit. NLG: Dutch guilders. NOK: Norwegian kroner. NR: not reported. US$: US dollars.

Table 23. Characteristics of included studies (continued)

Study	Year*	Intervention	Study population	Study design	Primary outcome
Gloucester [176]	2001	Individualised marketing of alternative modes to households showing an interest in using them (TravelSmart: see Perth) Identified costs: £30,000	Households in a suburb of Gloucester	Controlled prospective panel with common baseline dataset	Reported main mode of all household trips, expressed in terms of estimated trips per person per year by mode extrapolated from a one-day travel survey
Maidstone [222]	1994	Campaign using mass media and community activities to raise awareness of alternative modes	Households on trunk route corridors approaching Maidstone and Tunbridge Wells	Controlled repeated cross-sectional	Reported frequency of all household trips in a typical week by mode
Perth [223]	2000	Individualised marketing of alternative modes to households showing an interest in using them (TravelSmart), using a tailored combination of e.g. public transport information, cycle route map, walking information booklet with motivational challenge chart, sometimes followed up with home visits Identified costs: Capital A$1,300,000 Operating A$300,000 per year	Households in South Perth and Victoria Park	Controlled repeated cross-sectional, using a mixture of survey sources to compile the baseline dataset, a combination of random and quota sampling for follow-up, and analysing outcomes in a sample representative of all local households irrespective of their interest or participation in the intervention	Reported main mode of all household trips, expressed in terms of estimated trips per person per year by mode extrapolated from a one-day travel survey

* Year in which the intervention started. A$: Australian dollars. ECU: European Currency Unit. NLG: Dutch guilders. NOK: Norwegian kroner. NR: not reported. US$: US dollars.

Table 23. Characteristics of included studies (continued)

Study	Year*	Intervention	Study population	Study design	Primary outcome
Phoenix [239]	1988	Campaign using mass media and community activities to promote voluntary no-drive day Identified costs: US$750,000	Drivers living in Maricopa County and commuting to work	Uncontrolled repeated cross-sectional	Reported mode of all commuting journeys over five days
San Francisco [177]	NR	Neighbourhood-based car-sharing co-operative	Members and aspiring members in San Francisco	Controlled repeated cross-sectional	Reported mode of all trips on any two days selected by the respondent
Stockton [178]	1985	New shared pedestrian and cycle route (4 km)	Secondary school pupils in Stockton	Partially-controlled repeated cross-sectional	Reported usual mode of journey to school
Tampere [66]	NR	Participation in a trial of the effects of walking and cycling to work on physical fitness and blood lipids	Car or bus commuters in Tampere	Randomised controlled trial [no actual intervention to promote modal shift except for participation in trial]	Included for health effects only
Trondheim [244]	1991	Toll ring for motor vehicles inbound towards the city centre, Monday to Friday between 0600 and 1700 Identified operating costs in first year: NOK 7,200,000 Revenue raised in first year: NOK 70,700,000	Households in Trondheim	Uncontrolled prospective panel	Reported mode of all trips made by residents aged over 13 recorded in a one-day travel diary

* Year in which the intervention started. A$: Australian dollars. ECU: European Currency Unit. NLG: Dutch guilders. NOK: Norwegian kroner. NR: not reported. US$: US dollars.

Table 23. Characteristics of included studies (continued)

Study	Year*	Intervention	Study population	Study design	Primary outcome
Voorhout [249]	1997	Opening of a railway station in a commuter town	Households in Voorhout	Uncontrolled prospective panel	Reported mode of (a) all activities and (b) work and school activities of residents aged over 12 on two consecutive days selected by the respondent
Århus [172]	1995	'Inveterate motorists' invited to try to use bike and bus as much as possible in exchange for free bike, free bus pass and other accessories and information for one year (BikeBusters) Identified costs: ECU 450,000	Car commuters in Århus	Uncontrolled prospective panel	Reported mode of all weekday trips over one week

* Year in which the intervention started. A$: Australian dollars. ECU: European Currency Unit. NLG: Dutch guilders. NOK: Norwegian kroner. NR: not reported. US$: US dollars.

Table 23. Characteristics of included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Targeted behaviour change programmes				
9	Glasgow [218]	Sample Response Follow-up Length	102 commuters 89% 66% 6 months	*Reported time spent walking to work in seven-day recall physical activity diary* Among those who had not walked to work at the start of the study, those in the intervention group (n=14) reported spending a significantly greater mean time per week walking to work than controls (n=12) (125 mins vs 61 mins) There was also a significant increase in the reported mean time spent walking to work per week, in favour of the intervention group, among those who already walked to work (intervention group (n=61): 52 min to 79 min, control group (n=43): 50 min to 60 min) Using analysis of covariance, the average relative increase in the time spent walking to work at six months, for someone given the intervention, was estimated as 1.93 (95% CI 1.06 to 3.52) times any increase in walking time for a corresponding control who walked the same amount at baseline *Reported time spent cycling* 'No difference' in the reported average weekly minutes spent cycling between cyclists in the intervention group (n=9) and control group (n=9) *Progression to higher stage of change* A significantly higher proportion of the intervention group (49%) had progressed to a higher stage of active commuting behaviour change compared with the control group (31%: difference 18% (95% CI 5% to 32%). At 12 months, 25% of the intervention group had progressed to the 'action' or 'maintenance' stages (95% CI 17% to 32%)

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Table 24. Descriptive and primary outcome data for included studies

Score*	Study	Descriptive data†		Primary outcome data‡
Targeted behaviour change programmes (continued)				
7	Perth [223]	Sample Response Follow-up Length	706 households 75% NA 6 months	*Reported main mode of all household trips* Intervention group: estimated absolute modal shift of +5.5% from a baseline of 13.9%. Changes in all mode shares were 'significant' whether using the number of trips or persons as the denominator (walking: $P<0.01$ in either case; cycling: $P<0.01$ using trips, $P<0.10$ using persons; car driver: $P<0.01$ in either case; car passenger: $P<0.01$ using trips, $P<0.10$ using persons). Changes sustained at 18-month follow-up (but comparable control group data not shown) Control group: estimated absolute modal shift of –2%. Based on reported data and using the number of trips as the denominator, the change in walking mode share is likely to have been of borderline significance (estimated 95% CI -4.1% to +0.1%) and the changes in car and cycling mode shares are unlikely to have been significant (estimated 95% CIs -0.5% to +4.5% and -1.1% to +1.1% respectively)§ *Reported time spent walking and cycling* Estimated mean time spent walking increased from 10 to 13 minutes per person per day. Estimated mean time spent cycling increased from two to three minutes per person per day
9	Frome [175]	Sample Response Follow-up Length	748 households (C) 74% 80% 3 months	*Reported main mode of all household trips* Estimated absolute modal shift of +3.6% from a baseline of 31.1% after adjustment for changes in control group. Decrease in car driver share of all trips reported to be significant ($P<0.05$). Not possible to assess significance of changes in other mode shares without access to raw paired data

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Targeted behaviour change programmes (continued)				
9	Gloucester [176]	Sample Response Follow-up Length	624 households (C) 66% 76% 3 months	*Reported main mode of all household trips* Estimated absolute modal shift of +4.4% from a baseline of 28.7% after adjustment for changes in control group. Decrease in car driver share of all trips reported to be significant ($P<0.05$). Not possible to assess significance of changes in other mode shares without access to raw paired data
7	Århus [172]	Sample Response Follow-up Length	150 commuters NR¶ 88% 11 months	*Reported mode of all weekday trips over one week* Estimated absolute modal shift of +25.3% from a baseline of 18.4%. Not possible to assess significance of changes without access to raw paired data
6	Tampere [66]	Sample Response Follow-up Length	35 commuters NR 96% 10 weeks	None — included for health effects only
4	Adelaide [180]	Sample Response Follow-up Length	403 households NR¶ 35-50% 1 month	*Reported frequency, mode and duration of all trips in a seven-day travel diary* Among households that participated in the intervention, there was an overall reduction in all trips of 8% and 11% in Dulwich and Christies Beach respectively. Car driver trips decreased by 10.2% and 14.6% respectively, and car passenger trips decreased by 9.4% and 8.6% respectively. Walking trips increased by 1.0% in Dulwich and decreased by 2.0% in Christies Beach. Time spent walking increased by 8.2% in Dulwich. Cycling trips decreased by 11.0% in Dulwich and increased by 20.9% in Christies Beach. Not possible to assess significance of changes without access to raw paired data

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Agents of change and publicity campaigns				
8	Camden-Islington [221]	Sample Response Follow-up Length	714 school pupils 85% NA 14 months	*Reported mode of journeys to school on one day* Pupils in intervention schools were more likely to travel to school by car (24.1% vs 22.5%) and less likely to walk to school (69.9% vs 71.0%) than pupils in control schools. There was no significant difference in the odds of a pupil travelling to school on foot, by bike or on public transport between intervention and control schools (odds ratios and 95% CIs: unadjusted 0.98 (0.54, 1.76); adjusted for baseline characteristics of the school 1.20 (0.81, 1.82); adjusted for baseline characteristics of the school and other covariates 0.98 (0.61, 1.59)
7	Maidstone [222]	Sample Response Follow-up Length	761 households 20% NA 2 years	*Reported frequency of all household trips in a typical week by mode* Intervention area: average number of weekly trips by car increased (12.74 to 12.82, NS), on foot decreased (5.02 to 4.95, NS), and by bike decreased (0.75 to 0.45, P<0.05) Control area: average number of weekly trips by car decreased (12.83 to 12.10, NS), on foot increased (6.72 to 6.85, NS), and by bike decreased (1.03 to 0.56, P<0.10)

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Agents of change and publicity campaigns (continued)				
5	Phoenix [239]	Sample Response Follow-up Length	701 drivers NR NA 7 months	*Reported mode of all commuting journeys* Estimated absolute modal shift of +1% following the current year's intervention from a baseline of 5% (+3.5% from a baseline of <2.5% when compared to the previous year's baseline survey; a proportion of this shift occurred between the waves of the intervention). Based on reported data and using the number of drivers as the denominator, the changes over the two year period for car and cycling mode shares are likely to have been significant (estimated 95% CIs -5.6% to -2.4% and +0.3% to +1.7% respectively) and that for walking mode share is likely to have been of borderline significance (estimated 95% CI 0.0% to +2.0%); over the most recent study year, the changes in walking and cycling mode shares are likely to have been significant (estimated 95% CIs +2.0% to +3.0% and +0.3% to +1.7% respectively) but that for car mode share is not (estimated 95% CI -3.0% to +1.0%)§
4	Eugene [174]	Sample Response Follow-up Length	263 commuters NR NA 9 months	*Reported most commonly used mode for commuting* Estimated absolute modal shift of 0 from a baseline of 2-6% depending on area of residence

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Engineering measures				
7	Delft [195]	Sample Response Follow-up Length	1937 households Before: 68% After: NR NA 3 years	*Reported mode of all trips of residents aged 10 and over on one of a number of specified days covering all the days of the week* In the main intervention area, cycling mode share increased from 40% to 43% of all trips, with an increase of 4% in the frequency of bike trips; car and walking mode shares did not change. At baseline, mean daily travel included 9 minutes of walking and 21 minutes of cycling; at follow-up, the total estimated bike-kilometres travelled had increased by 11%. In a secondary intervention area which received only improvements to the bike route to the city centre, cycling mode share increased from 38% to 39%. In the control area, the frequency of car trips increased by 15% and the frequency of bike trips did not change. A comparison of similar trips made by a sub-panel of respondents in the intervention area who participated in both survey waves (a sample described by authors as 'biased', sample size not reported) found a positive modal shift of 0.6% of all trips from a baseline of 66.2%; 8.8% of cycling trips after the intervention had been shifted from other modes, of which 4.4% came from walking and 3.3% came from the car. Not possible to assess significance of changes without access to raw paired data

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Engineering measures (continued)				
6	Detmold-Rosenheim [173]	*Detmold*		*Reported mode of all trips of residents aged 10 and over on one of a number of specified days covering all the days of the week*
		Sample Response Follow-up Length	583 households 53% NA 5 years	Estimated absolute modal shift of -8% (unadjusted) or –5% (adjusted for changes in age structure and car ownership) from a baseline of 41%. Based on reported unadjusted data and using the number of trips as the denominator, the changes in car and walking mode shares are likely to have been significant (estimated 95% CIs +9.5% to +12.5% and -9.3% to -6.7% respectively) and the change in cycling mode share is not (estimated 95% CI-1.1% to +1.1%)§
		Rosenheim		*Reported mode of all trips of residents aged 10 and over on one of a number of specified days covering all the days of the week*
		Sample Response Follow-up Length	598 households 62% NA 5 years	Estimated absolute modal shift of 0 (both unadjusted and adjusted for changes in age structure and car ownership) from a baseline of 49%. Based on reported unadjusted data and using the number of trips as the denominator, the changes in walking and cycling mode shares are likely to have been significant (estimated 95% CIs -3.2% to -0.8% and +1.9% to +4.1% respectively) and the change in car mode share is not (estimated 95% CI -0.3% to +2.3%)§
5	Stockton [178]	Sample Response Follow-up Length	2946 school pupils 73% NA 17 months	*Reported usual mode of journey to school* Estimated absolute modal shift of –2% from a baseline of 81%. Based on reported data and using the number of pupils as the denominator, the changes in all mode shares are likely to have been significant (estimated 95% CIs: car +1.1% to +2.9%, walking -3.6% to -0.4%, cycling –2.9% to –1.1%)§ 'Despite the overall decline in the numbers cycling to school, the schools within the "catchment area" had cyclist percentages 2-6 times higher than those for the "control" schools outside the catchment area (4 to 6% compared with 1-2%'. The authors did not report a before-and-after comparison of cycling mode share in the notional intervention and control areas

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Engineering measures (continued)				
5	England (20 mph zones) [179]	Sample Response Follow-up Length	200-350 residents in each of six zones NR¶ NR 1 year	*Stated change in travel patterns* In three of the zones a 'significant proportion' (27%, 11% and 9% respectively) of respondents in the follow-up survey said that the intervention had made them more likely to walk. However, after comparing the reported frequencies of actual trips by purpose and mode before and after the intervention, the authors concluded that the introduction of the 20 mph zones did not appear to have influenced the frequency or purpose of walking or car trips. Respondents did not indicate any increase in cycling following implementation of the zones
4	Boston [188]	Sample Response Follow-up Length	5449 commuters 31% NA 2 years	*Reported mode of journey to work on day before survey* Estimated absolute modal shift of +0.3% to +0.9% from a baseline of 6.0% (cycling mode share included 'miscellaneous', therefore estimated effect size depends on assumptions made about this category). Based on reported data and using the number of commuters as the denominator, the changes in car and cycling mode shares are likely to have been significant (estimated 95% CIs -8.3% to -6.1% and +0.4% to +0.8% respectively) and the change in walking mode share is not (estimated 95% CI -0.3% to +0.9%)§
3	England (bypasses) [213]	Sample Response Follow-up Length	1446 residents NR NA 12-28 months (varied between towns)	*Reported main mode of residents' trips to town centres* Estimated absolute modal shift of –3% from a baseline of 55%. Based on reported data and using the number of residents as the denominator, the changes in car and walking mode shares are likely to have been significant (estimated 95% CIs +0.4% to +5.6% and -6.6% to -1.4% respectively) and the change in cycling mode share is likely to have been of borderline significance (estimated 95% CI -2.0% to 0.0%)§

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Financial incentives				
8	California (cashing out) [192]	Sample Response Follow-up Length	1694 commuters >90% NA 1-3 years	*Reported mode of all journeys to work over five consecutive days* Intervention workplaces: estimated absolute modal shift of +1% from a baseline of 2.8%. Overall change in distribution between all modes was significant at each workplace separately (P<0.01) Control workplace: estimated absolute modal shift of −1%. Overall change in distribution between all modes not significant (P>0.10)
7	Trondheim [244]	Sample Response Follow-up Length	1900 households 77% 62% 1 year	*Reported mode of all trips made by residents aged over 13 recorded in a one-day travel diary* Estimated absolute modal shift of −2.6% for all trips from a baseline of 35.9%. Not possible to assess significance of changes in mode shares without access to raw paired data Mean number of reported daily trips per traveller decreased from 4.46 to 3.92 (a decrease of 12.2%; P<0.05). Within this overall decrease, the proportional decreases in walking and cycling trips were greater than the decreases in car trips as driver and as passenger (decreases of 28.1%, 14.9%, 5.6% and 14.3% respectively). All decreases were significant at P<0.01 except for that for car driver trips, which was significant at P<0.05 Proportions of respondents who reported any walking or cycling trips decreased (for walking by 6.6%, P<0.01; for cycling by 2.6%, P<0.10)

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Table 24. Descriptive and primary outcome data for included studies (continued)

Score*	Study	Descriptive data†		Primary outcome data‡
Providing alternative services				
7	San Francisco [177]	Sample Response Follow-up Length	247 members 22% NA 9 months	*Reported mode of all trips on any two days selected by the respondent* Estimated absolute modal shift of 0 from a baseline of 48.4%. Car and combined walking and cycling mode shares in both intervention and control groups increased between the 'before' and 'after' surveys: car mode share increased from a pooled baseline of 5.2% to 22.2% (intervention) and 22.8% (control), and combined walking and cycling mode share increased from a pooled baseline of 36.1% to 39.8% (intervention) and 48.4% (control). Author's analysis of trips excluding trips in car share club vehicles found that the differences in changes in private car, walking, and cycling mode shares between the intervention and control groups were not significant (P>0.10)
7	Voorhout [249]	Sample Response Follow-up Length	197 households 56% 59% 1 year	*Reported mode of (a) all activities and (b) work and school activities of residents aged over 12 on two consecutive days selected by the respondent* Estimated absolute modal shift of +5.0% for all activities (from a baseline of 42.1%) and +1.9% for work and school activities (from a baseline of 29.0%). Changes in overall distribution of mode choice for both activity categories were significant (P<0.001); combined walking and cycling mode share included 'marginal' contribution from powered two-wheelers (Arentze T, personal communication)
4	California (telecommuting) [194]	Sample Response Follow-up Length	72 commuters 35% NA NA	*Reported mode and distance of all trips recorded over two periods of three consecutive days* Estimated absolute modal shift of −0.2% from a baseline of 6.1% (car mode share included vanpooling). Not possible to assess significance of changes in mode shares without access to raw paired data. Absolute distance travelled by walking and cycling on telecommuting days was 24% lower than on control days

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Table 24. Descriptive and primary outcome data for included studies (continued)

* Total number of validity criteria met (maximum 10) (Table 25).

† Sample: the number followed up in the intervention group in a controlled study, or the number responding to the 'before' or 'after' survey wave (whichever was the smaller) in an uncontrolled study. Response: the response rate for the 'before' wave of a panel study, or the response rate for the 'before' or 'after' survey wave (whichever was the smaller) in a repeated cross-sectional study. Follow up: the proportion of participants in an experimental or panel study who completed the follow-up survey wave. Length: the interval between the start of the intervention (or, if this was not reported, the 'before' survey wave) and the follow-up survey wave chosen for data extraction (the last wave, the most seasonally-appropriate wave, or the wave at which the most relevant outcome data were collected). NA: not applicable. NR: not reported. C: sample size includes control group.

‡ Where a baseline is cited for a modal shift, this is the combined mode share for walking and cycling before the start of the intervention. 95% CI: 95 per cent confidence interval. NS: reported by authors to be 'not statistically significant'.

§ Estimated 95% confidence intervals for difference between independent proportions based on published counts or proportions and denominators.

¶ Incalculable due to complex and/or non-random method of recruitment.

Table 24. Descriptive and primary outcome data for included studies (continued)

Criterion	Study: Adelaide [180]	Boston [188]	California (cashing out) [192]	California (telecommuting) [194]	Camden-Islington [221]	Delft [195]	Detmold-Rosenheim [173]	England (bypasses) [213]	England (20 mph zones) [179]	Eugene [174]	Frome [175]	Glasgow [218]	Gloucester [176]	Maidstone [222]	Perth [223]	Phoenix [239]	San Francisco [177]	Stockton [178]	Tampere [66]	Trondheim [244]	Voorhout [249]	Århus [172]
Comparability																						
Before-and-after	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Controlled			✓	✓	✓	✓					✓	✓	✓	✓	✓		✓		✓			
Seasonally comparable	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Allocation																						
Random allocation					✓							✓							✓			
Response																						
Representative sample			✓		✓	✓	✓				✓	✓	✓		✓			✓		✓	✓	✓
Sample size	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Attrition rate											✓		✓						✓			✓
Outcome																						
Statistical significance			✓		✓						✓	✓	✓	✓	✓		✓		✓	✓	✓	
Range of trips	✓		✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
Duration of follow-up		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Total criteria met	4	4	8	4	8	7	6	3	5	4	9	9	9	7	7	5	7	5	6	7	7	7

Table 25. Assessment of included studies against summary validity criteria

4.5.3 Evidence related to primary outcome

Targeted behaviour change programmes (six studies of four interventions)

These interventions aimed to change people's travel behaviour by offering an intervention only to a motivated subgroup of the population, by offering information and advice tailored to people's particular requirements, or both.

In **Glasgow**, the Walk In to Work Out interactive self-help package of materials to encourage a change in commuting behaviour was evaluated in a randomised controlled trial. The participants were commuters (mostly car commuters) working for three public sector organisations in Glasgow who had been identified through a screening questionnaire as contemplating or actively preparing for a shift to active commuting. The initial response rate was 89%, and 66% of participants completed follow-up at six months. Intention-to-treat analysis showed that after six months, respondents in the intervention group (n=102) were significantly more likely to have progressed to a higher stage of change for active commuting (49% vs 31%, 95 per cent confidence interval (95% CI) for difference 5% to 32%) than controls, and they reported an estimated average relative increase in the time spent walking to work in a seven-day recall physical activity diary of 1.93 (95% CI 1.06 to 3.52) times any increase in walking time for corresponding controls. Among those who did not already walk to work, there was a net increase of 64 minutes spent walking to work per week; among those who did already walk to work, the net increase was 17 minutes per week. There was reportedly no difference in the time spent cycling per week between cyclists in the intervention (n=9) and control groups. [218]

In **Perth**, the TravelSmart intervention was evaluated in a repeated cross-sectional study of households in South Perth (n=706 households, response rate 75%) and a neighbouring control community of Victoria Park (n=242 households, response rate 82%) following a previous local pilot study. As many households as possible in the intervention area were screened by telephone. The intervention was offered only to households that expressed an interest in changing their travel behaviour and were not already using alternative modes of transport to the car. Each eligible household then received materials according to their stated needs; these could include leaflets, timetables, maps, free trial bus tickets or home visits from bus drivers.

The study drew on a mixture of survey sources to compile the baseline dataset, used a combination of random and quota sampling for follow-up, and analysed travel behaviour for households irrespective of their interest or participation in the intervention (analogous to an intention-to-treat analysis). At six months, there was a positive modal shift of 5.5% of all household trips in the intervention area (based on an extrapolation from a one-day travel survey to estimated trips per person per year, with significant changes in the proportions of trips by car, on foot and by bike, $P<0.01$ in each case), compared with an estimated negative modal shift of 2% in the control area (of uncertain significance). Mean daily total travel time was 58 minutes; within this total, which did not change, walking time increased from 10 to 13 minutes and cycling time from 2 to 3 minutes, so the mean total increase in time spent using active modes of transport was 4 minutes per day. The modal shift in the intervention area was sustained after 18 months, but data were not collected from the control group at that time. [223]

Similar, although smaller, positive net modal shifts of 3.6% and 4.4% respectively were shown after three months in subsequent controlled pilot studies of an analogous intervention using random household samples in **Frome** (n=749 including controls, response rate 74%, follow-up rate 80%) [175] and in **Gloucester** (n=624 including controls, response rate 66%, follow-up rate 76%). [176] In both of these pilot studies the decrease in the share of all trips undertaken as a car driver was significant ($P<0.05$).

In **Århus**, suburban car commuters were invited to volunteer for the year-long BikeBusters uncontrolled panel study in which they received a free bike, a free bus pass and a variety of other equipment and support in exchange for an undertaking to try to use their cars less. The study panel was chosen to be representative of the 1700 people who volunteered. Among the panel (n=150 at follow-up, follow-up rate 88%), there was a large positive modal shift of 25% of all weekday trips from baseline to eleven months after the start of the intervention (a shift of uncertain significance). However, participants were not representative of the general commuting population and outcomes were not assessed in the general population. [172]

In **Adelaide**, the Travel Blending programme was evaluated in an uncontrolled panel study of households associated with two neighbourhoods, Dulwich (n=201 households) and Christies Beach (n=202 households). Households containing people who lived in, worked in, or visited the target neighbourhoods were recruited using a mixture of non-random sampling methods and asked to complete seven-day travel diaries. The intervention consisted of analysing and returned the diaries with tailored suggestions about changing travel behaviour, supported with customised information such as timetables or maps as appropriate. This intervention was combined with other measures in the neighbourhoods ('Living Neighbourhoods') such as minor improvements to local public transport, curricular materials for local schools and an informal 'green' (exercise) prescription scheme. The study was limited by poor representativeness, the lack of a control group, a follow-up period of only one month, and substantial attrition over that period (only 35% and 50% of households in the respective neighbourhoods completed follow-up.) Unlike the TravelSmart studies, only households that participated directly in the intervention were included in the evaluation. Although car use in both study neighbourhoods decreased, changes in walking trips were small (an increase of 1.0% and 2.0% respectively, of uncertain significance), and changes in cycling trips were inconsistent (an increase of 11.0% and a decrease of 20.9% respectively, of uncertain significance). [180]

Agents of change and publicity campaigns (four studies)

Unlike the targeted behaviour change programmes, these interventions were applied to whole groups of people undifferentiated by motivation or personal travel circumstances.

In a cluster randomised controlled trial in **Camden and Islington**, primary schools in a health action zone were randomly assigned to receive, or not to receive, sixteen hours of input from a school travel co-ordinator over the course of a school year. 51% of eligible primary schools agreed to participate. All schools were included in the analysis irrespective of the extent to which any measures had been implemented. Intervention schools were more likely than control schools to have instituted a school travel plan (9/11 vs 0/10) and to have implemented some form of safer route to school scheme (9/11 vs 4/10), but in the follow-up survey of parents (response rate 85%), there was no significant difference in the odds of a pupil having travelled to school on foot, by bike or on public transport on the day of the survey between pupils in intervention schools (n=714) and those in control schools (odds ratio 0.98, 95% CI 0.61 to 1.59, after adjustment for school baseline walking mode share, individual socioeconomic characteristics and other covariates). [221]

In **Maidstone,** a campaign was carried out using local mass media and community exhibitions, talks and discussions to raise awareness of alternative modes of transport as part of a wider sustainable transport initiative. A controlled repeated cross-sectional study was used to compare the reported frequency of trips in a typical week for households along a trunk road corridor approaching Maidstone (n=761 households) with those on a similar route in a control town. The overall response rate was 20%; no data on the representativeness of the sample were reported. After two years, the only significant change in travel behaviour was a decrease in the mean number of cycling trips per week in the intervention area from 0.75 to 0.45 ($P<0.05$). Car trips increased and walking trips decreased in the intervention area, with opposite changes observed in the control area, but these changes were not significant. [222]

In **Phoenix**, the Clean Air Force campaign used mass media and community promotional events (such as a bike-to-work day and competitions for local businesses) to persuade car drivers not to drive to work on one day a week. Drivers resident in the local area who responded to an uncontrolled repeated cross-sectional telephone survey seven months later (n=701; response rate not reported) reported a positive modal shift of 1% of all commuting trips (a shift of uncertain significance). When compared with the baseline survey for the previous year's campaign, the estimated shift was about 3.5%, but it was not clear what proportion of this might have been attributable to the intervention. [239]

In the Curb Your Car campaign in **Eugene**, alternative modes of transport were promoted through the use of transport fairs and transport co-ordinators in state workplaces and by providing free bus passes to employees. An uncontrolled repeated cross-sectional study found no evidence of a shift in employees' usual mode of travel to work after nine months (n=263, response rate not reported). [174]

Engineering measures (six studies)

Infrastructure for cyclists

In **Delft**, a controlled repeated cross-sectional study of a random household sample (initial response rate 68%) compared changes in the trips recorded in a one-day travel survey for households in an intervention area, north west Delft (n=1937 households), with those in a control area, Wippolder. In the intervention area, an existing extensive network of cycle routes was improved by resurfacing and by adding 3.3 km of new connections, including three bridges and two tunnels. After three years, in the intervention area the cycling mode share of all trips had increased from 40% to 43%; there was no change in car or walking mode shares. At baseline, mean daily travel included 9 minutes of walking and 21 minutes of cycling; at follow-up, the total estimated bike-kilometres travelled had increased by 11%, implying an increase of around 2 minutes of cycling per day. Among a nested panel of respondents who participated in both waves and reported comparable trips at both times (a panel described by the authors as 'biased'), there was a positive modal shift (of uncertain significance) of 0.6% of all trips; 38% of new bike trips were estimated to have been transferred from the car. Car mode share increased in the control area; intermediate effects were seen in a third study area (Tanthof) where more limited improvements were carried out. [195]

In **Detmold and Rosenheim**, the bicycle-friendly towns demonstration project mainly consisted of planning and building improvements to the cycle route networks, which were extended by 31 km and 13 km respectively. In an uncontrolled repeated cross-sectional study of a random household sample (response rates 53% and 62% respectively), households reported a negative modal shift of 5% of all trips (Detmold, n=583) and zero modal shift (Rosenheim, n=598) after five years. [173]

In **Stockton**, a repeated cross-sectional study was used to assess the effects of opening a single 4 km cycle route in the town. The study included elements of a controlled design, using a notional intervention area (close to the new cycle route) and a control area elsewhere in the town, but the data related to modal shift came only from uncontrolled before-and-after comparisons in which data from sites in both areas were combined. A survey of secondary school pupils (n=2946, response rate 73%) showed that their usual mode of travel to school was more likely to be the car after the intervention (an estimated negative modal shift of 2%, which is likely to have been significant). The authors also compared the distribution of the mode of transport of people (n=80529) passing seven survey stations along a screenline through the town before and after the intervention. They reported 'significant' decreases in the proportions of both pedestrians (an absolute decrease of 1.5%) and cyclists (an absolute decrease of 0.4%). Details of the statistical tests were not reported. [178]

Traffic restraint

In **England**, traffic restraint schemes were evaluated in studies of 20 miles per hour (mph) (30 kilometres per hour) zones in urban neighbourhoods and of a bypass demonstration project involving small towns.

The effects of **20 mph zones** were studied in an uncontrolled prospective study of between 200 and 350 residents in each of six urban neighbourhoods in northern England where zones were implemented. Residents were sampled by non-random door-to-door recruitment; no data on response rates, follow-up rates or representativeness were reported. The authors reported that twelve months after implementation in three of the zones, a 'significant proportion' (27%, 11% and 9% respectively) of respondents said that the intervention had made them more likely to walk. However, after comparing the reported frequencies of actual trips by purpose and mode before and after the intervention, the authors concluded that the introduction of the 20 mph zones did not appear to have influenced the frequency or purpose of walking or car trips. Respondents did not indicate any increase in cycling following the implementation of the zones. [179]

The effects of **bypasses** were studied in an uncontrolled repeated cross-sectional study of residents of six small towns around which bypasses were built. After the bypasses were opened, a variety of engineering measures were applied in the towns to calm traffic and improve conditions for walking and cycling. A random sample of residents (n=1446, response rates not stated) were more likely to choose the car as their main mode of transport to the town centre after the intervention (an estimated negative modal shift of 3%; the changes in car and walking mode shares are likely to have been significant). Although respondents were less likely to describe facilities for cyclists, pavement conditions and crossing the road as 'big problems' after the intervention, they were also less likely to describe congestion and parking as 'big problems'. [213]

In **Boston**, access by car to the Downtown Crossing central business district was restricted. This was accompanied by improvements to bus services and was followed over the next year by a programme of pedestrianisation. The authors acknowledged several concurrent potential confounding factors that could also have discouraged car use including rises in the cost of fuel and parking. In an uncontrolled repeated cross-sectional study of employees in city centre office buildings (n=5449, response rate 31%), respondents reported a positive modal shift of less than 1% of their journeys to work on the day before the survey. The changes in car and cycling mode shares, but not walking mode share, are likely to have been significant. [188]

Financial incentives (two studies)

In **California**, state legislation required employers who rented parking space to begin '**cashing out**' the cost of subsidising workplace parking, i.e. to offer at least equivalent subsidies to staff who chose to commute by other modes. Although the law was not actually enforced, a repeated controlled cross-sectional study of commuters in eight workplaces that had enacted the policy (n=1694, with a response rate of at least 90% in each workplace) found a positive modal shift of 1% in all commuting journeys over a five-day period after intervals of one to three years. The overall change in distribution of mode share was significant in each workplace (P<0.01). There was no significant change among employees in one control workplace that had not enacted the policy. [192]

In **Trondheim**, a toll ring was introduced for motor vehicles around the city centre at which a charge was payable for inbound car trips during the daytime, Monday to Friday. An uncontrolled panel study of a random sample of households in the city (n=1900 households; initial response rate 77%, follow-up rate 62%) compared trips recorded in a one-day travel diary one year before and one year after the introduction of the toll ring. There was a negative modal shift of 2.6% (of uncertain significance) of all trips, and no evidence of a modal shift in inbound trips across the toll ring. The proportions of respondents who reported making any walking or cycling trips decreased after the intervention (absolute decreases of 6.6% (P<0.01) and 2.6% (P<0.10) respectively). The authors considered that part of the decrease in reported walking trips was due to respondent fatigue in the follow-up survey. [244]

Providing alternative services (three studies)

In **San Francisco**, the effects of joining a car-sharing club were studied in a controlled repeated cross-sectional study comparing the behaviour of members who had joined (n=247; response rate 22%) with that of people who had expressed interest but were still waiting for the opportunity to join to be made available. Respondents recorded trips made on any two days which they were free to select. Both groups were atypical of the general city population, being comparatively unlikely to use cars at baseline. After nine months, there was no evidence of a net positive modal shift, as car mode share had increased in both groups (+17.0% and +17.6% respectively), as had the combined walking and cycling mode share (+3.7% and +12.3% respectively). In an analysis that excluded trips made in car share club vehicles, there was no significant difference in mode shares for private car, walking or cycling between the intervention and control groups. [177]

In **Voorhout**, an uncontrolled panel study of households (n=197, initial response rate 56%) compared travel patterns recorded over a two-day period before and after the opening of the first railway station in this commuter town. After one year (follow-up rate 59%), there was an estimated 5.0% positive modal shift in all trips, with an estimated 1.9% positive modal shift in the subset of trips related to work or school. For both trip categories, the changes in overall distribution of mode share were significant (P<0.001). [249]

In **California**, the effects of neighbourhood **telecommuting** centres were studied in a controlled retrospective study. In this study, 'before' and 'after' data from two three-day periods were pooled in order to compare the travel behaviour of employees (n=72; response rate 35%) on days when they did, or did not, use a local telecommuting facility as an alternative to commuting to their usual workplace. Participants therefore acted as their own controls in the study. No data were reported on the representativeness of the sample. There was an estimated negative modal shift of 0.2% on telecommuting days (of uncertain significance, since data were presented in a way which did not take account of the non-independence of the observations). The absolute distance walked or cycled on those days was 25% less than on non-telecommuting days.[194]

			Evidence for modal shift from using cars towards walking and cycling†			
Study	Score*	Comparison	Negative effect of uncertain significance	Inconclusive or no effect	Positive effect of uncertain significance	Significant positive effect
Targeted behaviour change programmes						
Glasgow [218]	9	Controlled				•
Perth (TravelSmart) [223]	7	Controlled				•
Frome (TravelSmart pilot) [175]	9	Controlled			•	
Gloucester (TravelSmart pilot) [176]	9	Controlled			•	
Århus [172]	7	Uncontrolled			•	
Adelaide [180]	4	Uncontrolled		•		
Agents of change and publicity campaigns						
Camden-Islington [221]	8	Controlled		•		
Maidstone [222]	7	Controlled		•		
Phoenix [239]	5	Uncontrolled			•	
Eugene [174]	4	Uncontrolled		•		
Engineering measures						
Delft [195]	7	Controlled			•	
Detmold-Rosenheim [173]	6	Uncontrolled	•			
Stockton [178]	5	Uncontrolled	•			
England (20 mph zones) [179]	5	Uncontrolled		•		
Boston [188]	4	Uncontrolled			•	
England (bypasses) [213]	3	Uncontrolled	•			

* Total number of validity criteria met (maximum 10) (Table 25).
† No study reported a significant negative effect.

Table 26. Summary of evidence of effectiveness of interventions to promote modal shift

Study	Score*	Comparison	Evidence for modal shift from using cars towards walking and cycling†			
			Negative effect of uncertain significance	Inconclusive or no effect	Positive effect of uncertain significance	Significant positive effect
Financial incentives						
California (cashing out) [192]	8	Controlled				•
Trondheim [244]	7	Uncontrolled	•			
Providing alternative services						
San Francisco [177]	7	Controlled		•		
Voorhout [249]	7	Uncontrolled				•
California (telecommuting) [194]	4	Controlled	•			

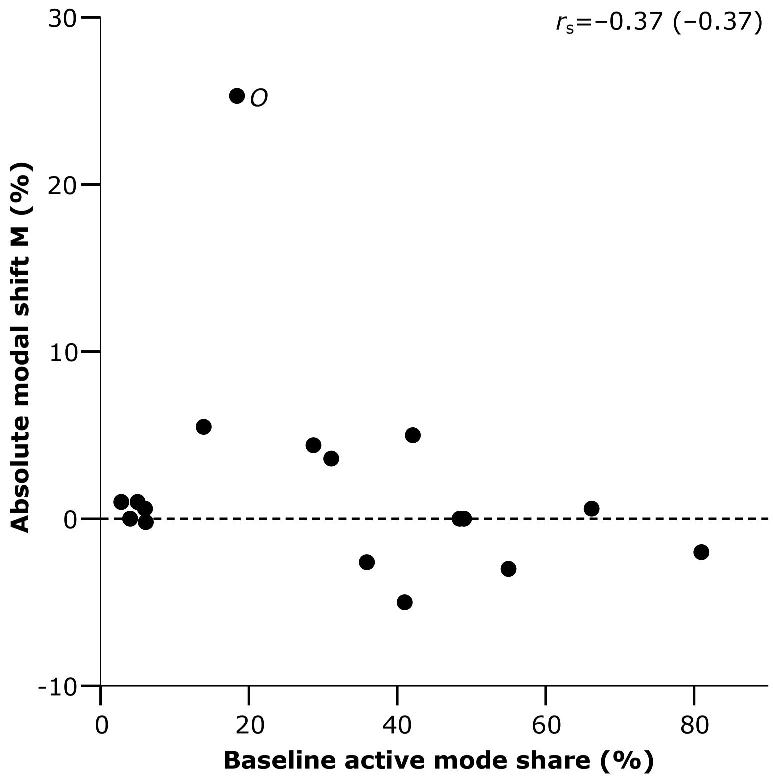
* Total number of validity criteria met (maximum 10) (Table 25).
† No study reported a significant negative effect.

Table 26. Summary of evidence of effectiveness of interventions to promote modal shift (continued)

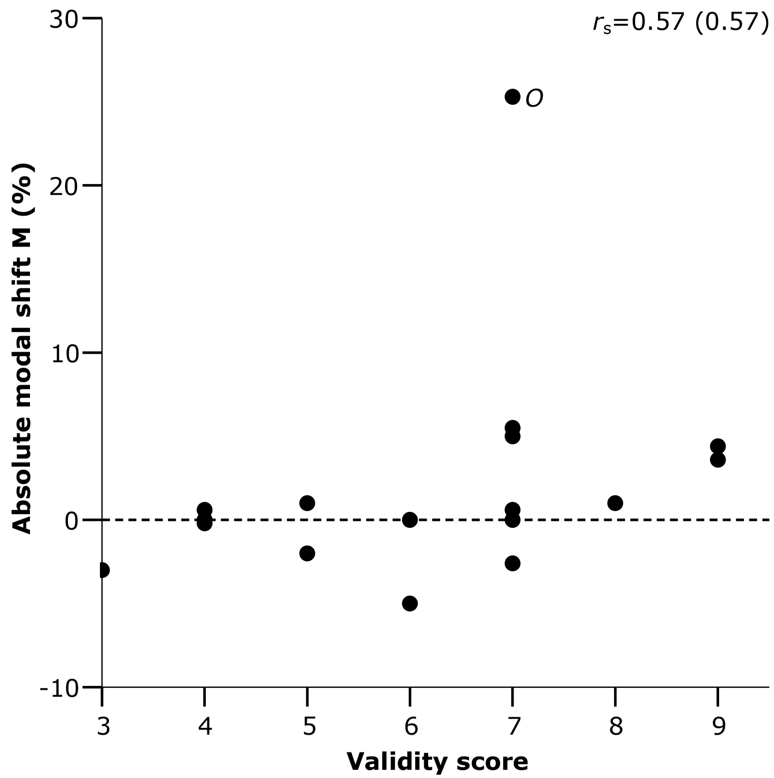
Study	Score*	Baseline active mode share†	Absolute modal shift *M*‡
Targeted behaviour change programmes			
Perth [223]	7	13.9%	+5.5%
Frome [175]	9	31.1%	+3.6% (C)
Gloucester [176]	9	28.7%	+4.4% (C)
Århus [172]	7	18.4%	+25.3%
Agents of change and publicity campaigns			
Phoenix [239]	5	5.0%	+1.0%
Eugene [174]	4	2% to 6%	0
Engineering measures			
Delft [195]	7	66.2%	+0.6%
Detmold [173]§	6	41%	-5%
Rosenheim [173]§	6	49%	0
Stockton [178]	5	81%	-2%
Boston [188]	4	6%	+0.3% to +0.9%
England (bypasses) [213]	3	55%	-3%
Financial incentives			
California (cashing out) [192]	8	2.8%	+1.0%
Trondheim [244]	7	35.9%	-2.6%
Providing alternative services			
San Francisco [177]	7	48.4%	0
Voorhout [249]	7	42.1%	+5.0%
California (telecommuting) [194]	4	6.1%	-0.2% (C)

* Total number of validity criteria met (maximum 10) (Table 25).
† Given to one decimal place except where published data did not permit this level of precision.
‡ Within the intervention group except for studies marked (C), where estimates were adjusted by authors to take account of changes in the control group.
§ Results for Detmold and Rosenheim have been disaggregated.

Table 27. Intervention effect sizes summarised using common metric *M*



5 (a)



5 (b)

r_s: Spearman rank correlation coefficients, first including all data points then (in parentheses) after excluding the outlier *O* (Århus).

Figure 5. Relationship between effect size and (a) baseline active mode share and (b) study validity score

4.5.4 Evidence related to secondary outcomes

Social distribution of effects (11 studies)

Most studies did not report the distribution of effects between groups in the population, and where information about distributional effects was reported this was usually presented very briefly, often without showing the data on which the statements were based. Taken together, the available data did not provide any clear overall evidence about the differential effectiveness of interventions (Table 28). However, three studies (Århus, Delft and Stockton) reported that males were more likely to cycle than females, [172 178 195] and the authors of two studies (Delft and Perth) noted that the observed increase in cycling mode share was largely attributable to existing cyclists making more trips, rather than to people taking up cycling. [195 223]

Health effects (six studies)

I found six studies in which effects on direct measures of human health, fitness, health-related behaviour or wellbeing had been reported (Table 29). These included a study from **Tampere**, which was a randomised controlled trial of the health effects of taking up active commuting in which the intervention to promote modal shift consisted solely of participation in the trial. In this study, members of the intervention group (n=35; follow-up rate 96%), who normally travelled to work by motor vehicle, were asked to walk or cycle to work as often as possible at their ordinary, self-selected speed.

I found evidence about effects on participants' health and fitness, but only from studies of selected volunteers from which findings may not be transferable to wider populations. I also found data on injuries and other effects on health at the population level, but only from studies of interventions that had not been effective in promoting a modal shift.

Health and fitness of participants in targeted interventions

Only two studies (the randomised controlled trials of active commuting in Glasgow and Tampere) reported robust data on health effects. In Glasgow, participants in the intervention group (n=102) showed significant increases in sample mean scores on three of the eight subscales of the Short Form 36 (SF-36) instrument compared with the control group (mental health from 72 to 76, vitality from 57 to 64, and general health from 71 to 76; $P<0.05$ in each case).[218] In Tampere, participants in the intervention group (n=35) showed significant net improvements in maximum aerobic power ($V_{O_2 max}$) (+4.5%, P=0.02) and maximum treadmill time (+10.3%, $P<0.001$), significant reductions in heart rate (P=0.04) and blood lactate (P=0.002) at submaximal standard work load, and an increase in high density lipoprotein (HDL) cholesterol of borderline significance (+5%, P=0.06); there was no significant change in serum total cholesterol or triglyceride concentrations.[66]

The study from Århus reported an increase in the proportion of participants with average or better self-rated fitness and little change in the distribution of blood pressure and cholesterol levels, but there was insufficient information in the reports to enable me to assess the validity of these findings.[172]

The studies in Tampere and Århus both reported that the interventions had no overall effect on participants' weight.[66 172]

Injuries to road users

Three studies of engineering measures compared counts of injuries to road users in the local areas before and after the intervention. In Stockton, the accident count for cyclists increased in both the intervention and control areas; there was said to have been a 'significant' shift in the distribution of these accidents from the intervention area to the control area. The 'before' and 'after' study periods lasted for only eighteen months and were not seasonally comparable.[178] In the study of bypasses in England, in which data were compared for at least two years before and after the intervention in each town, the accident counts for pedestrians and cyclists decreased in five of the six study towns.[213] In the study of 20 mph zones in England, data were compared for a minimum of 3.7 years before and 1.75 years after the intervention in the six intervention areas. The accident count decreased in all zones; the overall decrease was described as 'significant'. [179] All three injury studies shared the following limitations: they used relatively small study areas; they based their comparisons on absolute numbers of accidents rather than on population-based incidence rates; and they did not show the results of any tests of statistical significance.

Other effects on community health

I found scant evidence about other potential positive or negative health effects. In the study of bypasses in England, residents of the six bypassed towns were less likely to describe vibration, fumes and noise as 'big problems' after the intervention. [213] In the study of 20 mph zones in England, residents thought that noise levels had not changed after the intervention, except in one zone where most thought that noise levels had improved. The authors reported anecdotal evidence from two of the zones that it had become easier to cross the main roads, but found no evidence that people were using the streets more on foot as a result. [179]

Category	Study	Reported findings	Evidence suggests positive effects greater among
Targeted	Glasgow [218]	'There were no gender, age or distance to work effects… However, more women than men responded to the opportunity to be involved'	Females
Targeted	Perth [223]	'There was a minor increase in the number of cyclists', i.e. the increase in cycling trips was mostly the result of a larger number of cycling trips per cyclist per day. The intervention had no effect in the 'not interested' group. The car mode share decreased in all age/sex groups studied, but particularly among women of working age (males and females aged under 20: absolute decrease of 1% from a baseline share of 5%; males aged 20-60: absolute decrease of 3% from 38%; females aged 20-60: absolute decrease of 8% from 43%; males and females aged over 60: absolute decrease of 2% from 14%)	Existing cyclists Females of working age
Targeted	Frome [175]	The car mode share decreased in all age/sex groups studied (males and females aged under 20: absolute decrease of 1% from a baseline share of 11%; males aged 20-60: absolute decrease of 2% from 25%; females aged 20-60: absolute decrease of 2% from 34%; males and females aged over 60: absolute decrease of 2% from 30%)	—
Targeted	Gloucester [176]	The car mode share decreased in all age/sex groups studied, but particularly among adults of working age (males and females aged under 20: absolute decrease of 1% from a baseline share of 16%; males aged 20-60: absolute decrease of 3% from 39%; females aged 20-60: absolute decrease of 3% from 30%; males and females aged over 60: absolute decrease of 1% from 15%)	Adults of working age
Targeted	Århus [172]	There was a higher cycling mode share (and combined walking and cycling mode share) for men than for women at follow-up (combined mode shares approximately 53% and 49% respectively, estimated from graphs). Participants from households with more than one car had a lower cycling mode share (and combined walking and cycling mode share) than those from households with only one car (combined shares approximately 48% and 53% respectively, estimated from graphs). The authors also reported that 'use of the bicycle increases with age; use of the bicycle is independent of income; use of the bicycle drops the larger the number of adults in the household' (data not reported). The authors also reported a small negative modal shift in trips made by participants' spouses, who now had greater access to the family car (estimated absolute shift of –4% from a baseline of 35%)	Males Households with only one car Older adults Smaller households

Table 28. Social distribution of effects of interventions

Category	Study	Reported findings	Evidence suggests positive effects greater among
Targeted	Adelaide [180]	In stepwise logistic regression, household composition was shown to have a minor influence on the estimated reductions in vehicle emissions resulting from the intervention. The higher the proportion of retired persons in the household and the older the mean age for adults, the less the estimated reduction	Households without older adults
Engineering	Delft [195]	'The increase of bicycle mobility cannot be ascribed to a larger number of people using the bicycle, but is the result of a larger number of bicycle trips per cyclist per day. This finding is consistent with the findings… that many non-cyclists are captive users of their modes… and do not have freedom of choice. Bicycle use by men increased more than that by women'	Existing cyclists Males
Engineering	Detmold-Rosenheim [173]	Modal shifts were stratified by age, sex, occupational group and bike and car ownership in both towns (in this analysis, car mode share included motorised two-wheelers). In both towns, the modal shift was more positive (or less negative) among males, non-bike owners and car owners than among females, bike owners and non-car owners respectively. In Rosenheim, the modal shift was more negative among those aged over 65 compared with those in younger age groups, and among pensioners compared with those in other occupational groups	Males Non-bike owners Car owners
Engineering	Stockton [178]	Boys were more likely than girls to cycle to school, both before and after the intervention	Males
Engineering	England (bypasses) [213]	The decrease in walking mode share was seen in both males and females (absolute decreases of 2% and 5% respectively), in adults both under and over the age of 60 (4% and 6% respectively), and in people with access to no car, one car, and more than one car (2%, 1% and 6% respectively)	—
Financial	California (cashing out) [192]	The policy was said to have had a redistributive effect on income: some firms had previously offered higher parking subsidies to higher-paid employees, but after the intervention the benefits were offered at a flat rate to all employees	—

Table 28. Social distribution of effects of interventions (continued)

Category	Study	Effect sought	Findings
Targeted	Glasgow [218]	SF-36	The sample mean scores on three subscales of the SF-36 increased significantly ($P<0.05$) in the intervention group compared with the control group: mental health (from 72 to 76), vitality (from 57 to 64) and general health (from 71 to 76). There was no significant change in the sample mean scores on the other five subscales
		Accidents	'There were no adverse effects noted from this intervention such as traffic accidents'
Targeted	Tampere [66]	Fitness	Mean walking speed for commuting journeys increased from 5.8 km/h to 6.2 km/h. Mean cycling speed increased from 17.6 km/h to 20 km/h
			Net changes in intervention group compared with control group: maximal aerobic power and maximum treadmill time increased significantly (+4.5%, $P=0.02$ and +10.3%, $P<0.001$ respectively). Heart rate and blood lactate at submaximal standard work load decreased significantly ($P=0.04$ and $P=0.002$ respectively)
		Blood lipids	HDL cholesterol increased (+5%, $P=0.06$); no significant change in total cholesterol or triglyceride concentrations
		Weight	No changes in either group
Targeted	Århus [172]	Blood pressure	Prevalence of 'normal blood pressure' (not defined) increased from 87% to 90%, prevalence of 'high and slightly high blood pressure' decreased from 13% to 10%
		Weight	No change in average weight overall (79 kg), but men lost an average of 200 g and women gained an average of 1 kg
		Cholesterol	Prevalence of 'normal' cholesterol level (not defined) decreased from 66% to 61%; prevalence of 'grey zone' cholesterol level increased from 18% to 23%; prevalence of 'high' cholesterol level increased from 15% to 16%
		Fitness	Prevalence of 'poor' or 'low' self-rated fitness decreased from 65% to 51%; prevalence of 'average' self-rated fitness increased from 19% to 32%; prevalence of 'good' or 'high' self-rated fitness increased from 16% to 17%
		Smoking	No change in smoking prevalence ('one third')
			No details of methods, participation rates or tests of statistical significance reported in relation to any of these measures

Table 29. Health effects associated with interventions

Category	Study	Effect sought	Findings
Engineering	Stockton [178]	Accidents	The absolute number of accidents to cyclists increased in both a notional catchment area for the cycle route and in a control area elsewhere in the town (catchment area: from 23 to 26; control area: from 34 to 46). No tests of statistical significance were reported. Comparing 18-month periods before and after the intervention, the authors reported a 'significant' shift in the distribution of all accidents from the catchment area to the control area
Engineering	England (20 mph zones) [179]	Community severance	'There is anecdotal evidence from discussions held with groups of residents in the two largest zones that it was easier to cross the main roads after the speed limits had been reduced to 20 mph… No increase in adult or child street activity has so far been apparent… the numbers [reporting that they talked to neighbours and friends in the street] did not change significantly'
		Noise	'The majority of respondents felt that noise levels had stayed the same as a result of the introduction of the 20 mph zone. In the Warrington zone, where the most stringent measures have been introduced, almost three-quarters of those questioned three months after implementation felt that noise levels had been reduced'
		Accidents	The mean annual number of accidents decreased in all zones by between 32% and 100%. The overall decrease was described as 'significant' in the summary of results but no tests of statistical significance were reported
Engineering	England (bypasses) [213]	Disturbance	The proportion of respondents who described vibration, fumes and noise as 'big problems' decreased from 8%, 13% and 9% (respectively) before the intervention to 4%, 5% and 4% after the intervention. No tests of statistical significance were reported
		Accidents	The mean annual number of accidents decreased in all six towns. The annual number of accidents to pedestrians and cyclists decreased in five towns and increased in one town. No tests of statistical significance were reported

Table 29. Health effects associated with interventions (continued)

Costs of interventions

Cost data provided in reports are summarised as one of the characteristics of included studies (Table 23). Most studies did not report the costs of interventions, and for those that did, costs had been identified in different ways. It was not always possible to disentangle the costs of the intervention from the costs of the evaluation, or to account for contributions in kind from supporting organisations. I did not find sufficient data to enable any meaningful comparative analysis of the costs and benefits of different types of intervention with respect to the primary or secondary outcome measures of the review.

Theoretical basis of interventions

Most reports did not discuss the theoretical basis for interventions in any detail, but some interventions were explicitly or implicitly based on specific theories of behaviour change.

The targeting of the Walk In to Work Out intervention in Glasgow, and the design of the evaluation study, was based on the *transtheoretical model* of behaviour change as applied to the promotion of physical activity. [255] Potential participants were screened so that the intervention was only offered to those thought to be contemplating or actively preparing for change. People who were 'precontemplators' and had no intention of changing their behaviour did not receive the intervention. The content of the intervention was based on the same model, being designed to develop self-efficacy and encourage a decisional balance process, both of which are key constructs of the model. [218]

The TravelSmart and Travel Blending interventions typify what are sometimes called *soft measures*, to distinguish them from 'hard' engineering measures. [256] Both were based on an attempt to engage individuals and households in an exchange of information designed to increase their awareness of choices and to encourage them to make small but sustainable changes in their behaviour. However, they differed in their theoretical approaches. TravelSmart took a marketing approach ('Individualised Marketing') whereby the intervention was only offered to households thought to be receptive to changing their transport behaviour and the content was largely concerned with the marketing of alternative modes of transport. The results from Perth confirm that although there was a significant aggregate modal shift in the intervention area, none of this modal shift was contributed from households that had expressed no interest in the intervention. [223] The approach of Travel Blending, in which participating households were given tailored feedback about the impacts of their own car use, was more closely related to that of community development (as part of the 'Living Neighbourhood' concept), drawing explicitly on the notion that the target neighbourhoods were self-organising systems that could not be externally directed. [180]

The evaluation of the sustainable transport campaign in Maidstone was based on the *theory of planned behaviour*. [257] This theory predicts that people's perceptions of the likelihood and effects of the outcome of a particular behaviour informs their attitudes; that these attitudes, together with social norms and perceived behavioural control, influence their intentions; and that these intentions predict their behavioural choices. Although the intervention was not reported to have been explicitly based on this theory, the evaluation was designed to test the hypothesis that if the campaign were successful in influencing perceptions, this would lead in time to changes in intentions and behavioural choices. Among other findings, the study showed that respondents were much more likely to consider the convenience or reliability of a mode of transport, rather than its environmental effects, as important attributes influencing their mode choice; that respondents were much more likely to hold positive beliefs about car travel than about bus travel (no comparison with other modes of transport was shown); that most people neither desired nor expected to reduce their car use either before or after the intervention; and that most people did not expect to increase their walking or cycling either before or after the intervention, although most people did express the desire to increase their walking. [222]

The bicycle network intervention in Delft was based on a *choice theory* which predicted that travellers would make choices between alternative modes, routes and destinations, and choices about whether to make trips at all, by making a rational comparison of the perceived attributes of the alternatives and trading these off against each other to maximise personal utility. The theory predicted that the apparent *objective choice situation* based on the attributes of the alternatives would be constrained in practice to an individual *subjective choice situation* by personal factors such as the availability of a car or bicycle and knowledge about alternative modes of transport. The intervention was intended to make 'systematic, mutually interdependent' improvements to the network as a whole in order to improve both the objective characteristics of journeys (e.g. by offering more direct and therefore faster routes) and the subjective experience of cyclists (e.g by improving the perceived safety and comfort of cycling) — as opposed to making 'isolated' improvements to specific junctions or links, which were predicted to have a minimal effect on the propensity to cycle. Attitudinal surveys confirmed that the proportions of respondents who cited either objective or subjective factors as reasons not to cycle decreased after the intervention. [195]

4.5.5 Summary of evidence from included studies

I found evidence from a few relatively well-conducted studies that targeted behaviour change programmes can change the behaviour of motivated subgroups. At a population level (in the main TravelSmart study), this resulted in about 5% of all household trips being shifted from cars to walking or cycling. Single studies of commuter subsidies and a new railway station have also shown positive modal shifts of 1% and 5% of trips respectively. Volunteers participating in trials have experienced short-term improvements in certain measures of health or fitness after taking up active commuting.

The balance of best available evidence about agents of change, publicity campaigns, engineering measures and road user charging suggests that they have not been effective in terms of promoting a modal shift from using cars towards walking and cycling. I also found evidence from single controlled studies that car-sharing and telecommuting have not been effective in these terms; if anything, participation in these interventions may have encouraged car use or discouraged walking and cycling.

4.6 Secondary analysis of sources of evidence

The frequency distribution of the highest-order sources from which references were found for relevant studies is summarised in Table 30. Of the 69 relevant studies, about half were found through references indexed in the Transport database and had not been found through the databases more familiar to researchers in the health and social sciences. Only four studies had been found through one of the first-line health databases.

No study was identified solely on the recommendation of an expert. Where experts did suggest references, these proved to be either general background papers, or more up-to-date or comprehensive reports about studies already identified from higher-order sources.

Nine studies were identified through the purposive internet search; these had not been found through the higher-order literature databases. Seven studies were found by chance, either through undirected web browsing (surfing), or because a book or set of conference proceedings was ordered for one particular article and was then found to contain other relevant articles.

Source	Relevant studies		Included studies	
	Number	% of total	Number	% of total
First-line health databases				
Indexed in CINAHL, Cochrane Library (CDSR and CCTR), EMBASE, Medline (including PreMedline) or PsycInfo	4	6	3	14
First-line science databases				
Indexed in ASSIA, IBSS, Sociological Abstracts or Web of Science (SCI or SSCI)	5		2	
Found through reference list of another document indexed in one of these databases	1		—	
First-line science databases (total)	6	9	2	9
Other specialist databases				
Indexed in Dissertation Abstracts, GEOBASE, HELMIS, HMIC, Index to Theses, PapersFirst, REGARD or SportDiscus	8	12	2	9
Transport database				
Indexed in Transport	29		6	
Found through reference list of another document indexed in Transport	6		4	
Transport database (total)	35	51	10	45
Purposive search of websites	9	13	2	9
Reviewers' own collections	—		—	
Experts' recommendations	—		—	
Found by chance				
Found in a book or set of conference proceedings ordered for another document	6		2	
Found by undirected web browsing	—		1	
Found by chance (total)	7	10	3	14
Total	69		22	

Table 30. Sources of studies

4.7 Sensitivity analysis of thresholds for inclusion

4.7.1 Effect of including only randomised controlled trials

I found only three randomised controlled trials among the 69 relevant studies. These studies were well written and relatively easy to appraise because they contained clear methodological description and presentation of results, including the results of statistical tests. These were also the only studies that contained robust data on direct effects on the health of participants. However, it would only have been possible to include evidence about two small categories of intervention: targeted behaviour change programmes for commuters, [66 218] and school travel co-ordinators. [221] This set of studies provided no evidence about any population-wide health promotion activities, engineering measures, financial incentives or the provision of alternative services, and made no significant contribution to the evidence of possible unexpected or inequitable effects of interventions summarised in Table 28.

4.7.2 Evidence contributed by excluded studies

Following the convention of the Cochrane Library used earlier in this chapter, I have referred to each study by a short name (based on the place where the study was conducted) and a single primary reference (the most important citation). The full names of the studies or interventions, and a full list of citations, are shown in Table 31. Although most excluded studies had been published since 1990, very recent studies were less-strongly represented in this set (Table 32), and the large majority of excluded studies came from continental or Nordic Europe (Table 33). In contrast to the included studies, most of the excluded studies (30/47) did not appear to have been published in an academic journal, and no English-language report was identified for five of them. [258-262]

Short name and primary reference	Full name, location and all references
Aachen [263]	Town centre car ban, Aachen (Germany) [263]
Amsterdam [264]	Case study city, Amsterdam (Netherlands) [264]
Cambridge [265]	Core traffic scheme, Cambridge (England) [265]
Den Haag [266]	Car park closure, den Haag (Netherlands) [266]
Dublin [267]	EUROPRICE, Dublin (Ireland) [267 268]
Eindhoven-Rijswijk [269]	Reclassification and reconstruction, Eindhoven and Rijswijk (Netherlands) [269-271]
England (Feet First) [272]	Feet First (England) [272]
Enschede (campaign) [273]	Awareness-raising campaign, Enschede (Netherlands) [273-275]
Enschede (Stadserf) [273]	Stadserf [city centre], Enschede (Netherlands) [273-276]
Erlangen [261]	Case study city, Erlangen (Germany) [261 277 278]
Freiburg [279]	Case study city, Freiburg (Germany) [279-283]
Göttingen [284]	Göttingen (Germany) [284 285]
Graz (exercise) [286]	Exercise advice, Graz (Austria) [286 287]
Graz (case study) [288]	Case study city, Graz (Austria) [288-291]
Groningen [292]	Traffic management plan, Groningen (Netherlands) [292-299]
Hammersmith [300]	Hammersmith Bridge closure, London (England) [300 301]
Hannover [302]	City centre pedestrianisation, Hannover (Germany) [302]
Herning [303]	Sikker på cykel [Safe on the bike], Herning (Denmark) [303 304]
Hungary [305]	Regional cycle networks (Hungary) [305]
Kiel [306]	Case study city, Kiel (Germany) [306]
Langenlois [307]	Traffic saving community, Langenlois (Austria) [307 308]
Lübeck [263]	Case study city, Lübeck (Germany) [263 309]
Lüneburg [310]	Case study city, Lüneburg (Germany) [310 311]

Table 31. List of excluded studies

Short name and primary reference	Full name, location and all references
Malmö [258]	Pedestrian and cycle route network, Malmö (Sweden) [258]
Mariahoeve [259]	Information provision, Mariahoeve (Netherlands) [259]
Melbourne [312]	Travel management association, Melbourne (Australia) [312]
München [283]	Case study city, München (Germany) [280 283 302 313 314]
Münster [283]	Case study city, Münster (Germany) [280 283 315]
Odense [316]	Bicycle promotion, Odense (Denmark) [316-318]
OPIUM [319]	OPIUM traffic restraint project, Gent (Belgium), Heidelberg (Germany), Liverpool (England), Utrecht (Netherlands) and Nantes (France) [319 320]
Padova [321]	Pedestrian and cycle route network, Padova (Italy) [321]
Portsmouth [322]	Cycle route, Portsmouth (England) [322]
Præstø [323]	Indkøbscyklen [The shopping bike], Præstø (Denmark) [323 324]
Salisbury [325]	Doorstep walks, Salisbury (England) [325 326]
Seattle [327]	New passenger-only ferry, Seattle, Oregon (United States) [327]
Stockholm [261]	Case study city, Stockholm (Sweden) [261]
Stuttgart [328]	Case study city, Stuttgart (Germany) [302 328]
Södra Katarina [260]	Traffic re-routeing, Södra Katarina, Stockholm (Sweden) [260 329]
Thames Valley [330]	Health walks, Thames Valley (England) [330 331]
Thurgau [332]	Workplace parking levy, Thurgau (Switzerland) [332]
Troisdorf [306]	Case study city, Troisdorf (Germany) [306]
Uppsala [262]	Traffic management plan, Uppsala (Sweden) [262]
Wiener Neustadt [333]	Parking management, Wiener Neustadt (Austria) [333]
York (bridge) [334]	Road bridge closure, York (England) [334]
York (case study) [335]	Case study city, York (England) [335]
Yugoslavia [336]	Fuel rationing, Belgrade and Sombor (former Yugoslavia) [336]
Aalborg [337]	Arbejde-Bolig-Cykel [Work-Home-Bike], Aalborg (Denmark) [273-275 337-339]

Table 31. List of excluded studies (continued)

Year of publication	Number
1970-79	4
1980-89	5
1990-94	11
1995-99	17
2000-02	10
Total	47

Table 32. Year of publication of excluded studies

Country of origin	Number
European countries (excluding United Kingdom)	37
United Kingdom	8
United States	1
Australia	1
Total	47

Table 33. Country of origin of excluded studies

I have not tabulated full details of the methodological and outcome data for these studies. Instead, the key characteristics of these studies are summarised in three tables:

1. For discrete studies of discrete interventions (Table 34)
2. For case studies of multifaceted urban transport policies where modal shift could be summarised using the common outcome metric *M* (Table 35)
3. For other 'case study' cities (Table 36).

For each category of intervention, the evidence contributed by the excluded studies is summarised and compared with that from the included studies in Table 37.

These tables show that the excluded studies provide four types of additional evidence to supplement that provided by the synthesis of included studies:

1. **A larger taxonomy of interventions of interest.** Some specific types of intervention were only represented in excluded studies: health walks, charging for parking and fuel rationing. Most of these studies indicated potential for a positive effect, albeit based on designs with major methodological weaknesses; these types of intervention may therefore be fruitful areas for further research.

2. **Evidence about some interventions consistent with the stronger evidence already included in the review.** The synthesis of evidence from included studies found the strongest evidence of positive effect for targeted behaviour change programmes. Two excluded studies of targeted programmes also identified potential for a positive effect, as did two other excluded studies of workplace schemes involving free bikes (which had been the key feature of the targeted programme with the largest reported effect size). [172] Conversely, there were also numerous excluded studies of engineering measures whose findings were broadly consistent with the primary finding of little or no evidence of a positive effect, and single excluded studies of road user charging and alternative transport services which did not contradict the primary findings of the systematic review.

3. **Evidence about one category of intervention that could contradict the primary findings of the systematic review.** Two studies of publicity campaigns to promote sustainable transport, which both claimed a substantial positive effect, were excluded because neither was reported in sufficient detail (for example, there were no details of sampling strategy, response rate, sample size, survey instrument and so on), I could not identify any more detailed reports, and the authors did not reply to a request for more information. It is therefore possible that evidence exists to contradict the primary finding of little or no evidence of effectiveness for publicity campaigns, although it appears unlikely that such evidence would be strong.

4. **Evidence to challenge assumptions about 'successful' cities.** Such evidence was found in *post hoc* descriptions of cities cited as part of a book chapter, policy paper or similar document as an exemplar of what could be achieved as a result of a progressive urban transport policy. These articles did not seem to report the results of specific studies of specific interventions as such, so I characterised them as 'case studies' in which authors had reported trends in travel behaviour which were relevant to the systematic review, but had not presented data in a way that enabled the strength of the causal assertions being made to be assessed. These case studies typically comprised two parts. The first part was a list and, to a greater or lesser degree, a description of a variety of transport policy or infrastructure measures which were present in the city, often concurrently and often forming part of a complex integrated urban policy that included land use planning, public transport improvements, widespread traffic restraint, cycle routes, pedestrianisation, and related measures. The second part was the presentation of aggregate mode share data to support an implicit or explicit assertion that the observed mode shares were causally related to the interventions listed. The time periods of the various interventions were typically either not stated or not related to the time periods for the mode share data, and the methods by which the mode share data had been obtained were typically not reported. Even if it had been possible to attribute the observed trends in transport mode share in the case study cities to part or all of their multifaceted urban transport policies, a positive modal shift was only actually documented in three of the 13 cities, and in two of these that positive shift was only seen for trips into the city centre and was not seen for residents' trips overall.

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Aachen [263]	Ban on private cars in city centre	Weekend visitors to town centre	Uncontrolled repeated cross-sectional	Population	Use of the car for travel to the centre was reduced from 44% to 39% during the first phase and to 36% during the 'consolidation' phase. At the same time the proportion of travel on foot and by bus increased
Cambridge [265]	Closure of a city centre through route to cars	Vehicles	Uncontrolled repeated cross-sectional	Population	Overall cycling mode share remained static at 10.6%
Den Haag [266]	Closure of city centre car park	Driving commuters	Uncontrolled panel	Information: data for bikes and powered two-wheelers could not be disaggregated	Overall shift from car drivers to car passengers and public transport, not to active modes
Dublin [267]	Field trial of in-car equipment for road user charging	Driving commuters	Uncontrolled panel	Information: inadequate details of results	Total trips were reduced by 4%. Trips in the peak period were reduced by 22% 'due to a combination of trip suppression and use of cycling, walking and public transport'

Table 34. Characteristics of excluded discrete studies of discrete interventions

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Eindhoven-Rijswijk [269]	Neighbourhood traffic calming	Residents	Controlled repeated cross-sectional	Information: data for bikes and powered two-wheelers could not be disaggregated	Reduced car use in local streets, but also reduced bike use
England (Feet First) [272]	Neighbourhood traffic calming	Residents	Uncontrolled retrospective	Design	4-36% of driving residents claimed to make fewer local trips; 2-6% of residents claimed to make more trips on foot; 9-44% of residents thought people were walking more
Enschede (campaign) [273]	Public awareness campaign to reduce car use	Residents	Controlled retrospective	Information: inadequate details of methods	12% of respondents in intervention neighbourhood said they had switched from car to another mode, generally the bike, compared with 7% in the control area
Enschede (Stadserf) [273]	City centre traffic restraint	Residents	Uncontrolled repeated cross-sectional	Information: inadequate details of methods	Car mode share fell from 41% to 34%; cycling mode share rose from 34% to 38%; walking mode share did not change

Table 34. Characteristics of excluded discrete studies of discrete interventions (continued)

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Graz [286]	Advice to unfit patients to walk and cycle more often	Patients	Uncontrolled panel	Population	One-third of kilometres travelled were shifted from car to non-motorised transport
Groningen [292]	City centre traffic restraint	Visitors to town centre	Uncontrolled repeated cross-sectional	Population	Public transport gained mode share at the expense of the other modes
Göttingen [284]	Pedestrianisation of city centre and traffic calming inside inner ring road	Residents	Case study	Design	Large shift from car to all other modes for trips to the city centre, but the sampling area was changed between the two waves of the study
Hammersmith [300]	Closure of major road bridge across the Thames due to structural weakness	Drivers recruited at the roadside	Uncontrolled retrospective but with prospective recruitment	Population	7% of work trips and 9% of non-work trips across the bridge were shifted to walking; 2% of work trips and 1% of non-work trips across the bridge were shifted to bike
Hannover [302]	Pedestrianisation of city centre and construction of light rail tunnels	Not clear	Case study	Design	Shift from car to all other modes

Table 34. Characteristics of excluded discrete studies of discrete interventions (continued)

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Herning [303]	Improvements to cycle network, followed by issue of free bikes to participating workplaces	Driving commuters	Uncontrolled retrospective	Design	4% of car trips shifted to bike
Hungary [305]	Regional cycle networks	Not clear	Not clear	Design	Not available
Langenlois [307]	Information and demonstration project for alternative modes of transport	Residents	Uncontrolled prospective	Information: inadequate details of methods	Positive modal shift of 12% after four years
Malmö [258]	Pedestrian and cycle route network	Residents	Case study	Design	Shift from bike to car for journeys to work between 1973 and 1990
Mariahoeve [259]	Pilot study of provision of information about alternative modes of transport	Households Commuters	Uncontrolled panel	Information: inadequate details of results	Households: in one household, one person who used to travel five times per week by car now travelled twice a week by bike Commuters: no claim made for modal shift
Melbourne [312]	Travel management association for suburban employment zones	Commuters	Not clear	Design	No claim for a significant modal shift

Table 34. Characteristics of excluded discrete studies of discrete interventions (continued)

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Odense [316]	Complex bicycle-promotion intervention including cycle network, traffic calming and information provision	Vehicles	Case study	Design	Bike traffic grew by 50% over ten years, while car traffic grew by only 1.5%. No data on walking
OPIUM [319]	Range of physical traffic restraint measures	Not clear	Case study	Design	'A small but significant shift in favour of public transport and slow modes to the detriment of the private car'
Padova [321]	Partially-implemented pedestrian and cycle route network	Residents	Case study	Design	Large fall in walking mode share (from 32% to 28%), small fall in car mode share (from 44% to 43%) and small rise in cycling mode share (from 11% to 12%)
Portsmouth [322]	Experimental on-road cycle lane	Vehicles	Uncontrolled repeated cross-sectional	Population	Increase in cycling mode share along the road containing the cycle lane; no evidence of modal shift in the area overall

Table 34. Characteristics of excluded discrete studies of discrete interventions (continued)

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Præstø [323]	Promotion of shopping by bike by improving town centre cycle infrastructure, home delivery scheme and piloting of load-carrying accessories	Shoppers	Uncontrolled prospective	Population	Cycling mode share of shopping trips increased from 22% to 26%, but car mode share remained static at 59%; no overall evidence of modal shift from car to bike
Salisbury [325]	Information pack to promote walking from home	Participants	Uncontrolled retrospective	Design	41% of respondents at 6 months, and 27% of those at 18 months, said they had reduced their short-distance car trips
Seattle [327]	New passenger-only ferry as alternative to vehicle ferry for commuting to and from city centre	Commuters	Uncontrolled retrospective	Design	14% of passengers on the passenger ferry (about 2% of all homeward ferry movements) had previously travelled by car. No data about how they travelled to and from the ferry

Table 34. Characteristics of excluded discrete studies of discrete interventions (continued)

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Södra Katarina [260]	Area traffic calming	Residents	Uncontrolled repeated cross-sectional	Information: inadequate detail about results	No data expressed in suitable terms of modal shift
Thames Valley [330]	Programme of led brisk walks to promote fitness	Participants	Uncontrolled retrospective	Design	64% of participants said the scheme had changed their transport habits; 26% 'quite a lot' or 'a great deal'
Thurgau [332]	Workplace parking levy at government properties	Commuters	Uncontrolled retrospective	Design	Small effects which varied between sites; little overall evidence of modal shift
Uppsala [262]	City centre traffic circulation plan including closing roads to cars, bus and cycle routes, and parking restrictions	City centre shoppers Vehicles	Uncontrolled repeated cross-sectional	Population	Overall walking and cycling mode share fell according to interview data from shoppers on weekdays and vehicle counts, but rose according to interview data from shoppers at the weekend

Table 34. Characteristics of excluded discrete studies of discrete interventions (continued)

Study	Intervention	Study population	Study design	Primary reason for exclusion	Effects claimed
Wiener Neustadt [333]	Parking charges and restrictions in town centre	Driving commuters	Uncontrolled panel	Information: inadequate detail of methods	23% of employees who previously drove and parked on the street said they now walked or cycled
York [334]	Temporary closure of city centre road bridge, and associated traffic management measures	Drivers recruited at the roadside	Uncontrolled panel	Population	After the intervention, 1-2% of drivers said they now used a bike
Yugoslavia [336]	Fuel rationing	Drivers	Uncontrolled retrospective	Design	In a small city, weekly car trips were reduced by 12-45%, and 66-86% of the lost car trips were shifted to active transport; smaller shifts observed in a large city
Aalborg [337]	Improvements to cycle network, followed by issue of free bikes to participating workplaces	Employees	Uncontrolled retrospective	Design	57% of trips made on the trial bikes had previously been made by car or taxi. 9% of staff said they now cycled more: half said they cycled from home to work more often, half reported a general increase in cycling

Table 34. Characteristics of excluded discrete studies of discrete interventions (continued)

Case study	Trips studied	Changes in mode share*						
		Car		Walking		Cycling		
		Base	Change	Base	Change	Base	Change	*M*†
Erlangen 1974-85 [261]	All trips by residents on working days	44‡	0	30	-12	13	+12	0
	All trips by residents to town centre on working days	49‡	-15	32	-3	9	+15	+12
Freiburg 1976-95 [279]	All trips	39	-3	35	-14	12	+10	0
	All trips by residents	43	+1	30	-8	12	+6	-1
	All trips to city centre	60	-14	18§	+10§	—	—	+10
Graz 1973-98 [288]	All trips	36	+10	41	-20	7	+7	-10
Lüneburg 1991-94 [310]	Weekday trips sampled in town centre interviews	35	-9	10	+9	16	-4	+5
München 1976-95 [283]	All trips	42	-4	31	-8	6	+8	0
Münster 1976-94 [283]	All trips	39	-2	25	-3	29	+3	0
Stockholm 1975-85 [261]	Residents' journeys to work	27	+3	12	0	4	+2	0
Troisdorf 1989-96 [306]	All trips	56	-5	?	?	16	+5	?
York 1971-91 [335]	Journeys to work	22	+13	27	-3	22	-2	-5

* Base: baseline percentage mode share. Change: absolute percentage change in mode share. ?: incalculable or not reported.
† Absolute modal shift.
‡ Includes other private motor traffic.
§ Walking and cycling mode shares combined.

Table 35. Changes in mode share in case study cities (1)

Case study	Trips studied	Findings
Amsterdam 1960-89 [264]	All trips by residents on working days	Combined walking and cycling mode share decreased from about 64% to 45% between 1960 and 1977, then stabilised (data points estimated from graph)
Kiel 1988-99 [306]	Various	Cycling mode share of trips to shops in the central business district in 1988 was 6%; in the late 1990s, cycling mode share of general trips was 14%, and for shopping and errands, about 20% (no other data provided)
Lübeck 1989-? [263]	Weekend visitors to town centre	Of those who used to drive into the centre, 12% said they had shifted to an 'environmentally-friendly' mode (walking, cycling or public transport)
Stuttgart 1976-95 [328]	All trips	Conflicting data, none consistent with a net positive modal shift

Table 36. Changes in mode share in case study cities (2)

Category of intervention	Summary of findings from included studies	Excluded studies	Summary of findings from excluded studies	Comparison with included studies
Targeted behaviour change programmes	Can change behaviour of motivated subgroups (six studies) [172 175 176 180 218 223]	One uncontrolled prospective study of advising patients to take more exercise [286]	Both identified potential for modal shift	Consistent
		One pilot study of targeted information for households and commuters [259]		
Cycling promotion	Intensive targeted programme including free bike can be effective (one study) [172]	Two uncontrolled retrospective studies of free workplace bikes plus local infrastructural improvements [303 337]	Both identified the potential for modal shift	Consistent
		One uncontrolled prospective study of promoting cycling for shopping [323]	No evidence of modal shift	Additional category of intervention with no evidence of positive effect
Agents of change and publicity campaigns	Little or no evidence of positive effect (four studies) [174 221 222 239]	One case study of travel management association [312]	'Inability to achieve any significant shift in travel behaviour'	Consistent
		Two studies of sustainable transport campaigns, one uncontrolled prospective and one controlled retrospective [273 307]	Both suggested substantial modal shift	Contradictory, but of unknown validity
Health walks	No included studies	Two uncontrolled retrospective studies of participants [325 330]	About a quarter of participants claimed to have changed their travel behaviour	Additional category of intervention with potential for positive effect — may warrant further research

Table 37. Evidence contributed by excluded studies

Category of intervention	Summary of findings from included studies	Excluded studies	Summary of findings from excluded studies	Comparison with included studies
Networks of routes for cyclists and pedestrians	Increase in cycling mode share in only one of three studies [173,178,195]	Five studies, all either case studies reported with scant detail or based on vehicle counts [258,305,316,321,322]	One study based on vehicle counts suggested increases in cycling, but no data on walking; the others showed no evidence of modal shift	Consistent
Traffic restraint	Little or no evidence of positive effect (three studies) [179,188,213]	One uncontrolled retrospective study of neighbourhood traffic calming schemes [272]	Small proportions of residents claimed to have changed their travel behaviour	Consistent overall
		Nine studies of a variety of urban traffic restraint schemes, either using unclear or case study designs or based on vehicle counts or shoppers [260,262,263,265,273,284,292,302,319]	Most showed no clear evidence of modal shift; where a modal shift was demonstrated, it was only among weekend city centre shoppers	
		Two uncontrolled retrospective studies of drivers' trips across road bridges [300,334]	Small proportions claimed to have shifted mode after the bridge was closed	
		Two studies from which data for bikes and powered two-wheelers could not be disaggregated [266,269]	Impossible to assess	

Table 37. Evidence contributed by excluded studies (continued)

Category of intervention	Summary of findings from included studies	Excluded studies	Summary of findings from excluded studies	Comparison with included studies
Road user charging	No evidence of positive effect (one study) [244]	One pilot study of the effect of an in-car charging unit on commuting journeys [267]	'Another peak-period alternative for two of the sample was cycling'	Consistent — no clear quantification of modal shift
Parking charges	No included studies	One uncontrolled prospective study of town centre parking charges [333]	Identified potential for modal shift among commuters, but not among residents	Additional category of intervention with potential for positive effect — may warrant further research
		One uncontrolled retrospective study of parking charges at government workplaces [332]	No overall effect	
Fuel rationing	No included studies	One uncontrolled retrospective study of changes to car trips after introduction of fuel rationing [336]	Identified potential for substantial modal shift	Additional category of intervention with potential for positive effect — may warrant further research
Providing alternative services	Evidence of positive effect in only one of three studies [177, 194, 249]	One uncontrolled retrospective study of introducing a passenger-only commuter ferry [327]	Not designed to collect relevant outcome data	Consistent — no clear quantification of modal shift
Multifaceted urban transport policies	No included studies	Thirteen case studies (reported in 11 primary references) of trends in mode share in cities where multifaceted transport policies had been enacted over a long period [261, 263, 264, 279, 283, 288, 306, 310, 328, 335, 340]	Three cities reported a modal shift for trips to the city centre only, but in two of these cities there was no modal shift in residents' trips overall. All other cities reported zero or negative shifts	No comparison possible, but evidence from excluded studies raises questions about effectiveness of interventions in case study cities

Table 37. Evidence contributed by excluded studies (continued)

5 Systematic review: discussion

5.1 Overview of this chapter

In this chapter, I discuss the results of the systematic review.

In the first half of the chapter, I discuss the implications of the 'output phase' of the review: the approaches used to synthesise and explore the evidence about the effects of interventions and the substantive findings identified as a result. I also discuss one particular aspect of the available evidence relevant to the design of the intervention study for the second part of the thesis: the methods used to quantify the effects of interventions in the included primary studies.

In the second half of the chapter, I discuss the implications of the secondary methodological analyses of selected aspects of the 'input phase' of the review: the utility of different sources of evidence and the implications of the inclusion thresholds applied in the review.

Where relevant, I have related the findings to other systematic reviews on related topics. To the best of my knowledge, no other systematic review of primary studies on the same topic has been published, but the following recently-published systematic reviews (including one systematic review of systematic reviews) have addressed related or partly-overlapping topics and exemplify the range of approaches which have recently been applied to synthesising evidence about the effects of interventions to promote physical activity more generally:

- Systematic reviews of the effects of interventions to promote physical activity for the Community Guide of the Task Force on Community Preventive Services by Kahn and colleagues (2002) [63] and Heath and colleagues (2006) [64]

- A systematic review of the effects of 'environmental' interventions to promote physical activity by Foster and Hillsdon (2004) [65]

- A Cochrane systematic review [41] and a systematic review of systematic reviews for the Health Development Agency (HDA), [68] both of the effects of interventions to promote physical activity and both by Hillsdon and colleagues (2005)

- Systematic reviews of the effects of pedometers and organised walking and cycling schemes, conducted to inform the physical activity intervention guidance published by the National Institute for Health and Clinical Excellence (NICE) (2006). [69]

The chapter concludes with a section outlining the priorities for further intervention studies in the field and advances which have recently been made in this direction, illustrated by a selection of new studies published since the systematic review was completed. The overall conclusions for the thesis as a whole, encompassing both the systematic review and the M74 study, are presented in Chapter 10.

5.2 Evidence for effects of interventions

5.2.1 General approach

In Chapter 2, I set out three research questions for the systematic review concerned with the primary effectiveness of interventions in promoting a modal shift from using cars towards walking and cycling: what interventions are effective in promoting a modal shift, what is the size of their effect, and what interventions are not effective?

I found that the available evidence did not permit me to identify types of intervention, or groups of studies, that were unequivocally either 'effective' or 'not effective' in these terms. Neither was it possible to pool the effect sizes from different studies, even within categories of intervention, using a formal statistical technique such as meta-analysis. Instead, in light of the nature of the available evidence, I found it most appropriate to use a combination of textual, tabular and graphical methods to explore and synthesise the available evidence, adopting the principles of narrative synthesis and best evidence synthesis described by Popay and colleagues [166] and Slavin [84] respectively and outlined in Chapter 2.

Other recent systematic reviews on related topics have tended not to include meta-analysis either. The principal exception is Hillsdon and colleagues' Cochrane review: this included a meta-analysis which found that interventions had a positive and moderate effect on self-reported physical activity (pooled standardised mean difference 0.31, 95% confidence interval 0.12 to 0.50) but not on the odds of achieving a predetermined threshold of physical activity (odds ratio 1.30, 95% confidence interval 0.87 to 1.95). This review was subject to comparatively stringent inclusion criteria for study design and types of intervention which helped ensure that the included studies were reasonably comparable; even so, the authors reported 'marked' heterogeneity in the content of interventions and significant heterogeneity in their observed effects. [41] For some categories of intervention, the Community Guide reviews tabulated and averaged study outcomes where these could be expressed using a common metric, but no meta-analysis was performed. [63 64]

Because studies had used a variety of outcome metrics, I found it easiest to discern the balance of 'best available evidence' using the summary table (Table 26), in which I simply categorised the outcomes of studies along the lines of 'positive', 'negative', or 'inconclusive or no effect'. This enabled me to take account of all available data points (individual primary studies) rather than filtering out those studies which happened not to have used a particular outcome metric. For those studies whose outcomes could be expressed in, or converted to, the common metric *M*, plotting outcome against baseline mode share showed a weak negative correlation whereby interventions may be more effective in study populations which have a low baseline mode share for walking and cycling, and therefore a greater potential to respond to the intervention. On the other hand, plotting outcome against study validity suggested that the more robust studies tended to report larger effect sizes than the less robust studies. This finding is reassuring because it is not unusual for systematic reviews to find the reverse — that apparently-promising results from weak studies are not supported by the results of more robust studies (the so-called 'stainless steel' law of evaluation). [341] However, at least two alternative explanations should also be considered for this finding.

The first alternative explanation is that it reflects publication bias, or in other words that more rigorous studies which happen to have produced 'null' or 'negative' findings may have been less likely to be published than less rigorous studies. I did not formally assess the potential for publication bias using a statistical or graphical method such as a funnel plot because of the difficulty of interpreting a plot of such a heterogeneous set of studies. The primary defence against the threat of publication bias in this systematic review consists of the extensive search strategy and the detailed consideration of studies which had not been published in academic journals or, in some cases, in English. However, it remains possible that the available evidence is biased towards favourable evaluations of certain types of intervention, particularly those in which the evaluation was conducted or funded by the same organisation which advocated or implemented the intervention. The TravelSmart studies, for example, appeared to lack an independent academic evaluation. [175 176 223] On the other hand, any concern about potential bias arising from the lack of independent evaluation is at least partially offset by the observation that other interventions in the same category subjected to independent academic evaluation were also found to be effective. [172 218]

The second alternative explanation is that it reflects the inclusion of the sensitivity of the outcome measure in the methodological criteria used to summarise the validity of the studies. A study with a comparatively inclusive outcome measure, such as a change in travel behaviour over an entire day or an entire week, would have satisfied one more methodological criterion than a similar study in which the outcome had been based on a single trip on a single day, but as I show later in this chapter (Section 5.5), the former, more inclusive type of outcome measure is likely to be more sensitive to change.

5.2.2 Recapitulation of principal findings

It would be premature, on the basis of the available evidence, to characterise particular interventions or types of intervention as having been shown to be 'effective' or 'not effective'. Instead, I discuss and compare those areas of the evidence base where the evidence of effectiveness is most convincing and those where it is less convincing, seeking to identify what characterises those interventions with the most convincing evidence of effectiveness and to elucidate potential explanations for why other approaches are not currently supported by comparable evidence.

I found evidence from a few relatively well-conducted studies that targeted behaviour change programmes can change the behaviour of motivated subgroups and bring about a modal shift from using cars towards walking and cycling. At a population level (in the main TravelSmart study) [223] this resulted in around 5% of all household trips being shifted from cars to walking or cycling. Single studies of commuter subsidies [192] and a new railway station [249] also reported positive modal shifts of 1% and 5% of trips respectively.

The balance of best available evidence about agents of change, publicity campaigns, engineering measures and road user charging suggests that they have not been effective in bringing about a modal shift in the terms specified for this systematic review. I also found evidence from single controlled studies that a car-sharing club [177] and neighbourhood telecommuting centres [194] had not been effective in these terms; if anything, participation in these interventions may have encouraged car use or discouraged walking and cycling.

5.2.3 Most convincing evidence of effectiveness

Targeted behaviour change programmes

The most convincing evidence of effectiveness was for the category of interventions which I labelled *targeted behaviour change programmes*. This was the only category of intervention in which the balance of evidence in the summary matrix suggested a positive effect rather than no effect or a negative effect (Table 26). Studies in this category also fulfilled more of the appraisal criteria on average than those in any other category.

A common feature of these interventions was that they were either (in one case) explicitly based on the transtheoretical model of behaviour change, [218] or based on a somewhat similar approach which involved targeting the intervention at recipients identified as being motivated to change their behaviour by means of screening in an telephone interview [175 176 223] or by virtue of having responded to a newspaper advertisement, flyer or roadside recruitment point. [172] The Travel Blending study in Adelaide [180] was an exception in this respect, but since this study neither met the methodological standards of the other studies in the category nor showed evidence of an overall positive modal shift, it may be considered an atypical outlier within the category rather than a case which contradicts the general observation.

This group of studies also provides the most useful estimates of the potential population-level effect size which a successful intervention might achieve. The modal shift observed in the BikeBusters study in Århus (+25%) was the largest of any study in the review, but was measured only among those directly participating in the intervention and without comparison with a control group. [172] A more realistic estimate of the potential size of effect at population level is provided by the main TravelSmart study, in which around 5% of all household trips were shifted from cars to walking or cycling. [223] The subsequent UK pilot studies of TravelSmart reported effects of comparable magnitude and therefore provide some corroboration for this estimate. [175 176]

5.2.4 Less convincing evidence of effectiveness

For all other categories of intervention, the evidence of effectiveness was less convincing than that for targeted behaviour change programmes, for a variety of reasons.

Agents of change and publicity campaigns

Only one study in this category, that of the Clean Air Force campaign in Phoenix, [239] could be considered to have found any evidence of a positive effect; this was an uncontrolled survey of a sample of drivers of unknown representativeness. Two more robust studies in the same category found no evidence of a positive effect. [221,222]

Although the modal shift observed in Phoenix was small (+1%) and its statistical significance was not reported, it should not necessarily be assumed that such an effect would be insignificant in 'real' terms. If an effect of this size were to be convincingly demonstrated in a more robust population-based study of a general publicity campaign of this kind, it would represent a substantial achievement in changing drivers' behaviour: the observed *relative* increase in the proportion of trips made by active modes was large (at least 40%, although not all of this increase was necessarily attributable to the intervention) and occurred in a city with a very low baseline mode share for active modes (5%).

In the field of physical activity promotion, it has typically been difficult to demonstrate any effect of publicity campaigns on the behaviour of the general population. [342,343] It is not clear whether the evidence from Phoenix reflects a promising intervention 'let down' by a comparatively weak study, or an ineffective intervention 'talked up' by a potentially biased study, but the failure of the controlled study in Maidstone [222] to demonstrate a positive effect suggests that, on balance, this may not be an effective approach in isolation.

The interventions in Camden and Islington and in Eugene both involved agents of change, rather than the more disembodied approach of a general publicity campaign; despite this, neither study found evidence of a positive effect. [174,221]

This may reflect genuine ineffectiveness, but — particularly in the case of Camden and Islington — three competing potential explanations should be considered: an inadequate 'dose' of intervention, a study design unlikely to detect the outcome of interest, or a ceiling effect. The schools in the intervention arm of the schools trial received only 16 hours of input from their travel co-ordinator over an entire school year; this 'dose' was enough to ensure that almost all intervention schools had established a travel plan, but perhaps it could reasonably have been expected that more intensive input, a longer follow-up period, or both would be required to observe a significant modal shift, particularly in schools where, on average, 69% of children already walked to school at baseline. [221 344] It is possible that the realistic capacity for using active modes had already been reached in these schools and that a significant positive effect might have been observed for the same intervention applied to other schools with a greater capacity to benefit.

Engineering measures

The overall case for or against the effectiveness of engineering measures appears not proven, in that the balance of evidence was distributed approximately symmetrically either side of 'inconclusive or no effect'. The strongest study in this category was the controlled study of improvements to the Delft cycle route network. [195] Although this study reported an increase in cycling, this was not shown to constitute a significant overall modal shift from using cars towards walking and cycling, and other studies of improving infrastructure for cyclists did not find any increase in cycling. [173 178] The balance of evidence from studies of traffic restraint, which tended to be of lower methodological rigour than those of improving infrastructure for cyclists, was similar. [179 188 213]

The potential explanations for the failure of most of these studies to identify a positive effect are similar to those for the previous category. The Stockton study examined the effect of a single new cycle route, but drew respondents from all over the town (not just from the area close to the route) in assessing changes in mode share; [178] in this case, the 'dose' of the intervention with respect to the study population may have been too small. The study of bypasses and associated engineering measures in six small English towns used for its outcome measure the main mode of travel to the town centre, [213] but considerable changes in travel behaviour could have been missed using this relatively insensitive measure; for example, a respondent who previously always drove to the town centre but now walked or cycled on a third of such trips would still report their 'main' (i.e. usual) mode as being the car. The increase in cycling trips observed in the Delft study may have been limited by a ceiling effect; [195] with a baseline mode share for cycling of 40% of all trips, it is possible that little realistic capacity for more cycling remained to be realised. As the authors of that study observed, most of the trips not made by bike at baseline may have been made by so-called 'captive users' of other modes — those who were constrained in their mode choice by factors which ruled out cycling as a realistic alternative, such as a disability or the length of the trip.

Financial incentives and providing alternative services

These categories of intervention were characterised by isolated promising studies of commuter subsidies [192] and a new railway station; [249] by a lack of overall coherence of interventions or their effects within either category; and by cautionary tales from two other studies.

The positive results for commuter subsidies in southern California derive from a more robust study [192] than the study of the Clean Air Force campaign in Phoenix, but are of a similar magnitude and may reflect a similar context in which only modest modal shifts can be expected from an intervention aimed at changing individual drivers' behaviour in an environment designed around car use. It is harder to interpret the results from the study of the new railway station in Voorhout; [249] although an overall positive modal shift was reported, it was not clear to what extent this could reasonably be attributed to the intervention, partly because of the lack of a control group and partly because it was not entirely clear by what mechanism the provision of the new railway station might have influenced residents' trips other than the journey to work: there was a smaller absolute modal shift in trips related to work or school (2%) than for all trips (5%).

The Californian studies of a car-sharing club [177] and of neighbourhood telecommuting centres [194] both illustrate the potential for interventions that appear, at face value, to be self-evidently beneficial to have unintended or counterintuitive effects. Different people may respond to the opportunity presented by a car-sharing club in different ways. If those who already own a car join a club, sell their car and only use a club vehicle when they need to, they may make an overall modal shift away from car use because the real cost of using the car is made more apparent to them at the point of making the decision to use the club car. [240] However, in San Francisco the people who joined the club were predominantly those who did not own a car and joined in order to gain access to cars; it is therefore not surprising that, if anything, the intervention resulted in an increase in car use. Similarly, one might have predicted that commuters would choose to travel to work by active modes on days when they were working closer to home, but in fact the use of active modes was lower on telecommuting days, perhaps because it may have been easier for clients to park at the local centres than at their usual city centre workplaces.

5.3 Social distribution of effects and effects on health

5.3.1 Social distribution of effects

The review for the Health Development Agency drew attention to the lack of evidence about the effectiveness of physical activity interventions in different social groups. [68] In this systematic review, I also found that the evidence available to answer the research question about how the effects of interventions were distributed in the population was very limited. Even where differential effects were mentioned by authors, this often occurred only in the discussion section of a report, unsupported by the reporting of actual data.

Although the evidence was limited (Table 28), it can be summarised as identifying three ways in which interventions to promote a modal shift *may* have the potential to produce inequitable or unanticipated effects. These three caveats all relate to the promotion of cycling rather than walking. First, where differences were reported by gender, the tendency to cycle (or to cycle more) as a result of an intervention was greater among men than among women. Second, in the studies from Perth and Delft, where an overall increase in the mode share for cycling was observed, this was reported as having been largely attributable to existing cyclists making more trips than to people taking up cycling. [195 223]

Third, in the BikeBusters study in Århus, the substantial modal shift among study participants was partly counterbalanced by an increase in car use among their spouses, who had greater access to the family car which the study participant was now leaving at home during the working day. [172]

5.3.2 Effects on health

Most studies did not include the assessment of changes — whether beneficial or adverse — in any direct measure of health or wellbeing. This is not surprising in view of the dominance of studies conducted from the perspective of transport research rather than health research. The difficulty of finding relevant evidence may reflect hitherto different priorities in the transport and health policy and research communities. Walking and cycling have long been marginalised in transport planning, recognition of their potential wider social benefits has been limited until recently, and evaluation studies of transport interventions have often not been designed to assess effects on important determinants of population health such as physical activity. [70]

Among recent systematic reviews on related topics, only one (the Cochrane review by Hillsdon and colleagues) included a substantial volume of evidence about the 'downstream' benefits of individually-focused interventions to promote physical activity on health or fitness. On the basis of a meta-analysis of seven studies, these authors concluded that the pooled effect of these interventions on cardiorespiratory fitness was positive and 'moderate' in magnitude, with an estimated standardised mean difference of 0.40 (95% confidence interval 0.09 to 0.70), but they acknowledged that the participants in most of the included primary studies were likely to be highly-motivated volunteers not necessarily representative of the general population; furthermore, there was no clear evidence that the benefits observed in the short-to-medium term were sustained in the longer term. [41]

From the public health perspective, the most useful and promising evidence of health benefits from the current systematic review was from the two randomised controlled trials which showed that volunteers experienced short-term improvements in certain measures of health or fitness after taking up active commuting. [66 218] Given the limited population from which the participants in these trials were recruited, it would be premature to argue on the basis of these studies that promoting active commuting has been shown to produce measurable improvements in health in the population as a whole, but it would be reasonable to interpret these studies as illustrating the potential for health gain among people who make a significant individual change in their travel behaviour.

These trials were both conducted from a health research perspective and included outcome measures such as the SF-36 or maximum aerobic power (V_{O_2max}), which have wide currency as health-related measures. Some other studies included efforts to assess health-related outcomes which were either not measured, or not reported, with a comparable degree of rigour; this represents a missed opportunity which could have been taken if greater collaboration had been established between transport researchers and health researchers in the design or the reporting of the study. This is illustrated most clearly by the BikeBusters study from Århus, which included measures of blood pressure and lipid profile; these were reported only vaguely in the main report, [172] and although the authors undertook to send additional details of the health outcome data, these were never received.

The health effect most often measured in studies included in this review was the incidence of accidents. This is not surprising, given the historical importance attached to this outcome in studies of transport and health discussed in Chapter 1. However, the utility of this evidence is limited because none of the studies that included the incidence of accidents as an outcome measure showed that there had been any positive modal shift. The main concern about accidents in this context is that if people are encouraged to walk and cycle more instead of using cars, the presence of more pedestrians and, especially, more (and more inexperienced) cyclists on the roads may result in more frequent collisions between pedestrians or cyclists and motor vehicles. This appears a legitimate and frequently-voiced concern, although some evidence to the contrary is provided by a cross-national ecological analysis by Jacobsen which shows an inverse relationship between per-capita injury rates and the quantity of walking and cycling in populations. [28] However, evidence about changes (or lack of changes) in injury rates after transport interventions which do not bring about a modal shift towards active travel do not help to answer this question. The most constructive interpretation that can be made of the evidence about adverse effects on health is that I found no evidence that interventions which were effective in promoting a modal shift were associated with any adverse effects, but this largely reflects an absence of evidence rather than positive evidence for the absence of adverse effects.

5.4 Understanding effectiveness of interventions

5.4.1 Theories of behaviour change in health promotion

At face value, the available evidence provides limited basis for drawing clear conclusions about the validity or applicability of theories of behaviour change in health promotion, simply because the theoretical basis of most interventions was not discussed in any detail in the primary studies. Other systematic reviews on related topics have also found it difficult to identify information about the theoretical basis of interventions [65] or have concluded simply that interventions are more likely to be effective if they are based on *a* theory of behaviour change which 'teaches behavioural skills' and is 'tailored to individual needs' [68] rather than finding clear support for any particular theory over its rivals.

Having said that, a common feature of the targeted behaviour change programmes which constituted the category of intervention supported by the most convincing evidence of effectiveness was that they were either (in one case) [218] explicitly based on the transtheoretical model of behaviour change, [255] or based on an implicitly-related approach which involved targeting the intervention on recipients identified as being motivated to change their behaviour. [172 175 176 223] The results from Perth confirm that although there was a significant aggregate modal shift in the intervention area, none of this modal shift was contributed from households that had expressed no interest in the intervention; [223] this observation supports a view that the targeting of this type of intervention at 'susceptible' recipients is an important aspect of how they might work.

This is not to say that the results of this systematic review provide definitive support for either the transtheoretical model or the more general targeted behaviour-change approach over alternative approaches. In general, although the transtheoretical model has been widely used as a means of designing and evaluating interventions to change behaviour, including physical activity, there is no consensus that it represents the best, or even an adequate, model of behaviour change in the field of physical activity promotion. [345 346] More specifically, in a study of the promotion of cycling in Odense in Denmark (published after I had completed this systematic review) longitudinal panel data showed that the number of people who 'progressed' in their stage of change in the transtheoretical model with respect to daily cycling (for example, from 'contemplation' to 'preparation') was balanced by an almost equal number of people who 'regressed'. [347]

In this review, I found that the most robust evidence of effectiveness was concentrated around interventions targeted at motivated groups of volunteers. As shown in the secondary methodological analysis (discussed in the second half of this chapter), this skewed distribution of evidence of effectiveness may reflect, at least partly, an 'evaluative bias' whereby other types of intervention (especially those applied to whole populations or areas) have tended to be evaluated using less rigorous methods. In other words, it may reflect the absence of evidence as much as it reflects evidence of the absence of effectiveness; it is not that alternative theories or models of changing behaviour have been tried and found wanting in comparison to the targeted approach exemplified by the transtheoretical model, so much that evaluating those alternative approaches has been found comparatively difficult and left untried [348] — or, if tried, has not been completed to the same degree of methodological rigour.

Two studies of interventions — those in Maidstone and Delft — were not based on targeted groups of volunteers but did draw on explicit theoretical bases. In the case of Maidstone, although the evaluation of the sustainable transport campaign was based on the theory of planned behaviour, [222] the failure of this study to demonstrate a positive modal shift should not be taken to represent significant evidence against that theory. On the contrary, the follow-up study validated the predictions of the theory: most respondents neither desired nor expected to reduce their car use, nor did they expect to increase their walking or cycling, and these expectations were confirmed. [257] In the case of Delft, the choice theory articulated by the authors appears to have been supported to some extent by the findings of the study: the observed increase in cycling, although modest, was reportedly accompanied by a decrease in the propensity of respondents to mention time, safety and comfort as reasons for not cycling — factors which had been targeted in the intervention on the basis that the theory predicted that these would constrain people's mode choices. [195]

5.4.2 A broader population perspective

In light of the difficulty of changing long-standing and complex patterns of behaviour in any area of health promotion, the evidence that some in-depth, targeted interventions have achieved any measurable modal shift should be regarded as encouraging. Without making a clear case 'for' or 'against' any particular intervention, theory or model, the findings of the systematic review can be summarised as being consistent with a view that interventions which engage people in a participative process and address factors of personal salience may be more effective than those which simply aim to raise awareness or impose changes in the physical and economic environments, while recognising that the relative absence of evidence for the latter approaches may reflect the 'evaluative bias' referred to above and may therefore disappear over time if efforts are made to redress the evaluative bias.

This finding is consistent with, and extends, those of other recent systematic reviews of interventions to promote physical activity in general. In their review for the Task Force on Community Preventive Services, Kahn and colleagues found 'strong evidence that individually adapted health behavior change programs are effective in increasing levels of physical activity'. They also found 'strong' evidence for the effectiveness of multifaceted community-wide campaigns, but insufficient evidence for the effectiveness of mass-media campaigns which 'address[ed] messages about physical activity to large and relatively undifferentiated audiences.' [63]

Kahn and colleagues also concluded that there was strong evidence for the effectiveness of 'environmental' interventions. However, these had involved not only modifications to the physical environment but also a range of other measures such as education, counselling and support systems. [63] The follow-up review by Heath and colleagues which focused on transport, environmental and policy interventions found insufficient evidence for the effectiveness of 'transportation policy and practices'; although the evidence for the effectiveness of both street-scale and community-scale urban design and land use policies and practices was found to be 'sufficient', all but two of the 16 studies included in these categories were cross-sectional studies, and the outcome measures used in the two longitudinal studies were pedestrian or bicycle flows. [64] Foster and Hillsdon's review of 'environmental' interventions to promote physical activity found that the limited available evidence of effectiveness was largely derived from studies of the effects of motivational prompts to use stairs — in other words, using the physical environment as the setting for a 'behavioural' intervention — rather than from studies of the effects of changing the physical environment. [65]

Although the current distribution of evidence appears to favour targeted behaviour change programmes, such approaches are unlikely to be sufficient to bring about sustained change in the population distribution of travel behaviour, let alone overall physical activity, because — by definition — only a motivated subgroup of the population chooses to participate in (or is offered) this type of intervention. None of the primary studies reported any data comparing, for example, the baseline travel behaviour, physical activity or general health of the people who were offered, or took up, this type of intervention with that of the rest of the population. However, in one of the TravelSmart studies [223] and the study of the Delft cycle route network, [195] it was noted that the observed increases in cycling were largely attributable to existing cyclists making more trips rather than to people taking up cycling. This small nugget of insight raises the possibility that an apparently successful intervention — that is, one which results in an overall positive modal shift — could conceal widening disparities in physical activity levels between subgroups of the population if those who are already more healthy, more active or better off are more likely to take up and respond to an intervention. Although I found no clear evidence that this was the case, neither did I find any evidence that this was not the case, whereas the literature in other areas of health promotion such as smoking cessation [349] or cervical screening [350] provides evidence of social gradients in the uptake or effectiveness of interventions which depend on the motivation of the individual to engage with them.

The question of how the effects of an apparently 'successful' intervention are distributed in the population highlights one important difference between the perspectives of public health and traffic management in framing evaluative questions about interventions to promote a modal shift. From the perspective of traffic management, it may not be particularly important who makes trips by different modes of transport; what matters most is the *aggregate* effect on, for example, congestion, which may be equally well served by existing cyclists (who are already physically active) making a modest increase in bike trips as it is by a modest number of sedentary motorists making a modal shift. From the perspective of public health, however, the latter offers greater potential population health gain than the former.

The findings of the systematic review support Wanless' more general observation that we know relatively little about the likely health impact of interventions to influence the wider determinants of population health. [74] One interpretation of the relative lack of evidence for the effectiveness of environmental modifications, such as improving infrastructure for cyclists or traffic-calming measures, is that — as inferred from the evidence on environmental correlates of physical activity by Giles-Corti and colleagues [51] and others — a 'supportive' physical environment may be a necessary, but not a sufficient, condition for people to become more active. The intervention studies included in this systematic review tended to involve *either* measures targeted at changing the behaviour of individuals or households *or* measures to change the physical environment, but not both together. It is possible that an intervention which combined both approaches in sufficient 'dose' might produce an effect which was larger overall and which resulted in an increase in physical activity among the more sedentary in particular, but no such intervention study was identified. An alternative interpretation which follows from the policy background discussed in Chapter 1 is that the distribution of available evidence may reflect, at least in part, a degree of ideological preference for funding, executing or evaluating interventions which emphasise the responsibility of the individual to make healthier or more socially responsible choices, as opposed to emphasising the responsibility of the state to create environments which encourage (rather than merely enable) those choices to be made.

Combining interventions in a genuinely integrated urban transport policy might be even more effective, but evidence from intervention studies to support this assertion is currently lacking. Indeed, as I showed in the analysis of the excluded studies of case study cities, there is little evidence that a positive population-level modal shift has occurred in those cities, let alone that such a shift is attributable to a particular combination of interventions. Furthermore, the ecological comparisons discussed in Chapter 1 show that the mode shares for walking and cycling can vary between populations, both between and within countries, by an order of magnitude greater than the population-level effect size of any intervention included in this review. It may therefore be unrealistic to expect interventions to produce substantial effects in relatively inactive populations without addressing the other, potentially complex reasons for such variations, such as attitudes towards cars and bicycles. Or, to put it another way, I found no evidence to support an assumption that, for example, applying the policies and infrastructure of a city with a high mode share for walking and cycling to another city with a low mode share will necessarily, or on its own, produce a modal shift from using cars towards using active modes of transport.

5.5 Methods for quantifying changes in travel behaviour

The methods used to quantify changes in travel behaviour in all the included studies are summarised in Table 38. They are tabulated in ascending order of completeness, grouped as follows:

- Non-specific assessment (i.e. limited to somewhat imprecise questions)
- Assessment of trips for specific purposes (e.g. commuting)
- Assessment of all types of trip.

Studying only one type of trip (such as commuting) is attractively simple and may be particularly relevant to traffic management, but ignores some important issues for public health including short local walking trips, trips made by children and elderly people, and the effects of off-peak traffic on local social networks. [75] Some of the simpler types of question used to assess commuting trips are also relatively insensitive to change. For example, a respondent who took up cycling to work two days per week would still be expected to report their 'usual mode' of transport to and from work as 'car', and a respondent who decided to get off the bus a mile before their destination and walk for the remainder of the journey would still be expected to report the 'main mode' of the journey as 'bus'; neither of these substantial changes in behaviour would be captured using an instrument based on questions about 'usual' or 'main' modes.

Choosing a more comprehensive method clearly involves trading off the quantity of data obtained and the sensitivity of the instrument to change against the effort required of respondents. Considering the range of possibilities illustrated by Table 38, I conclude that the best trade-off may lie in the area of the one-day travel survey, either as a prospectively-recorded diary or as a recall questionnaire. Unlike some other methods, this technique has been used successfully in studies of targeted interventions (in the TravelSmart studies) [175 176 223] and area-based interventions (in Delft, Detmold and Rosenheim and Trondheim) [173 195 244] with reasonable response and attrition rates, despite the respondents not necessarily being personally engaged with the intervention in all of these cases.

Specific examples of one-day written travel survey instruments are the trip questionnaire used in the study of the car-sharing club [177] and the widely-used New KONTIV Design (NKD; Socialdata, Munich) used in the TravelSmart studies [175 176 223] and in some national travel surveys. Response rates in the Dutch national travel survey rose sharply following a switch from telephone-based interviewing to a postal NKD survey. [351] However, the NKD questionnaire is not in the public domain.

These issues are considered further in the context of the design of the M74 study in Chapter 6.

Method	Studies in which used	Comments	Advantages	Disadvantages
Group 1: Non-specific assessment				
Simple question about whether people's travel patterns had changed	England (20 mph zones) [179]		None	Reflects a poorly-specified research question
Group 2: Assessment of trips for specific purposes				
Main or usual mode of trips for a specific purpose (to town centre, for commuting, or to school)	England (bypasses) [213] Eugene [174] Stockton [178]		An apparently simple question	Low sensitivity to change, e.g. deciding to walk to work two days a week would not be detected
Mode of trip to work or school on one particular day	Boston [188] Camden-Islington [221]	Response rate was high in the Camden trial (85%), but poor in the Boston survey (31%)	Likely to have high face validity (for single-mode trips)	Low sensitivity to change High sensitivity to fluctuating conditions, e.g. weather, therefore may be unsuitable for longitudinal analysis Assumes trips involve a single mode
Mode of all commuting trips in one week	California (cashing out) [192] Phoenix [239]	Response rate was high (>90%) in California, but probably because of compulsory data collection in the workplace; response rate not reported in Phoenix	More sensitive to change than previous category Likely to have high face validity (for single-mode trips)	Assumes trips involve a single mode
Time spent walking or cycling to work in seven-day recall physical activity diary	Glasgow [218]	High initial response rate (89%) and acceptable attrition rate (33% after 6 months), but this was a trial, not a population survey	Highly sensitive to change Can be linked to stage of change questionnaire	Does not provide data on distribution of mode choice

Table 38. Methods for quantifying changes in travel behaviour

Method	Studies in which used	Comments	Advantages	Disadvantages
Group 3: Assessment of all types of trip				
All trips on one day	TravelSmart [223] [175] [176] Trondheim [244]	Genuinely population- or area-based interventions Good initial response rates (66-77%) and reasonable attrition rates (up to 24% after 3 months; up to 38% after 24 months)	Reflects all types of trip Not excessively onerous	Respondent may select an atypical day unless the day is specified in advance
All trips on one of a number of specified days covering all the days of the week	Delft [195] Detmold-Rosenheim [173]	Genuinely population- or area-based interventions Reasonable response rates (53-68%); these were not panel studies, so attrition rates not applicable	Similar to previous category Could be used to exclude or investigate decay in effects towards the end of the week	Similar to previous category
All activities or all trips on two consecutive days selected by the respondent	San Francisco [177] Voorhout [249]	Low response rate in San Francisco (22% in the follow-up wave) In Voorhout (a genuinely area-based intervention), an acceptable response rate (56%), but a substantial attrition rate (41% after 12 months)	Similar to previous category, but more sensitive to change	Increasingly onerous Respondents were more likely to complete questionnaires on weekdays than at weekends in the San Francisco study

Table 38. Methods for quantifying changes in travel behaviour (continued)

Method	Studies in which used	Comments	Advantages	Disadvantages
Group 3: Assessment of all types of trip (continued)				
All trips on three consecutive days	California (telecommuting) [194]	Low response rate (35%)	Similar to previous category, but more sensitive to change	Increasingly onerous
All trips in a 'typical week'	Maidstone [222]	Genuinely population- or area-based intervention Low response rate (20%)	Similar to previous category, but more sensitive to change	Nature of a 'typical week' is susceptible to respondent bias
All weekday trips in one week	Århus [172]	Low attrition rate (12% after 11 months), but respondents had entered into a contract to do this and were receiving substantial personal incentives to participate	Possibly of particular relevance to studying interventions which specifically affect weekday travel (e.g. the journey to work)	Comparatively onerous
Seven-day diary of all trips	Adelaide [180]	Respondents knew they were going to receive tailored feedback on what they recorded Initial response rate unknown	Highly sensitive to change	Comparatively onerous High attrition rate in practice (>50% after only one month)

Table 38. Methods for quantifying changes in travel behaviour (continued)

5.6 Secondary methodological analyses

5.6.1 General approach to the 'input phase' of the review

In this systematic review, I sought population-level evidence to address a public health research question. I therefore searched for a wide range of evidence from diverse sources, making no assumptions about what types of intervention or study design would be relevant, and explicitly considered external validity (represented by the choice of study population) in selecting studies for inclusion.

Other recent systematic reviews on related topics demonstrate a spectrum of approaches, both to what sources might be searched for evidence and to what types of evidence might be selected for inclusion.

Approaches taken to literature searching have ranged from the focus on health databases exemplified by the reviews for the Cochrane library, the HDA and NICE [41 68 69] to the efforts made by Heath and colleagues to search databases in a wide range of relevant disciplines. [64] However, most of these reviews did not include any studies published in a language other than English, and even where databases from outside the health sector were searched, this was sometimes done in a way which may have biased the results of the search in favour of studies from the 'English-speaking world', particularly North America. For example, the search for the NICE review included the TRIS database, which is a subset of the full Transport database dominated by North American literature; the full Transport database (which includes European literature published in a variety of languages) was not searched. [69] In contrast, my pilot search clearly showed the importance of the European literature in this field (Table 14).

Approaches taken to specifying inclusion criteria have ranged from the comparatively stringent approach taken by Hillsdon and colleagues in their Cochrane review, which included only randomised controlled trials with a minimum follow-up period of six months and either an intention-to-treat analysis or a maximum attrition rate of 20%, [41] to the highly-inclusive approach adopted in the Community Guide reviews, [63 64] which included studies with a range of outcome measures and also included cross-sectional studies comparing communities which differed in their characteristics but where there had been no obvious intervention as such. For one category of intervention in Heath and colleagues' review in this series — 'community-scale urban design and land use policies and practices' — only cross-sectional studies were included. [64]

5.6.2 Recapitulation of principal findings

Finding the evidence

Most of the relevant evidence was not found by searching mainstream health literature databases. The Transport database was the key to this review; I also found relevant evidence by searching the internet and by chance. The contribution of experts was not to identify additional studies, but to help find better reports of studies I already knew about.

Thresholds for inclusion

I found only three randomised controlled trials (RCTs) of interventions which fell within the scope of this review. The interventions which had been studied in RCTs represent only a small subset of all those which could be or have been advocated. Restricting the systematic review to RCTs would therefore have severely limited its scope.

The studies identified as relevant to the scope of the review but excluded on the grounds of study design, study population or insufficient information provided four types of additional evidence to supplement that provided by the synthesis of included studies: a larger taxonomy of interventions of interest; evidence about some interventions consistent with the stronger evidence already included in the review; evidence about one category of intervention (publicity campaigns to promote sustainable transport) that could potentially contradict the primary findings of the review; and evidence to challenge assumptions about 'successful' cities.

5.7 Implications for finding the evidence

5.7.1 Searching electronic literature databases

Although the studies identified through first-line health databases were of relatively high methodological quality, they contributed a small minority of the total evidence which was relevant to the review. As I showed in Chapter 2, this is not the case for all systematic reviews, particularly those on clinical topics, [141] but even in the clinical arena the unique contribution of references found only in other specialist databases has been acknowledged. [138 139 142] In the topic area for this thesis, which lies far from the clinical focus of most health databases, my findings confirm the importance of searching widely in topic-specific databases which may be unfamiliar to those working in the field of public health. Researchers should not underestimate the complexity and time demands of searching across multiple databases with different technical and syntactical requirements. [144]

My pilot search confirmed that many of the abstracts identified were of poor quality, particularly in terms of the precision with which they identified the study design or the outcome measures used. I therefore decided not to apply a filter for study design in my definitive search strategy, preferring to design a highly sensitive search and filter the results 'manually'. However, sensitive searches tend to be imprecise and require researchers to scan thousands of irrelevant items: I examined over 5000 titles or abstracts in this review.

The poor quality of abstracts may also help to explain why the inter-rater reliability of decisions to select titles or abstracts for full-text retrieval was disappointing. Few authors appear to have reported or discussed inter-rater reliability in this phase of a systematic review, as opposed to the inter-rater reliability of the application of scoring systems for the appraisal of study quality. In a review which involved only a few, comparatively well-indexed, health-related databases (CINAHL, EMBASE, Medline, Psychlit and the Cochrane Database of Systematic Reviews), Cooper and colleagues reported values of Cohen's κ for inter-rater reliability ranging from 0.47 to 0.74 (for selecting titles for inclusion) and from 0.53 to 0.73 (for selecting abstracts for inclusion), depending on the professional qualifications of the pairs of raters being compared; [352] in another review, Taylor and colleagues reported values of κ ranging from 0.66 to 0.88 depending on the database searched, the highest value being associated with Medline and the lowest with Caredata, a social work database. [353] In the former study, the authors noted that 'despite what we believed were clear and precise instructions for inclusion and exclusion of abstracts, the process turned out to be very subjective', partly because some reviewers may have been inherently more cautious than others and therefore inclined to include more studies; [352] in the latter study, the authors attributed their findings to 'the general paucity of information in the abstracts on [the Caredata] database'. [353] There are other potential explanations for my findings — for example, that the inclusion criteria were specified with insufficient precision to enable the different raters to apply them consistently, or that the raters had genuine and valid divergent opinions of the relevance of different studies — but it is likely that both differences in reviewers' attitudes and the imprecision of many of the abstracts were at least contributory factors. Partly as a result of the low inter-rater reliability, I decided to maintain the initial highly-sensitive approach to the 'input' phase of the review by retrieving the full text of all studies which *any* rater thought capable of meeting the inclusion criteria.

5.7.2 Searching for fugitive literature

In this topic area, many relevant studies have never been fully reported in a scientific journal, so it can be difficult to find evidence that can be meaningfully appraised. In particular, the vast and rapidly-expanding amount of information available on the internet appears a mixed blessing. The advantages include quicker and cheaper access to some full-text journal articles and the increasing tendency to publish 'grey' literature online. However, as I showed in Chapter 2, other researchers have reported finding few or no useful studies by searching the internet; [142 149] of the nine relevant studies I found through purposive web searching, only two were included in the final synthesis. This suggests that most of the work found by searching the internet was of relatively low quality, reflecting the warning of Howes and colleagues about the quality of difficult-to-locate studies referred to in Chapter 2. [140] Nonetheless, finding and appraising such 'low-grade' evidence may still be important in order to develop a taxonomy of interventions, critique current approaches to evaluation, and show how the evidence base might be strengthened; this was the objective of tabulating the evidence contributed by such 'low-grade' studies in Table 37.

In contrast to the systematic reviews cited in Chapter 2, [5 149 153] in this review I identified no studies solely on the recommendation of an expert. Instead, I found that experts helped me to find better reports of studies which I had already identified by other means. Having said that, the warning in the Cochrane reviewers' handbook was confirmed by my experience: I obtained the information I requested from only seven of the 22 authors I attempted to contact. This success rate is similar to that reported for a much larger systematic review of interventions to promote weight loss in which 146 authors were contacted. In that review, responses were obtained from 32% of authors overall; contact by email was more likely to elicit a response than contact by letter, and authors of recently-published studies were more likely to respond than authors of studies published more than ten years previously. [354]

5.7.3 A surgical strike on the evidence?

In retrospect, my findings offer some support for the conclusion drawn by McNally and colleagues and referred to in Chapter 2 — that their time might have been better spent assessing the value of each database more critically at the outset. [136] It appears possible that most of the primary studies finally included in this review could have been found in — or in references from — documents indexed in a handful of key resources such as the Transport database. This suggests that I might have reached similar conclusions if I had followed an alternative search strategy by searching those few resources, then asking authors and experts directly for the most robust reports of studies of the interventions identified. This hypothesis could be tested prospectively in a future review by applying two or more search strategies in parallel and comparing the results.

A more targeted search — a 'surgical strike' to hit the most relevant evidence — might help to guard against the temptation to keep searching for just one more relevant study. It would also be expected to reduce the time and expense needed to carry out a systematic review. It is always necessary to find a balance between comprehensiveness and precision when developing a search strategy, and the law of diminishing returns applies as much to literature searching as to any other activity. [139] However, there is a subjective and serendipitous element to literature searching which would be lost in a highly-targeted approach. I did find some relevant studies purely by chance, and I have no way of knowing whether I might have found them by other means. As I showed in Chapter 2, Greenhalgh and colleagues and Hawker and colleagues also commented on the importance of serendipity in finding evidence for their reviews, [153] [154] and I certainly experienced the sense of saturation described by Hawker and colleagues towards the end of my comparatively exhaustive search when I began to turn up multiple references to the same, frequently-cited 'case study' cities such as Graz or München. [288] [283] Constraining the search, particularly when studies of many different types are being sought, must surely therefore reduce the likelihood that reviewers will reach a point at which they can reasonably judge their search to be complete.

5.8 Implications for thresholds for inclusion

5.8.1 Hierarchies of evidence for public health

In this systematic review, the most robust evidence of effectiveness was concentrated around interventions targeted at motivated groups of volunteers. The subsequent secondary analysis shows that this 'evidence bias' may reflect, at least partly, an 'evaluative bias': other types of intervention (especially those applied to whole populations or areas) have tended to be evaluated using less rigorous methods.

For those interested in improving population health, the most useful evidence of effectiveness is likely to come from population-level studies with designs of high internal validity — those located in the far right-hand corner of the matrix based on the two-dimensional hierarchy of study design and study population (Figure 3). In reality, however, the distribution of the available evidence was skewed. Many genuinely population- or area-level interventions have been studied using relatively weak study designs, and the 'gold standard' randomised controlled trial (RCT) methodology has only once been applied to an area-level intervention in this field, the school travel co-ordinator study in Camden and Islington. [221] In other words, we know least about the effects of those interventions that are most likely to influence the wider determinants of health — a problem described elsewhere as an evidence deficit, or 'inverse evidence law'. [126 127]

My findings therefore support concerns expressed in the literature and discussed in Chapter 2 that rigid or simplistic adherence to a hierarchy of study design as the primary marker of study utility may be unhelpful, particularly in the fields of health promotion and public health. [109 111 124 125] In particular, the interventions that have been studied in RCTs represent only a small subset of all those which could be or have been advocated. Extending the inclusion criteria for study design as far as I did enabled me to review evidence about a much larger range of interventions and identify some pointers towards potential unexpected effects. Having re-examined the evidence contained in the studies I did exclude, I do not think that any studies containing convincing evidence of effectiveness were unwittingly censored by the decision to apply the inclusion criteria which were finally chosen. However, I did identify some interventions which could have positive effects and should be the subject of further research. I also identified other studies, notably the case studies of cities frequently cited as examples of good practice in transport policy, in which I could find little actual evidence of success in promoting walking and cycling as an alternative to using cars.

My findings also support concerns expressed in the literature about the use of methodological checklists for critical appraisal. [117 160] Although it was convenient to use the number of methodological criteria met as an indicator of study validity, many studies which achieved a lower score according to this system did so because the authors, who had not been operating within the framework of public health research, happened not to have presented their reports in a way which made them easy to appraise against the standards of that framework, rather than because the methods had been manifestly deficient. Finding myself unusually dependent on assessing the quality of reporting as much as the quality of the research, it seemed preferable to include studies across the range of methodological transparency, albeit applying appropriate caveats to the interpretation of data from the less transparent studies.

5.8.2 Best available evidence

My experience in conducting this systematic review confirms the position adopted in the Cochrane handbook which, while acknowledging a place for systematic reviews that address broad questions, warns of potential difficulties with synthesising and interpreting data from a large set of heterogeneous studies. [112] I developed my inclusion criteria iteratively by searching widely, fully appraising all relevant studies, and thereby forming an overview of all available evidence before deciding what should be included. [154] In doing so, I was attempting to put into practice the possible approach I outlined in Chapter 2: 'deliberately to seek out a variety of evidence contained in a diverse range of studies and then use a hierarchical, or partly-hierarchical, method to identify the best available evidence in light of what is now known to constitute all the available evidence' (Section 2.7.1). The approach which emerged as most appropriate for this review reflects that described by Slavin as 'best evidence synthesis', in other words, not allowing a desire for the 'best' evidence to stand in the way of using the best available evidence. [84]

The contribution of this particular systematic review has turned out to be closer to Hammersley's metaphor of a mosaic or map of the 'bigger picture' [110] than to the more reductive answers provided by a typical meta-analysis. Systematic reviews may contribute to public health decision making in various ways, [92] and the setting of appropriate thresholds for defining the 'best available evidence' should therefore depend on what researchers, policymakers or practitioners think evidence synthesis is for and on what evidence is available in a given topic area. An editorial has highlighted disagreement between authors and peer reviewers over whether the topic of a systematic review of community-based interventions was sufficiently coherent or precise to permit generalisation, and argued that learning in public health is best promoted by the critical sharing of evidence, not by censoring suboptimal evidence. [355] I do not suggest that reviewers should incorporate the results of less-robust studies uncritically in their synthesis of evidence of effectiveness, because doing so can significantly change the resulting recommendations about what interventions are labelled 'effective'. [129] However, my sensitivity analysis shows that excluded-but-relevant studies can make an additional valuable contribution to the larger mosaic, even though I appear to have been justified in excluding them from the primary synthesis of evidence of effectiveness. Indeed, the preliminary mapping of all available evidence has been an explicit part of the process of some systematic reviews. [356]

Handbooks and protocols for systematic reviews, and the reports of their findings, can often given the impression of a linear, rational research process driven by a set of decisions made *a priori*. But the further a review strays from the world of the placebo-controlled drug trial, the less tenable this idea becomes. In this respect, a report of a systematic review is no different from any other scientific publication: it can give a misleading narrative of the research process. [357] The evidence never speaks for itself, but is always open to interpretation, and there are elements of the review process that involve judgment and cannot be made entirely transparent or replicable. [110 358] Designing and conducting systematic reviews of the effects of interventions to influence the wider determinants of health is a difficult task for which a standard methodology — whether for searching, study selection, or any other part of the process — has not yet emerged. The methods I adopted are open to challenge. Nonetheless, I suggest that it is preferable to reach conclusions, however tentative, that are based on the best available evidence rather than simply stating that no evidence is available. [130]

5.9 Further intervention studies

In this systematic review, I have shown that the distribution of available evidence of effectiveness is skewed towards interventions targeted at motivated individuals or households, partly because many genuinely population- or area-level interventions have only been studied using relatively weak study designs. Even for targeted interventions, evidence of effectiveness is limited in terms of both the quantity and the quality of the studies included in the review. There is therefore a case for further studies of targeted interventions, which could seek to replicate the findings of the promising but limited studies completed to date or, preferably, to subject the claims made for interventions such as TravelSmart to the rigours of an independent randomised controlled trial. However, from the perspective of population health improvement it may be more important to redress the 'evidence bias' by developing better methods to investigate the effects of interventions applied to whole populations or areas, concentrating on 'upstream' environmental and policy interventions rather than those focused on changing 'downstream' individual behaviour on the grounds that the former, 'upstream' type of intervention have been less well researched and may have greater potential to shift population determinants of health. Furthermore, in view of the very limited data available on the secondary outcomes addressed in this review, further studies should investigate effects on physical activity, not just on travel behaviour, and should investigate how the effects of interventions are distributed in the population.

Several studies have been published since this systematic review was completed which would have met the criteria for relevance (and, in some cases, for inclusion) had they been published earlier. I have selected three examples to illustrate recent advances in the evidence base and the limitations of the advances made.

The first example comprises multiple additional studies of the effects of the TravelSmart programme. Seven new controlled studies have been published, two from Australia and five from England. [359-365] These studies consistently corroborate the favourable results reported in the systematic review, finding effect sizes of similar magnitude associated with similar interventions under the same 'brand name' in a variety of urban and suburban settings, and therefore lend support to the general conclusion of the systematic review that targeted behaviour change programmes are likely to be effective. However, these studies also replicate most of the methodological limitations of the earlier studies: they lack clarity in the description of methods, the comparisons made with controls and the analysis of the statistical significance of the results, and no investigator has yet taken the step of randomly allocating different households or areas to the intervention and control arms of the study. [366]

The second example is a study of a discrete, area-based intervention such as I have suggested is needed to redress the 'evidence bias' referred to above. The London congestion charge is a particularly high-profile intervention of this kind which has been accompanied by an extensive monitoring programme both before and after its introduction in 2003. The reports from this study illustrate two contrasting methods of attempting to quantify modal shift in the area subject to the intervention. [367 368] Headline claims of a 20% increase in cycling are based on apparently robust data from the automated counting of vehicles crossing the charging cordons into central London, but these provide no data on walking or on changes in the overall travel behaviour of the population. In contrast, household survey data on travel behaviour, which could have been used to address these questions, are reported vaguely and in such a way as to suggest that the opportunity to design a survey instrument sensitive to changes in health-related behaviour may have been missed.

The third example is a study of a case study city. Between 1999 and 2002, multiple interventions to promote cycling were introduced in Odense, Denmark. The evaluation of this 'national cycling city' demonstration project appears to have been much more rigorous, and reported much more clearly, than the case study evidence examined in the systematic review: among other things, the study drew on a combination of data sources and included adjustments for regional trends and other potential confounding factors. [347] However, the longitudinal analysis of travel survey data showed decreases of 100 metres and 400 metres respectively in the mean distance walked and cycled per day; after adjustment for confounders, the positive effect attributable to the intervention was only 100 metres per day for each of the active modes. This suggests that, even where comparatively robust methods are applied to quantifying modal shift in an exemplar city, it can be difficult to demonstrate any substantial effect.

In summary, while recently published studies have contributed new evidence, and have demonstrated the use of comparatively sophisticated methods such as the interrupted time-series analysis used in London, clear evidence — particularly from controlled studies — that any environmental or policy intervention has had a substantial or sustained effect on the travel behaviour or physical activity of a population remains elusive.

6 M74 study: introduction

6.1 Overview of this chapter

In this chapter, I introduce the M74 study and show how it was developed in the light of the findings of the systematic review reported and discussed in Chapters 4 and 5.

I begin with a brief review of recent literature on the challenges of studying the health effects of ‘social’ interventions in general. I then develop the case for more rigorous studies in one field in particular: the effects of environmental and policy interventions on levels and patterns of active travel and physical activity in the population.

I then introduce the specific intervention to be examined in this study: the construction of a new urban section of the M74 motorway in Glasgow (hereafter referred to as the *M74 project*). I outline the background to this road-building project, critique some of the health-related claims made for and against the project, and review some of the specific methodological challenges in researching the effects of a ‘natural experiment’ of this kind.

I go on to show how I developed a focused set of research questions, a simple conceptual model, and an appropriate perspective on causal inference for the study. I then examine each of the principal types of data required to populate the conceptual model and consider how best these might be acquired, either by using existing sources of routinely-collected data or by collecting new data.

The chapter concludes with a statement of the aims and objectives of the study.

6.2 Researching health effects of social interventions

6.2.1 Introduction

The work reported in this thesis was carried out within a research programme in the MRC Social and Public Health Sciences Unit entitled *Evaluating the health effects of social interventions*. In this context, by 'social' interventions I mean policies, programmes or projects mainly undertaken for reasons other than improving health — in other words, to achieve social rather than health objectives — but which may influence health, albeit indirectly. [130 369] The general case for a critical examination of the effects of such interventions is encapsulated in the position adopted by Macintyre and Petticrew and referred to in Chapter 1, namely that good intentions and plausible theories are an insufficient basis for making decisions about policy and practice. [80] The case for doing so in this field in particular is encapsulated in the position adopted by Chalmers (among others) and reflected in the CONSORT statement referred to in Chapter 2, namely that having systematically assessed as much as possible of the existing research, researchers should go on to conduct additional primary research where a systematic review shows that this is needed. [85 98]

6.2.2 Public health interventions in general

Several authors have recently identified a need to shift research effort from describing public health problems and elucidating their causes (testing aetiological hypotheses) towards researching the effects of interventions (testing evaluative hypotheses). [111] An analysis conducted for the Health Development Agency in 2001 found that only 0.4% of published research output on priority topics for public health in England was relevant to public health intervention research. [88] Nutbeam subsequently described the imbalance between the 'substantial volume of work that provides sophisticated descriptions of public health problems' and the 'little by way of providing evidence on the effectiveness of proposed solutions'. [126] Commenting specifically on the evidence available to support the Acheson report on health inequalities in the UK, [370] Nutbeam goes on to note that even within the 'little' available research on the effects of interventions, the volume and quality of available evidence was concentrated in the area of individual risk factor modification rather than in approaches to tackling the wider social, economic and environmental determinants of health which may have greater potential effects in the population as a whole [126] — an inverse relationship also noted in the subsequent Wanless report *Securing health for the whole population*. [74]

In order to redress the balance, greater methodological flexibility is likely to be required. Nutbeam has argued for a shift away from a narrow, 'regressive' concept of evidence towards more complex and pluralistic approaches to evaluation design and methods [371] — a call echoed by others. For example, Moller has critiqued a perceived temptation to 'write off' certain types of public health intervention as too unstable or difficult to evaluate or replicate. [355] This temptation may partly reflect an assumption that interventions ought to be 'standardisable' and amenable to evaluation in a reductive manner, but this assumption has been critiqued by Hawe and colleagues, who point out that where interventions are intended to influence the operation of a complex system, the notion of a 'standardisable' intervention may be meaningless and the true essence of a complex intervention may be lost if researchers attempt to decompose it into its component parts. [372] Petticrew and Roberts have observed that although the research methods chosen will still need to be justified, it may be more important to concentrate on identifying the most appropriate research questions to be addressed in this type of evaluative research than to argue about the 'best' method in any given case. [124]

Some steps have been taken towards setting out how this type of evaluative research might be done for so-called 'complex public health interventions'. Rychetnik and colleagues acknowledge the general proposition that intervention research should 'confirm and quantify the causal relation between the intervention and its effects where such a relation exists', but also propose that public health intervention research should go further — by looking for unintended consequences, and by investigating the anticipated causal pathway or mode of action of an intervention rather than simply concentrating on the methodologically correct measurement of exposures and outcomes [111] (in other words, seeking to understand how an intervention works rather than simply asking if it works). The second Wanless report identifies 'an urgent need to develop an appropriate practical framework for evaluating public health interventions in practice', and enumerates four specific issues to be addressed in such a framework: the use of controls, the use of appropriate time frames, the choice of outcome measures, and the magnitude of change that should constitute 'success' for an intervention. [74] Although it is perfectly possible to conduct randomised controlled trials of some types of 'social' intervention, [373] in practice it has proved difficult or impossible to do this for many of the interventions which may influence the major social determinants of health for ethical, practical or political reasons (Table 39). The recent publication of a statement on the Transparent Reporting of Evaluations with Nonrandomized Designs (the TREND statement) represents one attempt to codify some principles for the reporting of non-randomised evaluation studies which recognises the need for a variety of research designs and types of evidence as identified by Nutbeam and others. [128] However, TREND has been described as a 'work in progress' [374] and may in any case be too restricted in scope for some public health intervention research — particularly studies of the indirect health effects of 'social' interventions [130] and studies of 'natural experiments', specifically identified by Wanless as a potentially important source of evidence. [74]

Example of intervention	Type of obstacle	Rationale for obstacle
Welfare benefit such as Attendance Allowance	Ethical	Considered unethical to withhold benefit from participants allocated to the control group, since in order to be comparable to the intervention group all members of the control group would have been assessed as eligible for (i.e. in need of) the benefit in question [130]
National mass media campaign to promote physical activity	Practical	Health education messages disseminated through national broadcast and print media, therefore no unexposed population available to act as control group [343]
Sure Start Local Programmes to improve services for children and families in prescribed areas	Political	Policy decision to rule out the random allocation of deprived areas to receive the intervention or to act as controls, on the grounds that to intervene in some areas but not in others was politically unacceptable [375]

Table 39. Examples of obstacles to establishing randomised controlled trials

In this context, by 'natural experiment' I mean an observational study in which researchers have no control over the allocation of an intervention to particular groups of people, but are able to take advantage of variations in allocation which occur outwith their control, for example by exploiting the opportunity created by a political decision to introduce a programme or project in one area and not in another. [376]

6.2.3 Environmental and policy interventions in particular

I now turn to the specific problem of evaluating the effects of environmental and policy interventions on levels and patterns of active travel and physical activity in the population. I showed in Chapter 1 that a considerable body of evidence now exists to show that a variety of characteristics of the physical environment may be associated with physical activity, including specific modes of activity such as walking for transport, but very few longitudinal studies (let alone intervention studies) have examined whether changes in environmental characteristics are causally associated with changes in physical activity. Bauman's analysis of the current state of research in this field mirrors the observations made by Nutbeam and others about public health intervention research in general:

> Despite burgeoning correlational and measurement research around environments and physical activity, few opportunistic studies have evaluated the effects of environmental interventions on population physical activity levels... it is timely to prioritise these natural experiments and the opportunistic evaluation of environmental improvements... Even tentative examples here will provide further evidence on which to progress public health policy decisions. [56]

Bauman's observations provide some corroboration (from the perspective of physical activity in general) of the findings of my systematic review of the effects of transport interventions in particular (see Chapter 5), from which I identified a need to develop better methods to investigate the effects of 'upstream' environmental and policy interventions. Bauman's use of the term 'opportunistic studies' highlights the fact that many such interventions which have the potential to influence active travel and physical activity — whether in a favourable or an unfavourable direction — arise in the form of an opportunity to which researchers must react, rather than as a decision to introduce a specific intervention to test a specific hypothesis. At the time when the systematic review was nearing completion, such an opportunity presented itself in the form of the most expensive and controversial major transport project of its time in Scotland: the construction of a new urban section of the M74 motorway in Glasgow. This 'natural experiment' would introduce a major modification to the urban transport infrastructure which was expected to change people's travel behaviour, and was announced with sufficient notice to allow for the planning of a longitudinal study. The M74 project therefore offered an ideal opportunity to develop and demonstrate methods which could be used to research the effects of an environmental intervention, in the form of a major transport project, on active travel and physical activity.

6.3 The M74 project

6.3.1 Background

Glasgow

Glasgow is the largest city in Scotland, with a population of about 578,000 in the area covered by Glasgow City Council and about 867,000 in the area covered by Greater Glasgow NHS Board. [377] Formerly a centre of heavy industry, Glasgow experienced rapid de-industrialisation in the latter part of the twentieth century. As a result, the city now has a mixed economy, dominated by industries such as financial services and retailing, and a post-industrial legacy of some of the most deprived and least healthy working-class communities in Europe. Of the 73 parliamentary constituencies in Scotland, the seven with the shortest life expectancy are all in Glasgow; in 1999-2001, life expectancy at birth for males in Shettleston was 63.9 years, 9.5 years less than that for Scotland as a whole. Large inequalities in health are also apparent within the Glasgow conurbation, which includes constituencies such as Strathkelvin & Bearsden and Eastwood with male life expectancies more than 12 years greater than that in Shettleston. [378]

The regeneration of deprived communities in the west of Scotland is therefore a leading objective of regional policy. The Glasgow and Clyde Valley Joint Structure Plan, approved by Scottish ministers in 2002, sets out a strategic vision which includes a corridor of growth for new economic development along the River Clyde. Part of this is referred to as the Clyde Gateway project, which encompasses a large area in the east and south-east of the city, much of which lies within the Shettleston constituency. Problems identified in this growth corridor include a large quantity of vacant land and derelict buildings (brownfield sites) which are poorly located with respect to transport infrastructure. The plan therefore envisages that in order to stimulate economic regeneration of this area, it will be necessary to fill gaps in the strategic road network, and specifically to construct a northern extension to the M74 motorway. [379]

The strategic road network in the west of Scotland

The strategic road network in the west of Scotland includes several urban motorways in Glasgow (the M8, M77 and M80), which have been built since the 1960s, and the M74, which forms the Scottish section of the only motorway link between Scotland and England (Figure 6).

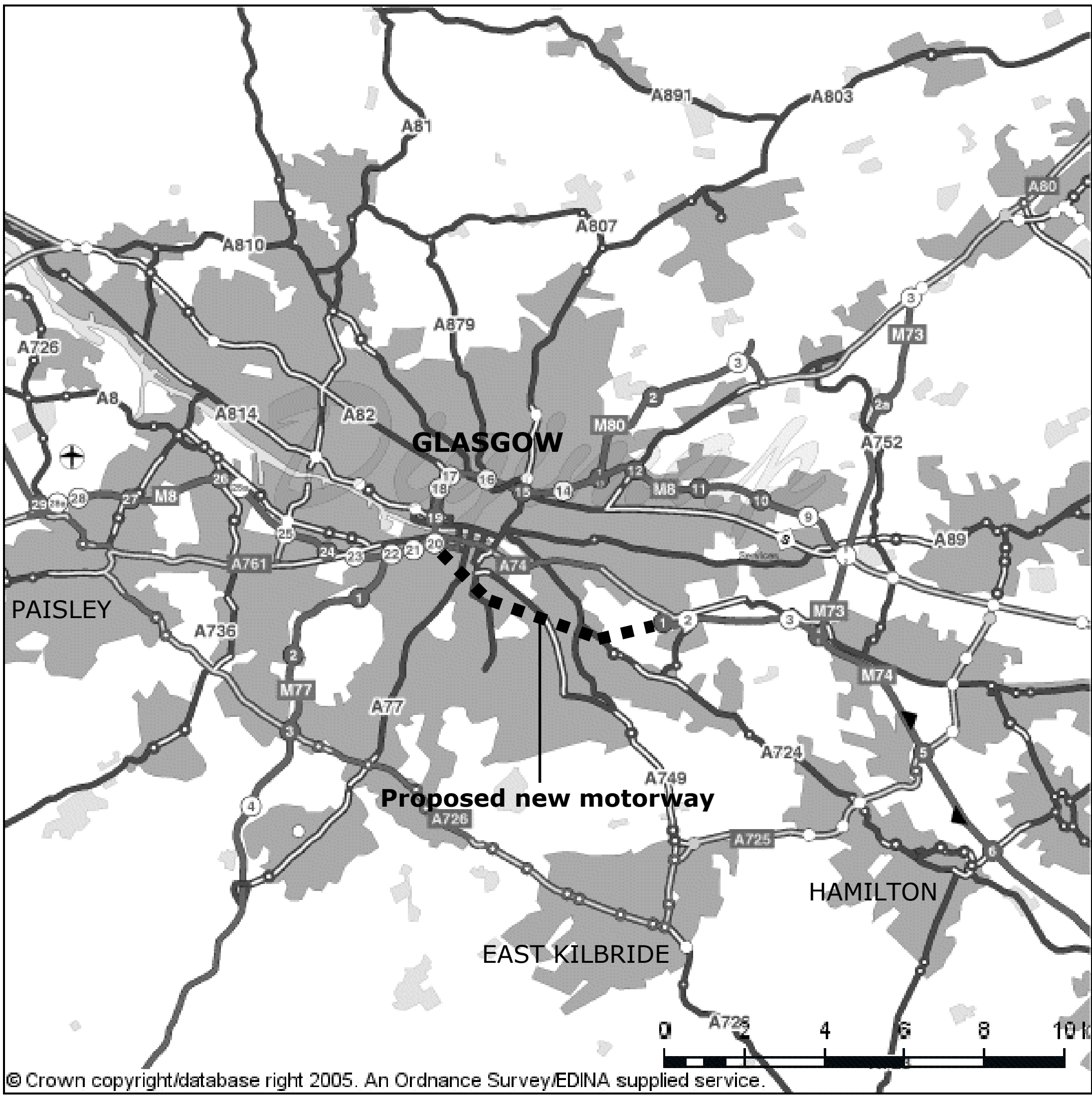


Figure 6. Strategic road network in the west of Scotland

In 2001-2002, the Central Scotland Transport Corridor Studies (CSTCS) examined transport issues in the corridors around three trunk routes: the A8, the A80 and the M74. One of the problems identified was congestion on the M8 motorway through the city centre, which led to knock-on congestion on other roads in the area, particularly at peak periods. Various reasons for this congestion were identified, including an insufficient number of through lanes and the vulnerability of traffic flow on the M8 to accidents and breakdowns, but also including an increased need for car trips owing to the dispersal and increasingly transient nature of employment opportunities and the deficiencies of the public transport network. The strategy recommended in the CSTCS included applying congestion charging across the whole conurbation and imposing controls on development close to trunk road junctions, but the authors recognised that such measures were unlikely to be politically acceptable and therefore suggested that road-widening and other approaches to traffic management would have to be adopted instead. [380]

Options for extending the motorway network around the south side of Glasgow first appeared in highway plans for Glasgow in the 1960s and subsequently in the Strathclyde Structure Plan (1988). Planning permission for a northern extension of the M74 was granted in 1995, and was renewed in 2001 after the minister for transport in the newly-formed Scottish Executive (government) announced in 2000 that she had, in principle, accepted the need for it to be built. [381] From this time onwards, commitments to fund the M74 extension appeared in national policy including the Executive's programme for government (2001) [382] and the report *Scotland's transport: delivering improvements* (2002). [383]

Other significant themes in national transport policy

The Executive’s planning guidance *SPP 17: planning for transport* (2005) sets out the general policy objective ‘to support sustainable economic development within a pattern of land use and integrated transport which serves the economy and communities, promotes genuine choice of transport mode, facilitates a reduction in car use, and supports more use of walking, cycling and public transport.’ [384] Similar aspirations are reflected in local plans — such as that for Rutherglen and Cambuslang, which lie in the M74 corridor [381] — and in two other more specific national policy commitments: a commitment made in 2002 to strive to stabilise road traffic at 2001 levels by 2021, [385] and a commitment made in 2003 to devote 70% of all transport expenditure to public transport by 2006. [386]

6.3.2 Details of the project

The M74 currently ends at Fullarton Road junction on the south-east edge of Glasgow. The proposed northern extension of the M74 involves constructing five miles (eight kilometres) of new motorway to join the M8 at the southern end of the Kingston Bridge, close to the city centre (Figure 6). [387] The main purpose is to improve motorway access to south-east Glasgow and provide a more direct route for through traffic, which currently uses the most congested section of the M8 through the city centre. The new section of motorway is to carry three lanes of traffic in each direction and is to include two new intermediate junctions. Most of the new motorway is to run close to the route of the main west coast railway line from Glasgow to London, and most is to run through what has been described as a 'heavily urbanised area' [381] elevated on embankments, bridges or viaducts, although one section is to run in a cutting.

Owing to the number of objections lodged by residents and businesses close to the proposed route, a public local inquiry into the proposal was held from December 2003 to March 2004. In March 2005, the Scottish Executive published the inquirers' report, which recommended against the project, [381] and simultaneously announced the final ministerial decision, which was to proceed with the project on the grounds that the inquirers had understated the potential benefits. [388] Construction was intended to begin in 2006 and last for three years; the official estimate of the likely cost was £500 million.

6.3.3 Claims made about likely effects

The public local inquiry heard numerous claims about the likely effects of the project, many of which related to the health, wellbeing or quality of life of local residents and of the population of the region and of Scotland as a whole. The most important of these claims are summarised in Table 40, which is based on the Executive's case for the project [387] and on the inquirers' synthesis of the cases made by the various objectors to the project. [381]

Domain	Claims made in favour of the intervention*	Claims made against the intervention*
Economic	Will create up to 20,000 jobs by enabling regeneration and encouraging inward investment Will increase business competitiveness by improving just-in-time delivery times Will create 350 jobs during construction	Will redistribute economic activity from other parts of Scotland rather than producing a net increase Will displace 100 local businesses
Traffic	Will reduce journey times, relieve congestion on existing motorways and main roads, and reduce traffic on local roads	Will increase traffic in general and on feeder roads in particular
Injuries	Will reduce accidents	
Active travel	Quieter local roads will lead to improved conditions for pedestrians, cyclists and public transport	Will encourage use of motor vehicles Local walking and cycling journeys will be made more difficult by having to cross new motorway junctions
Environmental	Noise and air pollution will be reduced on balance throughout the area Will produce minimal severance effects because much of the route follows an existing main line railway Chromium-contaminated land will be handled safely during construction	Moderate-to-major increases in noise are predicted at some sites Nitrogen dioxide concentrations will be increased within 100 metres of the route Very severe combined impacts predicted in four residential areas close to the route Chromium will be dispersed from contaminated land into the air or river during construction Contradicts stated overall sustainability objectives of transport policy
Social justice	Will improve quality of life in local communities Will result in better employment opportunities for local people	Unacceptable opportunity cost, e.g. the money could be used to fund improved public transport Will mostly benefit motorists from more distant and more affluent areas, causing adverse effects on local communities which have low levels of car ownership

* Summarised and adapted from the government's case for the project and the report of the public local inquiry. [381 387]

Table 40. Key claims made for and against building the new urban section of the M74 motorway

6.3.4 Critique

I was one of the co-authors of a systematic review of the health effects of new roads which had been published three months before the start of the public inquiry. [5] In this systematic review of 32 studies, we sought evidence of any health-related effect associated with the opening of new roads, but we only found evidence with respect to three types of effect: injuries, disturbance and community severance. We found some evidence that new out-of-town bypasses and new inter-urban roads were associated with decreases in the incidence of injuries to road users, but the balance of best available evidence about new major roads in urban areas suggested no overall effect on injury rates. We also found evidence that new major urban roads were associated with an increase in disturbance experienced by residents and in indices of community severance. We found no evidence about the effects of new roads on physical activity or social inequalities in health, and concluded that more rigorously-designed prospective studies were required to assess the size and social distribution of some of the wider health impacts of road-building projects. We offered summaries of our findings to the inquirers, to the trunk roads division of the Scottish Executive (the principal proponents of the M74 project) and to the leading objectors participating in the public local inquiry, but to our knowledge the evidence was not cited in the inquiry; it was certainly not mentioned in the report. [381]

My subsequent systematic review, reported in the first part of this thesis, did not identify any additional studies of the effects of building new roads on the distribution of mode choice between cars and active travel; indeed, the evidence that transport engineering interventions of any kind had resulted in a modal shift towards walking and cycling was very limited.

In the light of these findings, some of the claims made about the likely effects of the M74 project (Table 40) appeared open to question. The Executive laid particular emphasis on the projected reductions in casualties, but our systematic review had found no clear evidence from previous studies to support such a prediction. Similarly, the claims that the motorway would lead to overall improvements in noise and air pollution and in the quality of life of local residents appeared at odds with our finding that previous studies had found that local residents complained of increased disturbance.

Many, if not all, of the claims made in favour of the project were refuted by the inquirers, [381] sometimes on the basis of the Executive's own analyses such as the environmental impact assessment for the project. [389] An important theme often cited by objectors to the project, and which emerged in the inquirers' report, was the question of whether the project was compatible with the Executive's stated aspirations for social justice. Objectors noted that the neighbourhoods likely to experience 'very severe' combined adverse environmental impacts, such as noise and air pollution and visual intrusion, were relatively deprived, and argued that the residents of these neighbourhoods would bear the brunt of the adverse effects, while residents of more affluent and more distant areas would experience most of the benefits. The inquirers reached the same conclusion. [381]

6.4 Approaches to evaluation

6.4.1 A prime example of a natural experiment

The M74 project typifies what I referred to previously as a *natural experiment*, referring to the exposure of different populations to different conditions or interventions on account of the 'natural variation' resulting from policy decisions made outwith the control of researchers and not necessarily with any intention of evaluating their effects. Any attempt to 'evaluate the health effects' of this intervention would inevitably be complex for several reasons:

1. The path to implementation was an uncertain and unpredictable political process. The plans for the new motorway had wide political and business backing, but the public local inquiry recommended against the scheme. [381] The government overruled this advice, [388] but its apparently final decision to go ahead was then the subject of a legal challenge from a coalition representing residents' and environmental interests. This prolonged uncertainty complicated any aspiration to conduct longitudinal research based on collecting 'before' and 'after' data, because to do so required that I knew when to collect baseline data

and was able to do so. I therefore faced a dilemma: if I had waited until a definite start date for construction was announced, there may not then have been enough time to design a study, obtain ethical approval and collect baseline data; if I did plan ahead, I may have had difficulty obtaining funds or ethical approval to research an intervention which might never happen, and I would not know whether there was ever going to be a follow-up study.

2. No two major transport infrastructure projects are identical. The decision to build the motorway in this particular place was based on a consideration of the general economic needs of the region, which would not necessarily apply elsewhere, and the urban geography of the area and the way in which the new motorway was to be inserted into it were obviously unique. There is therefore no sense in which building a motorway in general, or this motorway in particular, constitutes a replicable intervention in the sense usually understood in public health intervention research. The uniqueness of the intervention also made it difficult to identify other areas which were sufficiently similar in terms of socioeconomic or spatial characteristics to act as credible control (comparison) areas.

3. It was also difficult to define exactly what the intervention consisted of or to distinguish its content from its context. For example, although the new motorway would have an apparently obvious start date — the day when traffic began to use it — it became clear that some of the claimed benefits would depend on local authorities taking subsequent, discretionary action such as installing traffic-calming features on local streets (Figure 7), while others would depend on private sector responses such as increased inward investment to the region. Other regeneration projects were also planned or under way in the area at the same time, notably the construction of the East End Regeneration Route (a new dual carriageway distributor road, to be completed first but intended to link with the new motorway) and the comprehensive redevelopment of Oatlands, a largely derelict area of housing close to one of the proposed new motorway junctions (Figure 8). In other words, there was no obvious way in which I could disentangle the effects of the motorway from those of a larger set of local and national policies and actions. It is not surprising, of course, that multiple interventions should be undertaken in deprived areas at the same time; this is an inevitable result of policies aimed at regenerating such areas. [376]

Figure 7. Main road in intervention area in 2005

Figure 8. Oatlands regeneration area in 2005

6.4.2 Need to focus the study

No single research study could conceivably examine effects across all the possible domains identified in the public discourse about the motorway (Table 40). In the face of such a wide range of putative effects, and the difficulties in designing and conducting a feasible study, it was essential to define clear boundaries for the study.

I established that I was aiming to conduct an empirical investigation of the actual effects, in practice, of the intervention on selected health-related outcomes. In doing so, I was defining my study as intervention research and not, for example, 'health impact assessment' as commonly understood. The term health impact assessment (HIA) has been used to mean different things in different contexts, but most HIA takes the form of a rapid appraisal of the likely effects of a proposal, undertaken with the tactical aim of modifying that proposal (sometimes referred to as 'predictive HIA'). [390 391]

Having said that, the literature on HIA did help to clarify an important feature of my proposed study, which was that I aimed to investigate the effects of the intervention on health outcomes after implementation, which Mindell and colleagues refer to as 'retrospective HIA', to distinguish it from 'evaluation' in the sense of monitoring the extent to which the proposal's stated objectives were achieved. [390] However, it would not have been feasible to conduct a retrospective HIA as defined by Mindell and colleagues because this would have involved assessing all possible health impacts. Rather, I envisaged my study as taking the opportunity provided by a particular natural experiment to address a specific gap in the evidence identified by my systematic review and other published literature cited previously. The research questions would be derived from the implicit and explicit claims made about certain effects of the intervention, but the study would not be intended formally to evaluate the 'success' of the project against its stated aims and objectives.

I therefore chose to focus on the comparatively under-researched question of effects on active travel and physical activity — whether directly, or via changes in the physical environment as suggested by the findings of the cross-sectional and ecological studies cited previously.

Because of the continuing uncertainties about the implementation of the intervention, I decided to frame the baseline phase of the planned longitudinal study as a cross-sectional study in its own right. This cross-sectional phase of the study would contribute original findings about the relationships between socioeconomic status, the physical environment, travel behaviour and physical activity, but it would also constitute a methodological demonstration of what sort of public health evidence could be collected for a longitudinal intervention study and provide the necessary baseline data. The study reported in this thesis comprises this initial, cross-sectional phase of the overall M74 study.

6.4.3 Conceptual model

Having decided on the focus and general remit of the study, I then developed a simple conceptual model to provide a framework for examining the putative causal relationships between the various health-related domains (Figure 9). More general logic models of the relationships between transport and physical activity have been proposed, for example by Killoran and colleagues, [73] but I needed a model more closely focused on the context and purpose of this particular intervention study. Having considered the findings of the public local inquiry, I concluded that the new motorway could be hypothesised to have positive effects, negative effects, or both in the local area. I articulated these hypothesised effects according to this model using vignettes of two alternative extreme cases. Although the vignettes are specific to the motorway, the conceptual model may, in principle, have more general applicability to other interventions which modify transport infrastructure or other elements of the built environment.

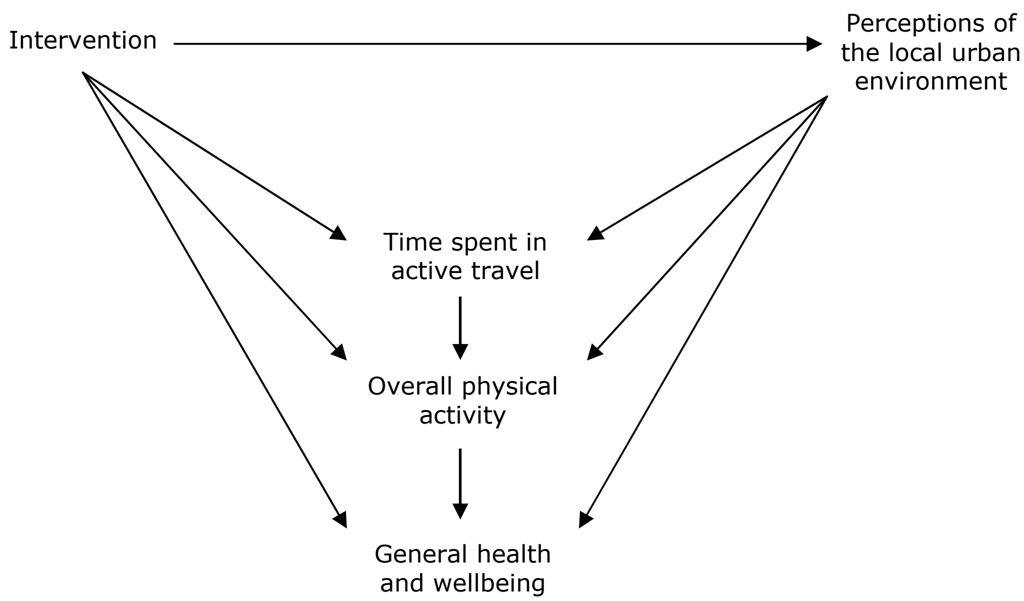


Figure 9. Simple conceptual model for the study

Vignette 1 — a virtuous spiral

The opening of the motorway encourages inward investment in the area, providing new local opportunities for work. Through traffic on local roads is reduced, which makes conditions more pleasant for pedestrians and cyclists and encourages people to spend more time out and about on local streets. Local businesses thrive and people perceive the local environment to have more positive attributes. Any noise or air pollution produced by the motorway is not noticed against the background of existing urban conditions. The wellbeing of local people and opportunities for physical activity both increase.

Vignette 2 — a vicious spiral

The opening of the motorway displaces some local businesses, whose employees now have to travel further to work, and gives easier access between the motorway network and the local area, which increases traffic on local roads and encourages local people to travel further and by car, not just for work but also for shopping and leisure. At the same time, the motorway and its junctions degrade the local environment, making conditions less pleasant or safe for people in their homes and for pedestrians and cyclists. The combination of fewer people out and about on local streets and the tendency to travel further afield to amenities leads to a decline in local shops and other amenities, which reinforces the decline in the attractiveness of the area and the car-bound exodus in search of alternatives. The wellbeing of local people and opportunities for physical activity both decline.

6.4.4 Framing the causal question to be addressed

Setting out to investigate the effects of an intervention implies examining and testing a putative causal relation between the intervention and the phenomena subsequently observed. However, it is not entirely obvious how one might frame this 'causal question' when researching the indirect effects of a complex and somewhat unique intervention on health.

The classical epidemiological approach to establishing causal relationships was outlined by Bradford Hill in 1965. [392] Bradford Hill proposed a series of 'viewpoints' from which one might assess the evidence for a causal relationship between exposure to a putative risk factor and a health outcome, including the strength of association, consistency of association, specificity of association and so on. These 'viewpoints' have subsequently often been described as 'criteria', as if they represented a checklist, but Bradford Hill explicitly distanced himself from the idea that his 'viewpoints' represented hard-and-fast rules of evidence or that any one of them could be considered either necessary or sufficient. [392] In a contemporary standard textbook of epidemiology, Rothman goes further, advising against the 'deceptive and mindless authority' of a checklist approach to causal inference and recommending instead an approach based on conjecture and refutation. [393]

The Bradford Hill criteria are useful as a guide to thinking about what sort of evidence it might be useful to seek, but they were proposed in the specific context of researching the health effects of exposure to occupational hazards, and are therefore more suited to the needs of aetiological epidemiology than to the needs of intervention research. Nonetheless, the approach currently being taken in most quantitative public health intervention studies (and in systematic reviews of those studies) is also — like that of classical aetiological epidemiology — cast in terms of producing evidence from which generalised causal inferences can be drawn. For intervention research, this approach is encapsulated in research questions such as 'What works in achieving X?', 'Is intervention X effective?' or 'Is intervention X more effective than intervention Y?'

This approach depends on several assumptions: first, that the intervention is intended to produce the outcome of interest (in other words, that the intervention is to be judged against whether it has 'worked', i.e. achieved its stated aims and objectives); second, that an intervention shown to be effective in one or more studies can be transferred and applied in other places; and third, that the effect size can be estimated in a way which can be generalised to those other places. However, none of these assumptions holds in the case of a study of the indirect health effects of a complex natural experiment. The intervention is being judged against criteria other than the primary aims of its instigators; the intervention is not a 'package' which could be applied in the same way anywhere else; and even if it could, the unique social and spatial context of this particular natural experiment make it unlikely that any claim could be made that the observed effect size would necessarily be replicated elsewhere.

Researching the indirect health effects of a natural experiment therefore requires a more nuanced or indirect approach to framing the causal question. I drew on an alternative, realist perspective in order to establish a meaningful approach in my own study.

Such a perspective recognises a need to move away from the assumptions of the experimental tradition that it is either possible or necessary to elucidate completely the causal conditions and mechanisms for a phenomenon in order to produce evidence that can be used to make generalised causal inferences. Matt has critiqued the assumption that reaching this 'holy grail' of causal explanation will ensure that 'we can recreate that phenomenon wherever and however its causal ingredients can be brought together'. [394] This critique, which draws on the approach of *critical realism*, has obvious face validity when attempting to research the effects of an intervention that is unique to its context and therefore not replicable in any obvious sense. Cook and Campbell, in their widely-cited work on designing experiments in the social sciences, make a distinction betwen probing and proving causal hypotheses, [395] a distinction reformulated in a later edition as that between causal description (quantifying observed effects) and causal explanation (investigating how effects might have occurred). [396] Berman has described the reality of causation in human societies as highly complex, suggesting that 'the best we can hope for is a gradual elucidation of causal connections which eventually may form a picture that is more or less recognizable'. [397]

One particular realist perspective is that of *realistic evaluation*, [167] which is related to the *realist synthesis* approach to systematic review referred to in Chapter 2. Realistic evaluation recognises that many social interventions take place in complex and changing social systems in which 'cause' and 'effect' are not discrete and in which the setting is as important as the intervention. Instead of asking if an initiative works or not (or comparing it to some other initiative), realistic evaluation seeks to understand why a programme works, for whom, in what circumstances, so that better policies can be developed in the future. [398] In outlining the rationale for adopting a realistic approach to the evaluation of one particular complex public health intervention, Health Action Zones in England, Judge describes a context which bears considerable similarity to that of this study:

> The fundamental problem is one of attribution. So many interacting factors impact on the programmes and activities that health action zones are undertaking that it is almost impossible to focus attention solely on the mechanisms or interventions of interest and to assume that contextual factors can be 'controlled for' in some way. New approaches to evaluation are required. [398]

Drawing on the simple conceptual model for the study and on these different perspectives and approaches to establishing evidence about the effects of an intervention, I returned to consider the putative causal chain under consideration in this study (Figure 9). I concluded that there would be both intuitive and theoretical difficulty in attributing any observed differences or effects to the intervention, and that I should therefore frame the causal question not so much in terms of testing a binary hypothesis, such as that the new motorway 'caused' or did not 'cause' a modal shift in travel patterns or an increase or decrease in levels of physical activity, but in more indirect terms inspired by a more 'realistic' perspective: under the conditions of the new motorway, is there any detectable change in travel behaviour, and if so, in which people, groups or areas does it occur, is it associated with a change in levels of physical activity or any other health-related measures, and how plausible is it that these effects are attributable to the intervention?

In order to do this, I felt it was important on the one hand to be circumspect about the quantity and strength of 'causal' evidence which could realistically be generated within a single study, but on the other hand not to dismiss the value of carefully-collected data obtained using a combination of the methods available. As Baum has argued, 'the relative crudeness of all the methods available to study public health mean we need as much methodological strength as possible', even where that requires researchers to embrace a pluralistic epistemological position which may be at odds with their own disciplinary background. [399] With respect to the problem of external validity and generalisability, described by Matt as the Achilles heel of any single intervention study, [394] Cook and Campbell note that no study is likely to be able to address all concerns about either internal or external validity, and in any case, external validity will depend more on replication, whether within one study or (more likely) between different studies; [395] this may sometimes be possible using formal methods of synthesising data across multiple heteregeneous studies, as Matt suggests, or at other times may depend on a less formal 'judicial review' of the best available evidence that can be found, along the lines discussed in Chapters 2 and 5. [109 130]

6.5 Data sources

In order to elucidate the nature and strength of the links in the putative causal chain (i.e. to populate the conceptual model for the study) it was necessary to consider the possible sources of data for the main constructs represented in that model: characteristics of the local environment, physical activity, travel behaviour, and general health or wellbeing. I did this first by investigating whether data could be obtained from existing sources, and then by exploring the options for collecting original data within the constraints of the available budget, which precluded the deployment of fieldworkers to conduct face-to-face interviews with a large sample of respondents.

6.5.1 Existing sources of routinely-collected data

Local environment

The main source of routinely-collected data on perceptions of the local environment in Scotland is the Scottish Household Survey (SHS). SHS is a continuous cross-sectional interview survey intended to provide a nationally representative sample of private households, with an achieved national sample of around 15,000 households each year. [400] One year's data are said to provide a representative sample for each of the larger local authority areas. In this survey, a randomly-selected adult in each sampled household is asked a series of items on neighbourhoods and community safety, including a four-point overall rating scale for their neighbourhood, lists of aspects they may like and dislike about their neighbourhood, and a rating scale for how safe they feel walking alone in their neighbourhood after dark. Most of the environmental characteristics of interest are only assessed using binary variables (yes or no), the validity and reliability of the items are unknown, and the level of spatial resolution is limited because respondents are not geocoded below the level of postcode sector. Neither SHS nor any other routine dataset in Scotland includes the collection of 'objective' local environmental data by observers.

Physical activity and health

The main source of routinely-collected data on physical activity and health in Scotland is the Scottish Health Survey, which is a cross-sectional interview survey conducted in discrete waves several years apart (the most recent waves were in 1998 and 2003). [14] It is intended to provide a nationally representative sample of adults and children, with achieved national sample sizes in 2003 of approximately 8000 adults and 3300 children. The sample is not designed or claimed to be representative at sub-national administrative levels such as local authority or NHS board areas, except in the case of the Greater Glasgow NHS board area. The survey includes a large number of items on self-reported health, illness and health-related behaviour, including self-reported frequency, duration and intensity of physical activity over the previous four weeks. It does not contain any items on travel behaviour.

An alternative source of data on physical activity is the Health Education Population Survey (HEPS), a survey conducted twice each year in most years since 1996 with a typical combined annual national sample size of approximately 1800 adults. [401] HEPS includes one item specifically about walking as well as items on the frequency, duration and intensity of participation in a list of other activities in a typical week.

The Scottish Household Survey (SHS) includes no items on physical activity. It does include a small number of items on health: these are restricted to asking about the presence of longstanding illness, health problem or disability, and if these are present, what they are and how the respondent's activities are restricted. [400] Other sources of routinely-collected health data in Scotland, such as the Scottish Morbidity Record (SMR) dataset of contacts with hospital services and the Practice Team Information (PTI) dataset of contacts with primary health care, depend on contact with services in connection with a presenting problem, diagnosis or procedure. They do not include data on physical activity. [402 403]

In summary, the survey with the most comprehensive data on physical activity (the Scottish Health Survey) had too limited a spatial resolution and too infrequent a sampling frequency for my purposes. The alternative, HEPS, had a considerably smaller sample size than the Scottish Health Survey; this ruled it out as a useful data source, despite its more frequent sampling and the inclusion of a specific item on walking.

Travel behaviour

There are three sources of routinely-collected data on travel behaviour in Scotland: the census, the Scottish Household Survey and the National Travel Survey.

The census includes an item asking for people's main mode of travel to work or school. [377] Although the census has the advantage of almost complete coverage of the population, the interval between census time points (ten years) is too long to be of use in measuring change attributable to interventions taking place over a shorter time scale, and as I argued in Chapter 5, a single item on main mode of travel to work or school appears inadequate as a means of understanding walking or cycling as part of multi-modal journeys or for other journey purposes.

The Scottish Household Survey (SHS) is by far the most comprehensive source of data on travel behaviour specific to Scotland. The data collected from adults include their usual main mode of travel to work or education, reasons for that choice, and any change over the past year; their frequency of walking and cycling in the previous week; and (where applicable) their children's usual main mode of travel to school, with reasons. Respondents are also asked to complete a detailed one-day travel diary which records all personal journeys made on public roads in order to reach a destination. Journeys or stages of journeys of less then a quarter of a mile, those made on foot and lasting less than five minutes, those made off public roads, those made outside the UK, and those made by drivers or crew of vehicles in the course of work are all excluded. [404]

The UK National Travel Survey (NTS) is also a cross-sectional household interview survey. Its advantages over SHS are that it includes a detailed seven-day travel diary and it is considered more sensitive for capturing walking trips than SHS: on six of the seven diary days, walking trips are only included if they are a mile or more, but on the seventh day all walks of any length are included. [405] However, only about 900 households in the whole of Scotland are sampled each year.

In summary, the 'survey' with the largest sample size and finest spatial resolution (the census) had the least comprehensive and useful travel data, whereas the most comprehensive travel data (those collected in NTS) were collected from too few people. SHS therefore offered a compromise which could be used to examine travel behaviour at an intermediate level of spatial resolution, that is at regional rather than local level. In addition, both SHS and NTS provided a useful source of instruments for collecting data on travel behaviour.

6.5.2 Collecting original data

Local environment

It was not feasible to contemplate collecting 'objective' data on environmental characteristics in this study because funds were not available to employ the fieldworkers needed to go out and make observations in many different locations in the study area.

I therefore chose to focus on subjective measures ('perceptions') of environmental characteristics. It seemed important that the items used should measure constructs shown to be related to physical activity in general or walking in particular and that could reasonably be expected to change as a result of the intervention; that they should have face validity in the local context; and that they should be suitable for completion as part of a postal survey.

From the literature on environmental correlates of physical activity reviewed in more detail in Chapter 1 and summarised by Humpel and colleagues [44] and Owen and colleagues, [20] I identified seven constructs that met these criteria: an aesthetically pleasing environment, convenient facilities for being active, the availability of green space, local access to amenities and services, disturbance from traffic, road safety and personal safety.

Comparatively little work has yet been done to produce valid and reliable measures of subjective environmental characteristics, [20] and I found that those instruments which have been shown to be valid and reliable proved unsuitable on other grounds. Validated instruments typically include items on non-modifiable characteristics which could not conceivably change as a result of the intervention, such as the scale used by Humpel and colleagues which includes one item on hilliness and four items on weather; [53] or refer to irrelevant features or use inappropriate language for the urban setting in Glasgow, such as the Neighbourhood Environment Walkability Scale (NEWS) which is written in American English and asks about the presence of sidewalks [406] or the scale used by Humpel and colleagues which asks whether there is a lake or beach within walking distance; [53] or are too long for inclusion as only one part of a longer postal survey, such as NEWS which contains 83 items over seven pages. [406] I therefore decided to design and pilot my own short, bespoke instrument based on the seven constructs identified from published work rather than committing myself to an existing scale, and also to establish the test–retest reliability of the items on the new neighbourhood scale, i.e the consistency of responses elicited from the same respondents at two points in time.

Physical activity

I was interested in measuring physical activity in this study for several reasons: to detect changes in physical activity related to active travel, but also to investigate how the effects of the intervention varied according to baseline levels of physical activity (in other words, whether sedentary groups were more or less likely to be affected), and to investigate the cross-sectional relationship between active travel and overall physical activity.

'Objective' measures of physical activity, using devices such as pedometers or accelerometers, have greater criterion validity with reference to a 'gold standard' measure of energy expenditure than self-reported measures, but a questionnaire is typically the only feasible method of studying physical activity in large-scale population studies. [407 408] Methodological reviews of physical activity questionnaires have concluded that existing questionnaires lack sufficient criterion validity for estimating absolute quantities of energy expenditure, but are adequate for categorising respondents into 'accurate but simple' levels of physical activity and monitoring changes in physical activity at a population level. In contrast to the measurement of subjective environmental characteristics, researchers wishing to measure physical activity using questionnaires have been advised not to develop new instruments unless they offer substantial improvements on existing instruments. [408 409]

International Physical Activity Questionnaire (IPAQ)

Until recently, physical activity questionnaires tended to focus on 'traditional' leisure time physical activities such as sports, often with an emphasis on vigorous physical activity, and were less able to capture physical activity in other contexts such as transport. The recent development of the International Physical

Activity Questionnaire (IPAQ), [410] which includes items on walking and sitting, exemplifies a growing recognition that it may be important to capture physical activity in as many domains of life as possible and at comparatively low levels of energy expenditure in order to detect changes in sedentary groups. Prompting respondents to recall physical activity across a wider range of domains of life does lead, unsurprisingly, to higher absolute estimates of energy expenditure than less inclusive questionnaires, particularly if responses are not probed by an interviewer for accuracy. [411] However, IPAQ has been shown in an international study to have criterion validity and test–retest reliability at least as good as other physical activity questionnaires. [412] IPAQ has been produced in both short and long forms; although the long form (five pages) is the version recommended for research, and contains some specific items on transport-related physical activity, the short form (two pages) obviously requires less effort on the part of the respondent and has been shown to have comparable criterion validity and test–retest reliability with the long form; some centres which participated in the validity and reliability study reported a preference for the short form. [410 412]

Effect sizes and sample size

According to the conceptual model for this study, levels of active travel could increase or decrease as a result of the intervention. In their review of environmental correlates referred to in Chapter 1, Saelens and colleagues found that the mean difference in walking for transport between 'high-walkable' and 'low-walkable' neighbourhoods was about 15-30 minutes per week. [47] In the systematic review, I found two studies which both reported a statistically significant positive modal shift and quantified the mean increase in time spent in active travel: these were, in the study from Glasgow, an increase of 17 minutes per week among those who already walked to work some of the time and of 64 minutes per week among those who did not, [218] and in the study from Perth, an increase of three minutes' walking and one minute's cycling per day. [223] It would therefore appear unrealistic to anticipate a mean change in active travel across a study population of greater than about 15-30 minutes per week. However, in a recent population survey using IPAQ in a UK sample, the mean reported time spent walking was over 300 minutes per week, with a standard deviation of over 500 minutes. [413] To detect a change of 15-30 minutes against a baseline mean and standard deviation of this magnitude would require a very large sample size (sample size calculations are given in detail in Chapter 7). This suggests that attempting to detect a change in total walking time, let alone overall physical activity, and attribute this to the intervention would be unrealistic.

On the other hand, results from the National Travel Survey show that if only walking as part of a journey to reach a destination is considered, respondents report an average of 11 minutes per day walking out of a total of just under 60 minutes' total daily travel time. [414] This suggests that attempting to detect a change of two to four minutes per day in walking for transport as the primary outcome measure would be much more realistic.

Travel behaviour

The requirements for an instrument to measure travel behaviour in this study were that it should be easy to complete in a postal survey and able to capture walking and cycling trips. In contrast to the development of physical activity questionnaires, there is little evidence in the literature of formal studies of the validity or reliability of questionnaires on travel behaviour, and as I showed in the systematic review, the use of more 'objective' methods in assessing the effects of interventions has generally been confined to counting the flows of vehicles past monitoring stations as opposed to tracking the movements of people. Global positioning systems (GPS) now offer the potential to track movement and to validate self-reported travel behaviour, but it is no more feasible to use this technology in large-scale population studies than it is to use the 'objective' measures of physical activity such as accelerometers discussed above. An additional problem specific to the use of GPS is the loss of data caused by signal dropout, recognised as a particular problem in urban areas with high-rise buildings. [415]

I showed in my discussion of the systematic review (Chapter 5) that the questionnaire-based methods used to assess travel behaviour could be divided into three categories — non-specific assessment limited to somewhat imprecise questions, assessment of trips for specific purposes, and assessment of all types of trip — and that the best compromise between the richness and sensitivity to change of the data obtained and the burden placed on the respondent may lie in the use of a one-day travel diary. There is a general view within the field of travel behaviour research that more complex instruments such as activity-based or overall time-use surveys capture travel behaviour more comprehensively than trip-based methods, [416] but it is also recognised that in the face of declining response rates to surveys, it may be better to concentrate on collecting only those data which are needed to answer the particular research questions of a particular study. [417]

For the purposes of this study, therefore, with its focus on the physical activity and health dimensions of active travel, I decided that an instrument based on time spent travelling would be most appropriate to the aims of the research and would also be much less demanding than an activity or overall time-use survey to complete. I was not able to use the New-KONTIV design referred to in Chapter 5 because that instrument is not in the public domain. I therefore decided to adapt the travel diary used in the UK National Travel Survey (NTS), in preference to that used in the Scottish Household Survey (SHS) which is held to be less effective at capturing walking trips.

Conclusions about measuring physical activity and travel behaviour

In summary, I decided that a change in travel behaviour (specifically, a change in the time spent in active travel) should be the primary outcome measure for the study, and that a measure of overall physical activity should be used both as a stratifying variable in analysis and as a secondary, more exploratory outcome measure. In the absence of a single best choice self-completion travel diary identified from existing published research, I decided to adapt and simplify an instrument from the diary used in the major UK survey in this field, the National Travel Survey. I recognised the limitations of measuring self-reported physical activity, but noted that the short-form IPAQ (the product of an international commitee of experts in measuring physical activity) has been shown to have test–retest reliability and criterion validity at least as good as those of other self-report instruments and is considered validated for use in people aged between 15 and 69. Although doubts remain about the accuracy of the absolute quantities of physical activity reported using instruments of this kind, IPAQ is sufficient as a means of categorising respondents by level of physical activity.

Health and wellbeing

Before considering how best to measure health and wellbeing in this study, it was necessary to clarify the position of these concepts in the framing of the research. I hypothesised that health or wellbeing might be influenced by the intervention, whether directly or indirectly — as a result of changes in people's perceptions of the local environment (for example because people experienced a change in disturbance from traffic), changes in travel behaviour or physical activity, or both. However, I did not see changes in health or wellbeing as an appropriate primary outcome measure, and I considered that the likelihood of detecting changes that could confidently be attributed to the intervention was low without using an extensive instrument, which would have been incompatible with a desire to minimise burden on the respondents; I considered it inappropriate to allocate a significant proportion of a postal questionnaire to the domain of effects in which I was least likely to detect changes.

I therefore decided to use an instrument whose validity and familiarity were well-established and which would be easy to complete. Many instruments for measuring overall 'health' or 'health-related quality of life' have been developed, mainly for use in clinical settings. For the purposes of this study, an instrument capable of measuring a less clinical construct such as 'wellbeing' would have been preferable. The concept of wellbeing comprises different components or facets which have been classified into categories, for example physical, psychological and social wellbeing [418] or subjective, psychological and objective wellbeing. [419] Despite increasing interest in the concept of wellbeing in public health, however, a recent literature review has concluded that the idea lacks a clear conceptual base and found little consensus about how wellbeing may be identified or measured. [418] A review of potential indicators of wellbeing for use in Scotland also found no accepted, universally used definition of wellbeing. [420] In the absence of a clear choice of overall measure of wellbeing, I therefore reverted to the subset of health-related quality of life scales which have been used in many different clinical populations and have established validity and reliability, albeit for measuring a somewhat restricted concept of 'wellbeing'. Of these, the Short Form 36 (SF-36) and its derivatives have a particularly wide international acceptance and established history of application. [421] I decided to use the SF-8 measure, which is short (eight items) and is validated and calibrated against the long-established SF-36. [422] Although this was not an entirely satisfactory measure of wellbeing for use in this context, since the study was not designed to detect a change in wellbeing as the primary outcome of interest it was beyond the scope of the study to develop a new and more suitable measure.

6.6 Conclusions

There is a need for methodologically flexible, empirical studies of the effects of natural experiments in public policy on health, health-related behaviour and their determinants.

The M74 project in Glasgow is one such natural experiment: an example of the type of intervention whose effects on health and health-related behaviour are poorly understood and about which rhetoric on both sides of the argument runs ahead of the empirical evidence.

Although a certain amount of relevant data were available from routinely-collected datasets such as the Scottish Household Survey, a specially-conducted survey was needed to investigate hypothesised changes (whether beneficial or deleterious) in perceptions of the local environment, travel behaviour, physical activity and general health or wellbeing.

The causal question for this study required to be framed not in terms of testing a binary hypothesis, such as that the new motorway 'caused' or did not 'cause' a modal shift or an increase or decrease in levels of physical activity, but in more indirect terms: under the conditions of the new motorway, is there any detectable change in travel behaviour, and if so, in which people, groups or areas does it occur, is it associated with a change in levels of physical activity or any other health-related measures, and how plausible is it that these effects are attributable to the intervention?

6.7 Aims and objectives of the study

The *eventual* aim of the M74 study, which extends beyond the boundaries of the thesis, will be to assess the effects of a major area-based natural experiment in transport policy on population health and health-related behaviour by studying the nature, size and socio-spatial distribution of changes associated with the construction of the new urban section of the M74 motorway in Glasgow.

The **aims** of the cross-sectional phase of the study, which constitutes the second study within the boundaries of the thesis, were:

1. To develop, pilot and demonstrate methods for investigating the effects of a major area-based natural experiment in transport policy on perceptions of the local environment, travel behaviour, physical activity and general health

2. To examine the socio-spatial patterning of travel behaviour and physical activity in the study population

3. To inform the design of a follow-up longitudinal study.

The **objectives** of the M74 study were:

1. To collect cross-sectional (baseline) data at two spatial levels: at local level, by means of a specially-conducted postal survey, and at regional level, using an existing source of routinely-collected data

2. To pilot and establish the test–retest reliability of a new instrument for measuring perceptions of relevant characteristics of the local environment

3. To quantify aggregate travel behaviour, aggregate physical activity, and the contribution of active travel to overall physical activity in the study population

4. To test the following specific cross-sectional hypotheses:

- that levels of active travel and overall physical activity vary with demographic and socioeconomic characteristics, but not necessarily in the same way

- that these relationships may be partly explained by the perceived characteristics of the local environment in which people live and their proximity to motorway and major road infrastructure.

Shifting towards healthier transport?
From systematic review to primary research

Volume 2 of 2

David Bruce Ogilvie

MA MB BChir MPH MRCGP FFPH

Submitted for the degree of Doctor of Philosophy to the University of Glasgow

Medical Research Council Social and Public Health Sciences Unit

Division of Community Based Sciences

Faculty of Medicine

University of Glasgow

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7 M74 study: methods

7.1 Overview of this chapter

Chapter 6 concluded with a statement of the aims of the M74 study, expressed in terms of a series of specific research questions (objectives). In this chapter, I describe the methods used to address these research questions.

The cross-sectional phase of the M74 study comprised three linked components, each using different sources of data to examine phenomena at different spatial levels. However, this second part of the thesis is primarily intended as a demonstration or case study of the development and use of quantitative methods for this type of population-based intervention study rather than as a complete account of the entire M74 study. In this chapter, I therefore deal with the methods for the quantitative components of the cross-sectional phase of the M74 study, which I refer to as:

1. The local area study
2. The regional area study.

I also conducted a third, complementary, qualitative component which I refer to as the micro area study. I planned all three components as part of a longitudinal study design which would examine, in time, the changes associated with the introduction of the intervention. In this chapter, I begin with an overview of the design of the whole study, and outline the methodological links between the local and micro area studies, but the micro area (qualitative) study is beyond the scope of the thesis and the longitudinal element of the study will not become possible for several years.

The methods for the study were developed iteratively in the light of the results of the findings of the pilot study, the cleaning of the data from the main survey, and so on. At certain points, therefore, this chapter contains cross-references to relevant sections of the results chapter (Chapter 8) which may help to explain the methodological decisions taken.

7.2 Overall study design

As I explained in Chapter 6, the M74 study was intended to serve not only as an exploration and demonstration of methods for investigating the health effects of interventions in the transport sector, but also to constitute a cross-sectional study in its own right and to provide a baseline dataset for a longitudinal study which I aimed to complete in the future.

Also as I explained in Chapter 6, I hypothesised that the intervention in question, the M74 project, was likely to have effects over a wide area and that these effects were likely to be inequitably distributed. I therefore designed three linked studies which would examine effects at three different spatial levels, using a combination of quantitative and qualitative methods and a combination of routinely-collected and specially-collected data to 'zoom in' progressively from regional to extremely local effects. I took as a model for this approach the MRC West of Scotland Twenty-07 study. [423] Although Twenty-07 is not an intervention study, it is a cohort study which has given rise to many different cross-sectional and longitudinal analyses and therefore has certain similarities with this study. Twenty-07 combines a regional sample representing the Clydeside conurbation with 'locality samples' of residents in specific neighbourhoods chosen for their contrasting socioeconomic and environmental characteristics, and with 'focused studies' of sub-samples of respondents to investigate specific research questions.

7.2.1 Local area study

As I showed in Chapter 6, routinely-collected data are insufficient for examining changes in health-related behaviour and the urban environment at local level. Specifically, the Scottish Household Survey — the most comprehensive source of data on travel behaviour specific to Scotland — does not provide data on physical activity, and it does not provide representative samples of the population below the level of a whole local authority area.

I chose three areas of Glasgow for more detailed study:

1. A south (intervention) area, consisting of residential addresses selected on the basis of their proximity to the proposed route of the new motorway

2. An east (first control) area, consisting of residential addresses selected on the basis of their proximity to the routes of the existing M8 and M80 motorways

3. A north (second control) area, consisting of residential addresses selected on the basis of their proximity to the route of a quiet suburban railway line.

The two control areas were intended to provide complementary comparative data against which any changes observed within the intervention area over the course of the longitudinal study could be compared. The control areas had similar morphology and aggregate socioeconomic characteristics as the intervention area, included areas experiencing similar concurrent area-based interventions such as housing regeneration as were planned in the intervention area, and were expected to be exposed to the same secular trends in travel behaviour. However, the two control areas offered different comparisons with respect to motorway infrastructure: the first (east) control area would be defined by its proximity to longstanding motorway infrastructure, whereas the second (north) control area would be defined by the absence of motorway infrastructure.

I conducted a postal household survey in these areas, collecting data on socioeconomic status, general health and wellbeing, perceptions of the local environment, travel behaviour and physical activity. I used these data to test specific cross-sectional hypotheses about the relationships between these constructs and to inform the development of the future, longitudinal phase of the study.

7.2.2 Regional area study

As I explained in Chapter 6, the predicted effects of the intervention include changes in the travel behaviour of people throughout the west of Scotland and a reduction in the incidence of injuries from road traffic crashes (Table 40). I decided that the most efficient way to investigate these phenomena would be to use routinely-collected data. I used data from the Scottish Household Survey to examine the current socio-spatial patterning of travel behaviour in the region, giving an alternative perspective which could be compared with, and used to validate or challenge, the findings of the local area study.

7.2.3 Micro area study

The environmental impact assessment for the motorway identified a number of small residential areas where particular effects (both positive and negative) were predicted. [381] I invited respondents to the local area study who lived in these areas to participate in semi-structured qualitative interviews to explore their experiences of living there prior to the intervention, with particular reference to local travel and perceptions of the local environment. In time, analyses of these qualitative data will help to inform the design of the longitudinal study, for example by identifying those potential changes to the local environment which local residents consider most likely, most desirable, or most undesirable.

7.2.4 Relationship to the planned longitudinal study

I designed the **local area study** to consist, eventually, of parallel repeated cross-sectional surveys in the intervention and control areas intended to detect and compare aggregate changes in the three study areas. These were to be augmented by a more exploratory cohort (panel) study of those individuals who could still be traced at follow-up. The cohort study would be intended to detect and compare individual changes in the three study areas and to identify typologies of responses to the intervention, both among those still living in the area (who would therefore have been exposed to the full local effects of the intervention) and among those who had moved away. The cohort study would enable me to sample participants who typified the different responses for a further qualitative study, in which semi-structured qualitative interviews would be used to explore the reasons and mechanisms for the changes observed at individual level.

I planned to continue the **regional area study** by comparing changes in travel behaviour in areas affected by the motorway with general trends for the region and for Scotland as a whole. I also planned to carry out a retrospective interrupted time-series analysis of police crash data to identify changes in the incidence, severity and spatial distribution of crashes and injuries following the opening of the motorway.

I planned to continue the **micro area study** by re-interviewing the participants in the original qualitative interviews, and others now living in the micro study areas, to explore how the intervention had affected them personally and life in their local areas.

7.3 Local area study

7.3.1 Study areas

Provisional identification

I began by examining the geography of the urban 'corridor' through which the new motorway would pass (Figure 10). I decided that the population exposed to the intervention should be defined as people living close to the proposed route, but far enough away from the existing motorway infrastructure at either end of the route to be unaffected by its immediate adverse environmental effects (visual intrusion, noise and air pollution). As a first step, I identified five postcode sectors which met this spatial criterion and tabulated selected aggregate data for the populations of those postcode sectors based on the 2001 census (Table 41). [424]

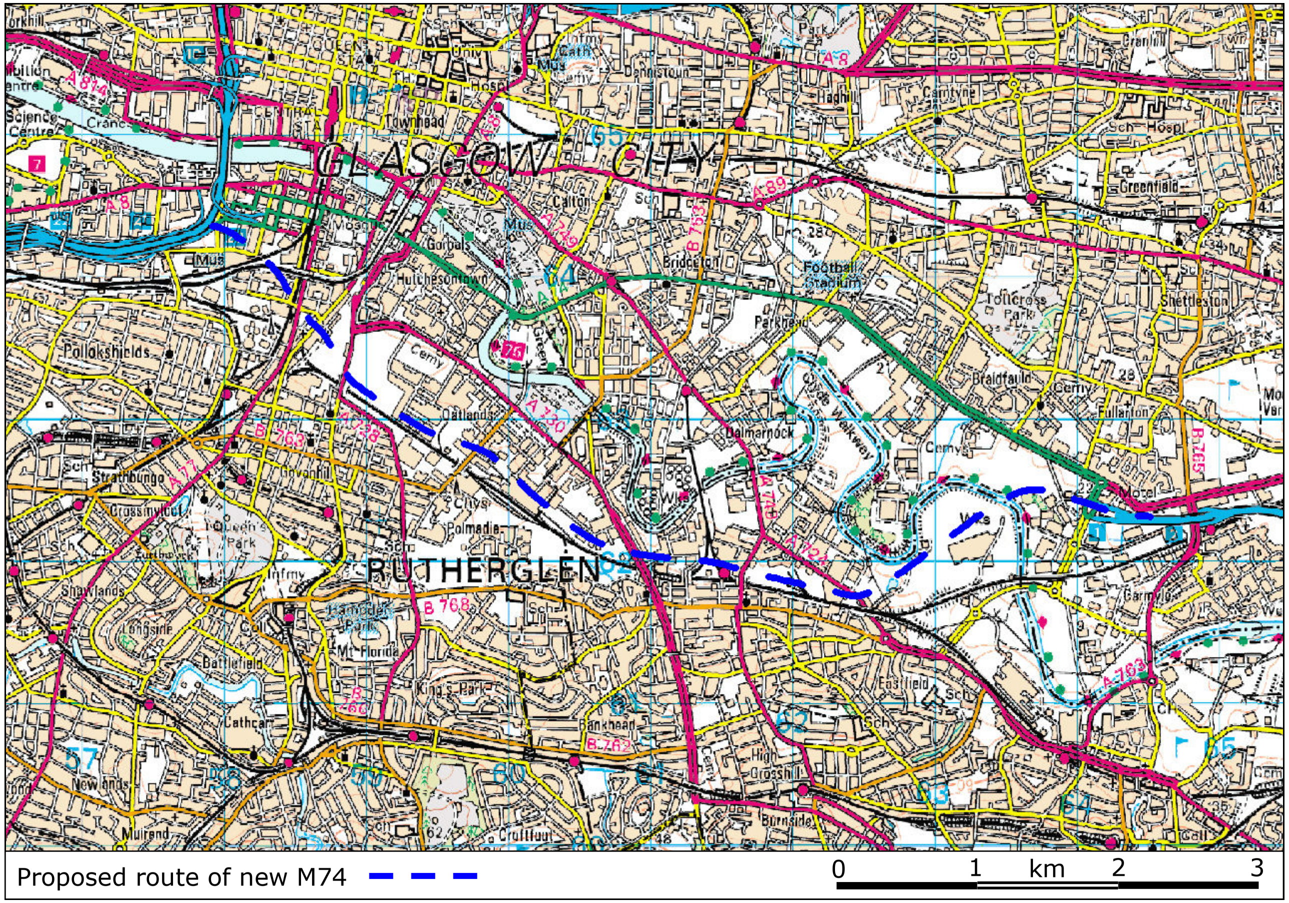


Figure 10. Proposed route of M74

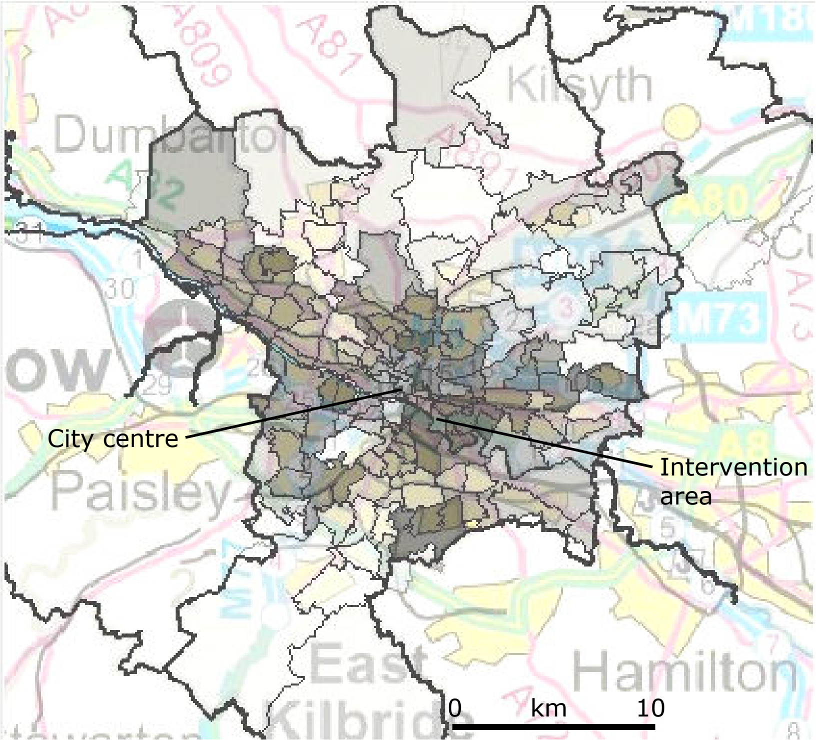
Sector	Area	Population	Households with no car	DEPCAT*
G5 0	Hutchesontown and Oatlands	5771	69%	7
G5 9	Eglinton and Laurieston	2415	76%	7
G42 0	Polmadie and Toryglen	5365	63%	7
G42 7	Govanhill	4687	61%	7
G73 1	North Rutherglen	3902	52%	6

* Carstairs deprivation category
All data derived from 2001 census [424]

Table 41. Postcode sectors used in provisional identification of intervention area

The Carstairs deprivation category (DEPCAT) is a seven-point ordinal scale based on a score calculated for each postcode sector from four indicators of deprivation: male unemployment, overcrowding, lack of access to a car, and low social class. [425] The table shows that the population living in the intervention area (crudely defined) were relatively deprived, with all postcode sectors being in the two most deprived categories (DEPCATs 6 and 7). There was a low level of car ownership overall, but considerable variation in aggregate car ownership between sectors.

I decided to focus on household car ownership as a variable which was associated with both socioeconomic status and travel behaviour. Using the service provided by Scotland's Census Results Online (http://www.scrol.gov.uk), I produced a thematic map of car ownership reported in the 2001 census for all postcode sectors in Greater Glasgow and used this to identify those parts of the conurbation in which I was likely to find suitable control areas (Figure 11). It was apparent that the north and east of the city contained areas at a similar distance from the city centre and with similar aggregate levels of car ownership, including (in the east) areas close to the existing M8 and M80 motorways (Table 42).



Postcode sectors shaded by decile of proportion of households with no access to a car (darker shading indicates lower prevalence of access to a car)
Source: Scotland's Census Results Online (http://www.scrol.gov.uk)

Figure 11. Households with no access to a car

Sector	Area	Population	Households with no car	DEPCAT*
East				
G20 0	North Maryhill	7355	52%	6
G20 9	Ruchill	3267	66%	7
G22 5	Firhill and Hamiltonhill	5312	76%	7
G22 6	Parkhouse and Possil	6049	63%	7
North				
G21 2	Roystonhill and Blochairn	5822	71%	7
G31 2	Dennistoun	6723	52%	6
G31 3	Haghill and Alexandra Park	5827	67%	7
G4 0	Cowcaddens and Townhead	7082	74%	7

* Carstairs deprivation category
All data derived from 2001 census [424]

Table 42. Postcode sectors used in provisional identification of control areas

Final definitions

The provisional identification using postcode sectors showed that broadly-similar control areas did exist elsewhere in the city, but using the arbitrary administrative boundaries of such large spatial units (postcode sectors) would have produced study areas whose boundaries bore little relation to the routes of the proposed and existing motorways or, in some cases, to the limits of natural communities. I therefore refined the definitions of the study areas using a geographical information system (GIS) — a computer system capable of capturing, storing, analysing and displaying geographically referenced information. [426] Using MapInfo GIS software, I delineated the routes of the proposed new motorway and of the existing motorways in Glasgow. I then constructed buffers of various sizes up to 1000 metres around the route of the new motorway and considered the relationship between these arbitrarily-sized buffers and the urban geography. Following a field visit, I concluded that a 500 metre buffer would produce the most meaningful inclusion zone for the intervention area — including all the neighbourhoods likely to be directly affected by the motorway, while more-or-less excluding the residents of more affluent suburbs. I noted that the River Clyde formed an obvious barrier along the northern edge, and decided to exclude the small and largely non-residential zones which lay north of the river but within the 500 metre buffer on the grounds that these were physically severed from the rest of the intervention area and did not form part of the same natural community.

In order to match intervention and control areas on aggregate socioeconomic characteristics, I decided to define the intervention area in terms of census output areas, the smallest spatial unit for which aggregate census data are available. The intervention area was therefore defined as those census output areas lying wholly or partly within a 500 metre buffer around the proposed route of the M74 motorway and not lying wholly or partly within a 500 metre buffer around any existing motorway.

I then selected a number of census variables on which I wished to match intervention and control areas, extracted the relevant data from Census Area Statistics on the Web (http://census.ac.uk/casweb) and calculated aggregate values for those variables for the output areas included in the intervention area.

I then constructed analogous 500 metre buffers around the routes of major arterial roads, railways and canals in Glasgow, used these buffers to define a variety of potential boundaries for the control areas, carried out field visits to ascertain the general characteristics of the built environment in those areas, calculated aggregate socioeconomic characteristics for each potential control area, and proceeded through an iterative process of refining boundaries and recalculating aggregate statistics. For example, in the process of defining the north control area one of the interim solutions I considered was based on a 500 metre buffer around the canal network (interim solution A in Figure 12). Compared with the intervention area, this area was characterised by an over-representation of higher social groups and an under-representation of owner-occupiers and people travelling to work by car or van, which reflected the inclusion of the area around the River Kelvin favoured by young professionals commuting to the city centre. (Table 43). I also considered another interim solution based on a 500 metre buffer around the railway network which included the Bishopbriggs area (interim solution B in Figure 12). Compared with the intervention area, this area was characterised by an over-representation of owner-occupiers and people who had access to cars and used them to travel to work, which reflected the inclusion of a more affluent suburb (Table 43). However, this interim solution matched the intervention area closely on other indicators, and by progressively restricting the north-eastern boundary and recalculating the aggregate statistics I was able to reach the final solution shown in Figure 12, i.e. a control area which had broadly similar spatial and morphological characteristics to those of the intervention area and matched as closely as possible on the selected socioeconomic indicators (Table 43).

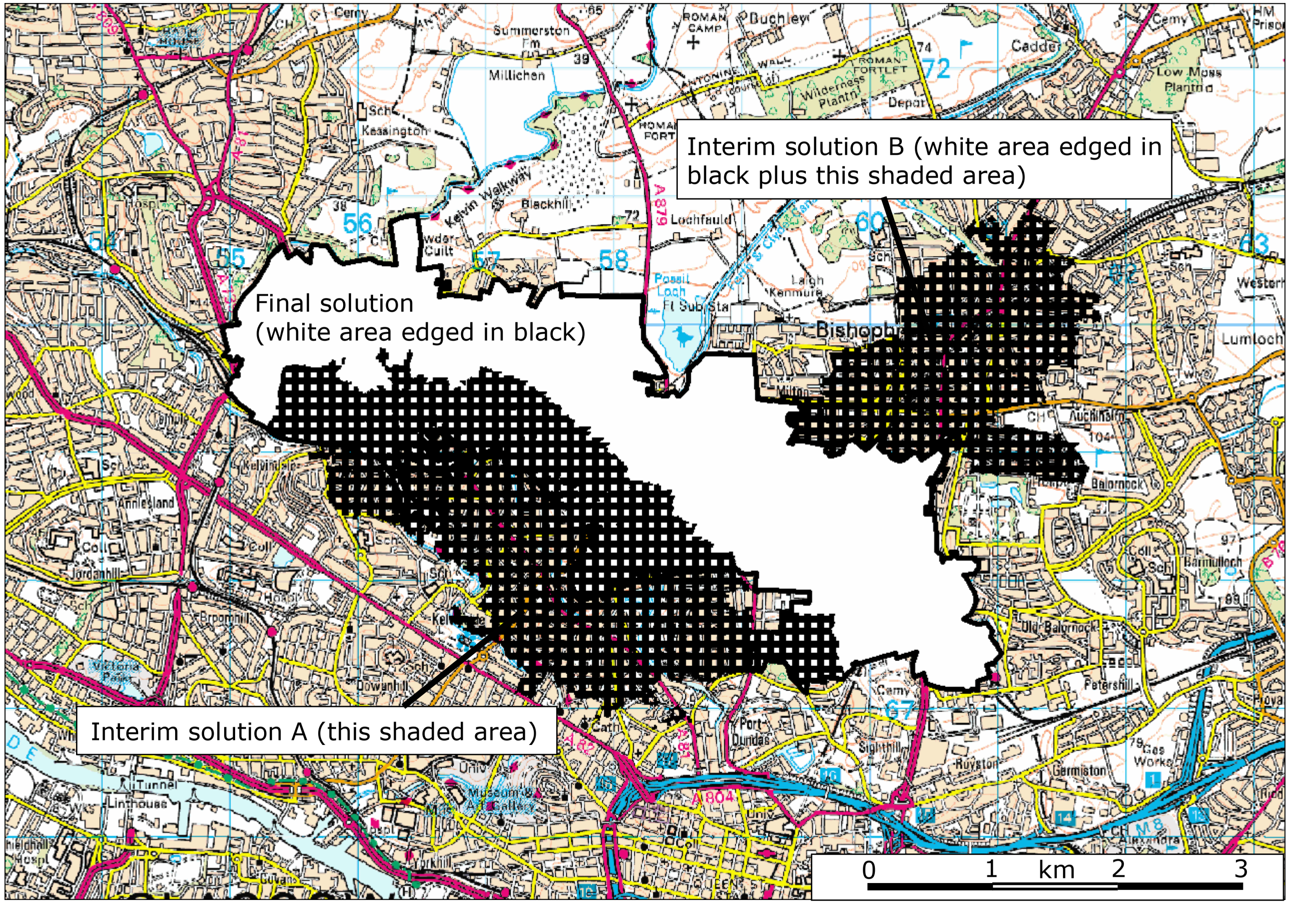


Figure 12. Examples of interim steps in defining north control area

Study area	South	East	North		
			A	B	Final
Households (number)	10059	12227	14691	20080	11808
Owner-occupiers*	38%	39%	32%	41%	38%
No access to a car or van*	66%	66%	63%	60%	64%
Limiting long term illness†	28%	27%	23%	25%	27%
Male unemployment‡	9%	10%	9%	8%	9%
Top three NS-SEC categories§	15%	12%	21%	16%	14%
Usually travelling to work by car¶	45%	44%	36%	49%	45%

'A', 'B' and 'Final' represent the two interim solutions for the north control area described in the text and the final chosen solution respectively. NS-SEC: National Statistics Socio-economic Classification
* Denominator: households
† Denominator: 'working age' population (men aged 16-64 and women aged 16-59)
‡ Denominator: men aged 16-74
§ Denominator: population aged 16-74
¶ Denominator: population who travel to place of work or study
All data derived from 2001 census [424]

Table 43. Aggregate socioeconomic characteristics of final study areas

The east (first control) area was finally defined as a set of census output areas lying wholly or partly within a 500 metre buffer around the routes of the M8 and M80 motorways between Glasgow Royal Infirmary and Ruchazie (on the M8) and Barmulloch (on the M80) (Figure 13, Figure 14). The north (second control) area was finally defined as a set of census output areas lying wholly or partly within a 500 metre buffer around the route of the railway between Cowlairs and Maryhill and not lying wholly or partly within a 500 metre buffer around any existing motorway (Figure 13). The section of railway in question mostly carries local stopping passenger services at 30-minute intervals and is therefore comparatively quiet The intervention and control areas all extend from inner mixed-use districts close to the city centre (e.g. Eglinton, Dennistoun and Firhill) to residential suburbs; all contain major arterial roads other than motorways (e.g. Pollokshaws Road, Alexandra Parade and Garscube Road), and all contain a mixture of housing stock including traditional high-density tenements (e.g. in Govanhill, Dennistoun and Maryhill), high-rise flats (e.g. in Toryglen, Barmulloch and Maryhill), and newer social housing (e.g. in the Gorbals, Roystonhill and Ruchill) (Figure 15).

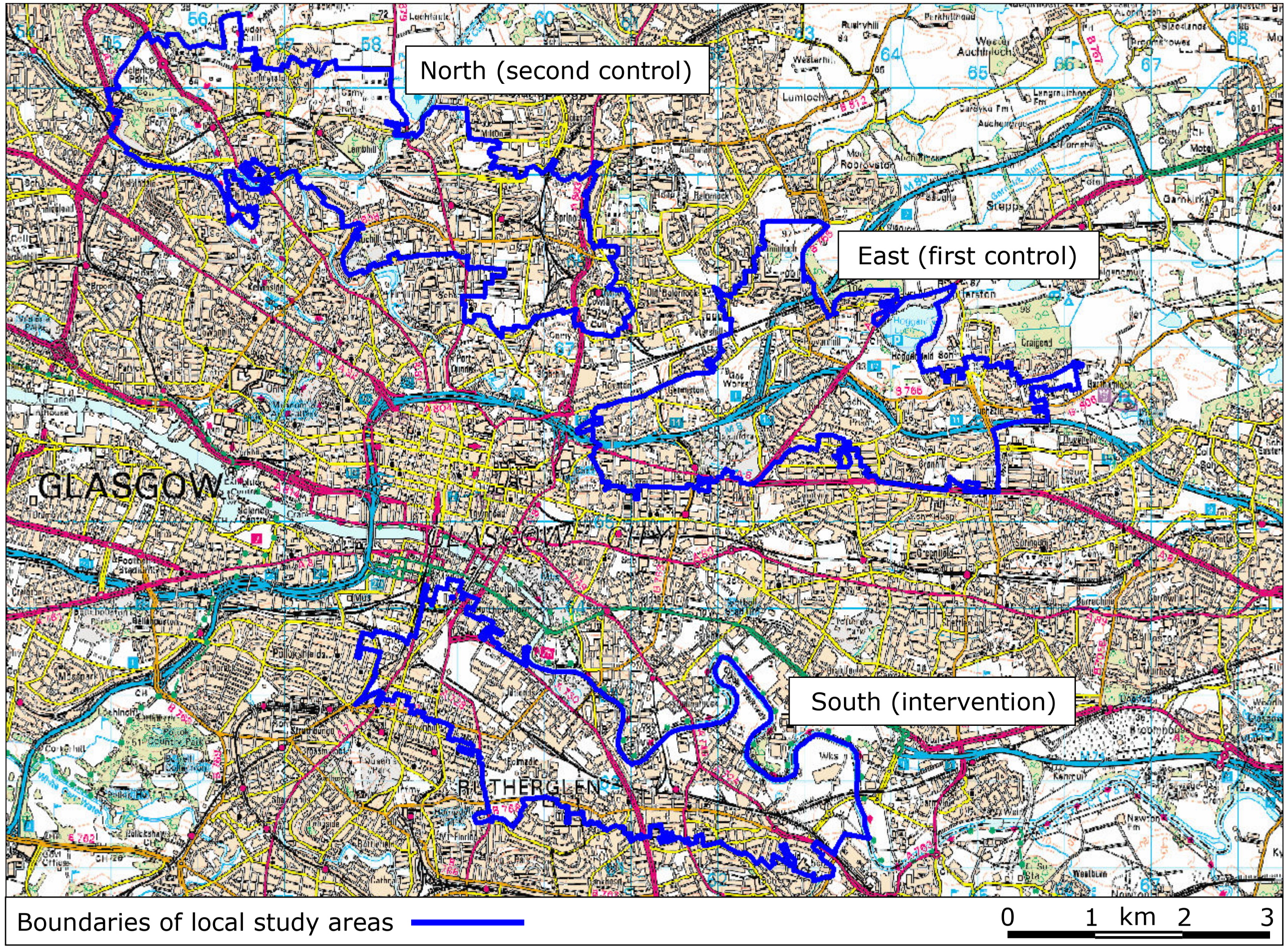


Figure 13. Boundaries of local study areas defined in terms of census output areas

Figure 14. Scene from east control area in 2005

Figure 15. Example of housing in intervention area in 2005

7.3.2 Pilot survey

I carried out a small survey of both an external (general population) sample and an internal (staff and student) sample to pilot the acceptability of my proposed survey methods and draft questionnaire and the test–retest reliability of the neighbourhood scale.

For the external (general population) sample, I identified a separate area of Glasgow, situated close to the M8 motorway and having similar aggregate socioeconomic characteristics to, but not lying adjacent to, the proposed study areas for the main survey. I then randomly selected from the Postcode Address File (PAF) (see Section 7.3.4) 200 residential delivery points (residential addresses) with postcodes beginning G51 3, G51 4A, G51 4D, G51 4N, G51 4Q, G51 4R or G51 4U, which corresponded to an area bounded by the River Clyde to the north and the M8 to the south, and extending from the Southern General Hospital in the west to Govan Cross in the east. Questionnaires addressed to 'The Householder' were sent on 7 July 2005 to these households, followed on 22 July by a reminder postcard to all non-responding households. The postcard included a free telephone number by which the respondent could request a replacement survey pack.

Respondents were asked to complete the questionnaire and also invited to return an optional consent form to participate in a follow-up telephone interview. As an incentive, respondents who consented to follow-up were entered into a prize draw to win a £50 gift voucher of their choice. I carried out these interviews between seven and 18 days after the completion of the original questionnaire. The purpose of the interviews was to ask respondents to identify any problems with the questionnaire, to re-administer the neighbourhood scale in order to establish its test–retest reliability, and to probe their responses to the travel diary. For the latter (probing) purpose, I took as a model a telephone follow-up study to assess the validity of responses to IPAQ in a population prevalence survey in Belgium. [411]

For the internal sample, I invited staff and students in the MRC Social and Public Health Sciences Unit to complete the questionnaire, identify any problems with the questionnaire, and repeat the neighbourhood scale between seven and 14 days after the completion of the original questionnaire. Internal respondents did not receive any incentive to participate and returned all their data in writing.

In light of the findings of the pilot survey, for the main survey I altered the wording of one item in the neighbourhood scale (see Section 8.2.3) and took additional steps to improve the response rate (see Section 8.2.1).

7.3.3 Sample size estimation

My sample size estimation was based on the eventual longitudinal objective of detecting a change over time rather than on the needs of the initial cross-sectional phase of the study. In light of the considerable uncertainty surrounding the likely effect size and the likely response rate, I chose to limit the exercise to a simple estimate of the sample size required to detect a change in time spent in active travel within the intervention area, rather than attempting a highly complex calculation including adjustment for changes in the control areas and the effects of confounders.

As I showed in Chapter 6 (Section 6.5.2), the results of previous studies suggested that any increase in active travel observed in the population was unlikely to exceed about 2-4 minutes per day. The studies cited in Chapter 6 provided no data on the variance of the changes in time spent in active travel, but early work on IPAQ found that total reported time spent walking varied with a standard deviation approximately 1.5 times the mean value. [413] Respondents to the National Travel Survey, on which I based my travel diary instrument, report an average of 11 minutes' walking per day (plus negligible cycling) out of about one hour's total travel. [405] Assuming, therefore, that the standard deviation of the daily time spent in active travel might be approximately 1.5 times its mean value — say, around 17 minutes — then the sample size required to detect a mean change of three minutes of active travel between repeated cross-sectional survey waves in the intervention area would be 475 ($\alpha = 0.05$ (two-sided), $\beta = 0.20$). This sample size would also be sufficient to detect a change of nine percentage points in the proportion of respondents meeting any given categorical threshold of time spent in active travel (assuming the 'worst case' for such a sample size estimation, i.e. a baseline proportion of 50%). The sample size required to detect a mean change of two minutes would be 1069.

The execution of two waves of a postal survey of this size within a four week period posed a considerable logistical challenge for the unit's survey department. I hoped that with the benefit of a second (reminder) mailing, it might be possible to achieve a final response rate of between 15% and 30%. In negotiation with the survey department, it was agreed that — given the time constraints and the resources available — it would be feasible to survey 3000 households in each of the three study areas (9000 in total). Anticipating an achieved sample of between 450 and 900 in each study area, the repeated cross-sectional survey was therefore expected to have sufficient power to detect a change in the mean time spent in active travel of about two to three minutes per day.

7.3.4 Sampling of households for main survey

In order to sample from households in the study areas, I needed to define the study areas in terms of unit postcodes. A lookup table was available for the attribution of unit postcodes to the 2001 census output areas, but this table would not have included any new unit postcodes introduced or re-assigned since 2001 — for example, to cover new housing developments. I therefore wrote queries in MapInfo to identify all unit postcodes in the most recent version of the Ordnance Survey Code-Point dataset (June 2004) which lay within the geographical boundaries of the output areas used to define the study areas, including those unit postcodes contained within 'vertical streets' (tower blocks). I checked the results of the queries visually and deleted a small number of anomalous spatial outliers incorrectly identified by the query. Figure 16 shows the centroids of the unit postcodes from which households were sampled in the three study areas.

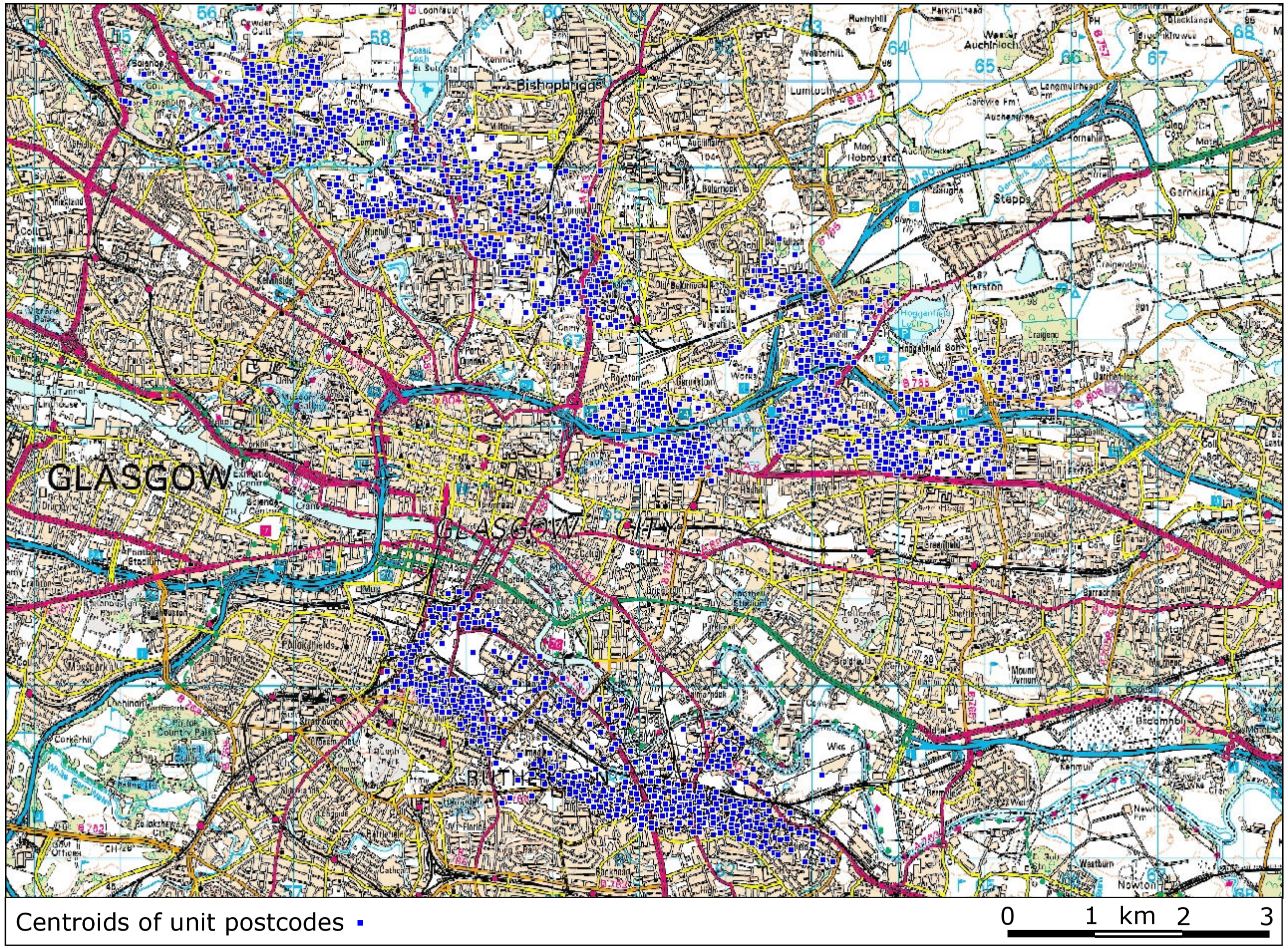


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Figure 16. Centroids of unit postcodes from which households were sampled

I obtained the most recent version of the Royal Mail Postcode Address File (PAF) (version 2005.3) and filtered the dataset to identify all residential 'delivery points' (individual residential addresses) whose unit postcode was within one of the three local study areas. The classification of delivery points in PAF as 'residential' or 'business' is known to contain inaccuracies, so I discarded a small number of delivery points (numbering 41, 12 and 79 respectively in the south, east and north study areas) whose address appeared unlikely to be residential, for example those containing terms such as 'Unit 6' or 'Industrial Estate', or addresses spanning more than one street number (e.g. 22-26) with no indication that the property was subdivided into flats. This left cleaned sampling frames consisting of the best available list of all residential addresses (households) in each study area (numbering 10222, 12656 and 12723 respectively in the south, east and north study areas).

Using the Statistical Package for the Social Sciences (SPSS 12) function *Select Cases: Random Sample*, I then drew a random sample of 3000 households from each area (representing a sampling fraction of between 0.24 and 0.29 in each area). These households were selected to receive the postal survey.

7.3.5 Administration of postal survey

I planned the timing of the survey to avoid the September weekend holiday (23-26 September) and school mid-term holidays (17-21 October) — both times at which local schools were closed, and families could have been expected to be away or not following their normal routines — but also to ensure that as much data collection as possible would be completed before the onset of winter.

Survey packs consisting of a covering letter, a questionnaire, an optional consent form by which respondents could agree to be approached for follow-up, and a prepaid return envelope were sent by second class post to all households in batches on four mailing days between 28 September and 4 October 2005 (Appendix 1). The mailing was staggered over several days to maximise the probability that questionnaires would be completed on different days of the week. Approximately equal numbers of packs were sent to each study area on each day, and households within each study area were sorted into random mailing order to ensure that the packs sent out on a given day would be received by households randomly distributed within their study area.

In an effort to improve the response rate over that obtained in the pilot survey, households were alerted to the imminent arrival of the survey by means of a postcard sent a few days in advance, some of the survey materials were printed on coloured paper, and the survey packs were posted in white envelopes printed with the university crest. I chose these methods because they have been shown in a meta-analysis to be associated with improved response rates to postal surveys. [427]

Householders were asked to ensure that the questionnaire was completed by an person aged 16 or over living at the sampled address; in the event that there was more than one resident eligible to participate, householders were asked to select the person with the most recent birthday. As an incentive, respondents who consented to follow-up were entered into the prize draw (initiated during the pilot survey) to win a £50 gift voucher of their choice.

Follow-up (reminder) complete survey packs were sent to all households from which a response had not been received from the occupant (a completed questionnaire, an indication that they did not wish to participate, or an indication that the sampled address was in fact non-residential) or from the Royal Mail (a survey pack returned to sender as undeliverable) in a second wave of four mailing days between 26 and 31 October 2005.

Questionnaires were identified solely by a unique identification (ID) number linking them to the address to which they were sent, recorded on the front of the questionnaire using human-readable numerals and a barcode. Completed consent forms were separated from completed questionnaires on receipt and stored in a locked cabinet. The barcodes on completed questionnaires were scanned on the day of receipt so that the respondents who had completed them could be immediately eliminated from the mailing list for the follow-up mailing wave. A decoding key (database) linking ID numbers, postal address and contact details was established and kept separate from the consent forms, the questionnaires and the survey data. I coded the purpose of each journey (recorded by the respondent using free text) on each questionnaire using a set of categories based on those used in the Scottish Household Survey. Questionnaire data were then entered into a computer file by two coders, with any discrepancies being resolved by reference to the original questionnaires. Processed questionnaires were stored in a locked cabinet separate from the consent forms. The dataset was stored on a password-protected network drive.

Survey responses received after 31 December 2005 (three months after the first mailing wave) were disregarded in analysis.

7.3.6 Test–retest reliability study

In order to establish the test–retest reliability of the neighbourhood scale, I sent a retest questionnaire to a stratified random sample of respondents to the original survey.

I first selected all respondents to the original survey who met the following **individual** criteria: they had replied within a month of the first mailing wave, they had given their consent to be approached for follow-up, and they had supplied their age, sex, and a full set of responses to the neighbourhood scale on their original questionnaire. The individual criteria were designed to ensure that the retest questionnaire was sent only to respondents who were likely to return a full set of valid data.

I then identified a list of unit postcodes whose residents I wished to exclude from the retest survey on **spatial** criteria. I excluded unit postcodes which encroached within 500 metres of any of four sites where I had identified a significant change to the local area occurring around or since the time of the original survey which might confound responses to the retest survey. The changes at these sites were housing regeneration at Oatlands and at Dukes Road and the demolition of high-rise flats at the Gorbals (all in the south study area) and the opening of a new suburban railway station at Kelvindale (in the north study area). I also excluded those unit postcodes which comprised the target areas for recruitment for the micro area study in order to avoid approaching the same respondent twice for different follow-up purposes in the same year.

I constructed the sampling frame for the retest survey by filtering the dataset of survey respondents to identify all those respondents who met the individual criteria and did not fail the spatial criteria. I partitioned the sampling frame by sex and into three age groups based on the five-year age bands closest to the cut-points for the tertiles of the age distribution. I then selected a random sample from each age/sex group (n=33 from the two youngest age strata for each sex, n=34 from the oldest age strata) and merged these to form a single final stratified random sample.

Survey packs consisting of a covering letter, a retest questionnaire and a prepaid return envelope were sent by second class post to all members of the sample on on 16 March 2006. The retest questionnaire consisted of the neighbourhood scale and a question to confirm that respondents were still living at the same address. As an incentive, respondents who returned a completed retest questionnaire received a £5 Kingfisher gift voucher redeemable at shops including B&Q, Woolworth and Comet. No reminders were sent.

7.3.7 Survey questionnaire

The data collected in the questionnaire are summarised in Table 44 and Table 45. The questionnaire is reproduced in Appendix 1.

Domain	Data collected
Demographic	Age; sex; distance to place of work or study; household composition
Socioeconomic	Working situation of respondent and spouse or partner; housing tenure; household financial situation*
Access to personal transport	Personal access to a bicycle; household access to cars or vans
Health and wellbeing	Presence of long-standing limiting illness, health problem or disability; difficulty walking for a quarter of a mile on the level; height; weight; self-rated health (SF-8 scale); how respondent felt about their life
Perceptions of neighbourhood	Duration of residence in local area; how respondent felt about living in their local area; perceptions of the local area (see Table 45)
Travel diary	Purpose, mode(s) and duration of all journeys made on the previous day; day of the week; whether at home at any time that day; whether a normal working day
Physical activity	Short form of the International Physical Activity Questionnaire (IPAQ) including additional examples of moderate- and vigorous-intensity activity as recommended by the IPAQ scientific committee
Miscellaneous	Date of completion

* Other variables related to socioeconomic status, such as level of education or actual household income, were not asked for in order to limit the length and perceived intrusiveness of the questionnaire and thereby maximise the response rate.

Table 44. Data collected in questionnaire

Construct	Questionnaire item	Abbreviation
Aesthetics	It is pleasant to walk	Pleasantness for walking
	The surroundings are unattractive	Attractiveness
Green space	There is a park within walking distance	Proximity to park
	There is little green space	Green space
Access to amenities	There is convenient public transport	Public transport
	The nearest shops are too far to walk to	Proximity to shops
Convenient routes	There are convenient routes for cycling	Routes for cycling
	There are no convenient routes for walking	Routes for walking
Personal safety	It is safe to walk after dark	Safety walking after dark
	People are likely to be attacked	Likelihood of attack
Traffic	There is little traffic	Traffic volume
	There is a lot of traffic noise	Traffic noise
Road safety	It is safe to cross the road	Safety crossing the road
	The roads are dangerous for cyclists	Road safety for cyclists

Table 45. Items in neighbourhood scale

7.3.8 Data cleaning

I transferred the raw data into SPSS, examined the distribution of all variables, and carried out range and consistency checks in order to identify any anomalous values or variables with a high proportion of missing responses. I discarded from analysis all respondents who had failed to enter their age or sex. I found that travel data required additional cleaning in light of the way some respondents had completed their travel diaries. These *post hoc* decisions are explained as part of the results in Chapter 8 (Section 8.4.5).

7.3.9 Derivation of variables

Spatial characteristics

I linked the ID number of each record in the dataset to a unit postcode. Using MapInfo, I constructed concentric buffers at 100-metre intervals up to 500 metres around the routes and access points of the existing and planned motorways and around the network of other major (A- and B- class) roads, and assigned each respondent to a category of proximity to each type of road infrastructure (within 100 metres, 101-200 metres, etc.) based on the location of the centroid of their unit postcode.

Demographic and socioeconomic characteristics

After examining the distributions of responses (see Section 8.4.1), I collapsed the responses to the items on housing tenure, household car access and working situation into fewer categories by merging categories with small numbers of responses, and categorised respondents into three age groups to enable comparability with the Scottish Household Survey (see Section 8.8).

Health and wellbeing

I calculated body mass index (BMI) by converting, where necessary, self-reported heights and weights from imperial to metric units and dividing the height in metres by the square of the weight in kilograms.

The SF-8 health survey is derived from and calibrated against the longer-established SF-36. The SF-8 manual includes norms obtained from a United States population sample in 2000 and recommends that data obtained using the SF-8 should be used to calculate physical (PCS-8) and mental (MCS-8) component summary scores scaled to these norms. [428] Although alternative normative data for the SF-36 obtained from regional samples in the UK have been published, it has been shown that using these instead of the US norms makes no significant difference either to the distribution of the resulting summary scores in cross-sectional analysis or to their sensitivity to change in longitudinal analysis. [429] I therefore elected to calculate and scale the summary scores using the methods published in the SF-8 manual on the grounds that these offer optimal international comparability.

Perceptions of local area

The individual five-point items on the neighbourhood scale were alternately positively and negatively worded, e.g. 'It is pleasant to walk' (positive) was followed by 'There is a lot of traffic noise' (negative). I recoded the responses to each item on a common scale from -2 (least favourable) to +2 (most favourable). I discarded from neighbourhood scale analysis any respondent who had answered none of the items on the scale, but if respondents had left one or a few items blank I recoded these responses from missing to zero (the midpoint of the scale corresponding to the response 'Neither agree nor disagree'). I summed these recoded individual items to produce a summary neighbourhood score which could take values ranging from -28 to +28, and then categorised respondents into tertiles of this summary neighbourhood score. For the purposes of analysing test–retest reliability, I also collapsed each individual item from a five-point scale to a three-point scale by merging the negative categories (-2 and -1) and merging the positive categories (+1 and +2).

Travel

I summed the reported travel time for each mode of transport, calculated a total travel time by active modes (walking plus cycling) and by all modes combined, and calculated the proportion of total travel time contributed by each mode of transport. After examining the distribution of responses (see Section 8.4.1), I recoded the responses to the item on distance to place of work or study into a categorical variable (four miles or more, less than four miles, or not applicable). I compared the day of the week which the travel diary was said to represent with the date on which the questionnaire was said to have been completed and identifed responses where these were inconsistent.

Physical activity

I cleaned the responses to the IPAQ items and calculated summary continuous and categorical measures of physical activity using the recommended scoring protocol. [430] I therefore:

1. Excluded from analysis any respondent who had reported more than 16 hours of physical activity per day (because higher durations are considered unlikely to be true) or who had missing or internally inconsistent data on the frequency (days per week) or duration (hours or minutes per day) of any of the three components of physical activity (walking, moderate-intensity activity or vigorous-intensity activity)

2. Recoded reported durations of activity of less than ten minutes to zero, and of greater than 180 minutes to 180 minutes

3. Calculated the estimated total energy expenditure for each respondent (MET-min/week)

4. Used a combination of frequency, duration and total energy expenditure to assign each respondent to a 'high', 'moderate' or 'low' category of overall physical activity using the criteria summarised in Table 46. The 'high' category is considered to correspond to the achievement of a sufficient level of physical activity to meet current public health recommendations for adults such as that of the Chief Medical Officer. [11]

Category	Criterion
Low	Failure to meet criteria for 'moderate' or 'high'
Moderate	Three or more days of vigorous-intensity activity of at least 20 minutes per day OR Five or more days of moderate-intensity activity and/or walking of at least 30 minutes per day OR Five or more days of any combination of walking, moderate-intensity or vigorous-intensity activities AND a total of at least 600 MET-min/week
High	Three or more days of vigorous-intensity activity AND total physical activity of at least 1500 MET-min/week OR Seven or more days of any combination of walking, moderate-intensity or vigorous-intensity activities AND a total of at least 3000 MET-min/week

Source: IPAQ scoring protocol, November 2005 [430]

Table 46. Criteria for categories of overall physical activity

7.3.10 Analysis

Descriptive analysis

I described the distributions of the raw and derived variables using frequency tables or bar charts for categorical variables and histograms, means and standard deviations or medians and interquartile ranges as appropriate for continuous variables.

For most comparisons involving significance tests, I used both parametric and non-parametric methods in order to ensure that the results were not sensitive to the distributional assumptions required for parametric methods.

I compared the age distributions of male and female respondents using a box-and-whisker plot and compared the average ages of male and female respondents using both parametric and non-parametric methods (the two-sample *t*-test and Mann-Whitney *U* test respectively).

I compared the age/sex profile of the achieved sample in each study area, and the proportions of respondents from owner-occupied households and households without access to a car, with the corresponding aggregate data from the 2001 Census for the output areas used to define the study areas.

I examined the relationships (collinearity) between 'health' variables, and also between items on the neighbourhood scale, using cross-tabulations and the chi-squared (χ^2) test for categorical variables and by calculating correlation coefficients for continuous variables using both parametric (Pearson's) and non-parametric (Spearman's) methods.

I estimated the proportions of total walking and overall physical activity which were contributed by active travel as follows, both in the overall study population and in selected subgroups. For walking, I multiplied the mean time spent walking in the travel diaries by seven (in order to scale up from a daily to a weekly estimate) and divided the result by the mean total weekly minutes of walking calculated from IPAQ data. For overall physical activity, I multiplied the mean time spent travelling by active modes in the travel diaries by seven and imputed an energy expenditure of 3.3 METs (the average value associated with walking in the IPAQ scoring protocol) [430] to this activity. I then divided the result by the mean total weekly MET-minutes calculated from IPAQ data.

Comparison of study areas

I compared the distributions of demographic and socioeconomic characteristics of respondents in the three study areas by testing the null hypothesis of no difference between areas, using the χ^2 test for categorical variables and using both parametric and non-parametric methods (analysis of variance and the Kruskal-Wallis test respectively) for continuous variables.

Neighbourhood scale

Factor and cluster analysis

In order to explore the underlying structure and reduce the complexity of the data obtained using the neighbourhood scale, I used two general approaches — factor analysis and cluster analysis — and three specific methods within these general approaches: maximum-likelihood exploratory factor analysis, principal components analysis, and two-step cluster analysis.

The principle of *factor analysis* is that by examining correlations between a set of variables it may be possible to identify a smaller number of underlying factors (components) which explain much of the variance in the original variables. This may be done either from the perspective of confirming factors believed *a priori* to be significant (confirmatory factor analysis) or from the perspective of having no such *a priori* belief (exploratory factor analysis). [431] Since my analysis was intended to be exploratory, I adopted the latter approach. Statistical packages such as SPSS offer numerous alternative methods for extracting factors in an exploratory factor analysis. In the absence of any clear consensus in the literature as to which is most appropriate for the analysis of social data, I chose to use two alternative methods: maximum-likelihood exploratory factor analysis, which some regard as the 'truest' method in statistical terms, [432] and principal components analysis, which has more often been used in practice in this field, for example by Humpel and colleagues in the development of their scale of perceived neighbourhood characteristics related to walking. [433]

For the maximum-likelihood exploratory factor analysis, I used the SPSS function *Factor Analysis: Extraction: Maximum Likelihood*, specifying first that one factor should be extracted, then two factors, and so on until the result was deemed to fit the data adequately (in other words, until the goodness-of-fit test ceased to indicate that the null hypothesis of adequate fit should be rejected, i.e. $P>0.05$).

For the principal components analysis, I used the SPSS function *Factor Analysis: Extraction: Principal Components*. To begin with, I did not specify the number of components (factors) to be extracted. Principal components analysis produces components ranked in descending order of how much variance each can explain (expressed as an eigenvalue for each component). I examined the results of the two statistical tests to assess the suitability of the data for this type of analysis reported by SPSS — the Kaiser-Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity — and then considered the eigenvalues for the extracted components against a variety of standard criteria which can be used to select the 'important' components (see results in Section 8.6), as a result of which I chose both three-factor and four-factor solutions for further investigation. Adapting the method used by Humpel and colleagues in the study referred to above, [433] I then repeated the three- and four-factor solutions applying Varimax rotation to simplify the interpretation, identified the correlation coefficients (loading factors) for each scale item on the components extracted, and considered whether the group of items most strongly correlated with each extracted component constituted a meaningful group. Having selected the three most appropriate components (see results in Section 8.6), I then calculated a summary score for each of three neighbourhood subscales, each defined as the sum of the scores for the individual items most strongly correlated with each of the three principal components. I then described the distribution of summary scores for each subscale and calculated Cronbach's α (a measure of internal consistency) and measures of test—rest reliability for each subscale and for the neighbourhood scale as a whole.

In contrast to factor analysis, which seeks common factors underlying the *variables* of interest, the principle of *cluster analysis* is that it may be possible to identify groups of *cases* which are relatively homogeneous for the characteristics of interest. SPSS offers three methods of cluster analysis: the hierarchical method, the K-means method and the two-step method. The two-step method is considered more efficient for large samples than the hierarchical method, and the K-means method requires the number of clusters to be pre-specified, which I considered inappropriate for an exploratory analysis. I therefore used the SPSS function *TwoStep Cluster Analysis* and ran the analysis without specifying the number of clusters, using the *handlenoise* option to compare the results of permitting (handlenoise=25) and not permitting (handlenoise=0) an outlier cluster to be identified. [434] I further investigated the output from the cluster analysis using the SPSS function *Variable Importance Plot*, which reports the importance of each item on the neighbourhood scale in defining each cluster in terms of a χ^2 statistic.

Test–retest reliability

Different authors have used different measures to report the test–retest reliability of similar items in the published literature. I therefore cross-tabulated the test and retest responses to each item on the neighbourhood scale and calculated several alternative measures of reliability:

1. The proportion of respondents who gave exactly the same response at test and retest (percentage exact agreement)

2. The Pearson, Spearman and intraclass correlation coefficients between test and retest

3. The chance-corrected agreement between test and retest (Cohen's κ)

4. The chance-corrected agreement between test and retest after collapsing each item from a five-point scale to a three-point scale (a 'weighted' version of Cohen's κ intended to take account of the fact that, for example, a change in response from negative to zero, or from negative to positive, could be considered more significant than a change from -2 to -1).

Regression modelling of correlates of active travel and physical activity

Several alternative approaches were open to me.

I could have analysed travel behaviour in terms of the mode share of trips or stages of trips, which was the approach used in many of the studies included in the systematic review. However, I considered it more useful from a physical activity perspective to quantify active travel in terms of the time spent using active modes.

The distributions of time spent walking and cycling and of overall physical activity were both strongly positively skewed (see results in Section 8.4.5), and owing to the large number of zero values it was not possible to transform the distribution into one more closely resembling a normal distribution using a conventional technique such as log-transformation. It therefore appeared unlikely that the statistical assumptions required for linear regression could be met. I therefore decided to model the correlates of active travel and physical activity using logistic regression, a method which requires no distributional assumptions about the data.

I defined as the primary outcome a binary variable, 'active travel', achieved by any respondent who had reported at least 30 minutes of travel by walking, cycling or both in their travel diary. I chose the threshold of 30 minutes to reflect the Chief Medical Officer's recommendation that adults should accumulate at least 30 minutes of moderate-intensity physical activity on most days of the week. [11] I began to examine the relationships between putative explanatory variables and this primary outcome variable by cross-tabulating individual explanatory variables with active travel and entering each explanatory variable into a univariate logistic regression model in order to estimate the odds ratio (with 95% confidence interval) for active travel, and the associated P-value, for each category of the explanatory variable compared with its reference category.

Statistical packages such as SPSS offer a variety of methods for selecting variables to be entered into a multivariate logistic regression model. These reflect a range of approaches which can be taken to this type of analysis: from entering all available variables irrespective of their significance in univariate analysis, through 'mechanical' stepwise methods in which variables are automatically selected or deselected solely according to statistical criteria, to the more thoughtful approach recommended by Hosmer and Lemeshow. [435] Entering all possible variables may be appropriate when the object of the exercise is to examine the relationship between the outcome and one particular explanatory variable, controlling for the effects of all available confounding variables, but this approach would have been more suitable for an analysis designed to test a specific causal hypothesis. 'Mechanical' methods have also been criticised on the grounds that they can produce implausible models which include variables which are technically 'significant' but irrelevant. I therefore adopted the approach of

Hosmer and Lemeshow in which the aim was to produce 'the most parsimonious model [i.e. the simplest model containing the smallest number of explanatory variables] that still explains the data'. [435]

I examined the unadjusted estimates of the odds ratios (see results in Section 8.7.1) and, having also examined the relationships between the 'health' variables (see results in Section 8.4.3), elected to enter all the demographic and socioeconomic variables as potential explanatory variables in a multivariate model along with a single 'health' variable, difficulty walking. For convenience, I refer to these demographic, socioeconomic and health variables as 'personal' variables to distinguish them from 'environmental' variables, although it should be noted that the 'personal' variables include some characteristics of the household rather than the individual.

I entered all these personal variables into a multivariate logistic regression model, removed those which appeared to be insignificant in the multivariate model, then re-entered them one or two at a time in order to investigate the effect of removing variables on the model. Having identified the optimal interim model, I then investigated the effect of adding interaction terms. Having identified the optimal interim model including interaction terms, I then proceeded to examine the contribution of environmental variables. The approach I took to modelling the influence of 'environmental' characteristics was to consider separately the influence of 'objective' characteristics (proximity to major roads and motorways and, in a somewhat similar way, study area of residence) and 'subjective' characteristics (perceptions of the local environment), and within the 'subjective' domain to examine the independent contribution of each item on the neighbourhood scale as well as a variety of summary measures. By definition, there was a degree of overlap or collinearity between the various summary measures, which is why it would not have been appropriate to enter them all into a model simultaneously. Instead, I entered both individual and summary measures separately as an exploratory exercise to see which, if any, of these would contribute meaningfully to an overall model and selected the most promising to be retained. I then continued to remove variables and refit the model until I was satisfied I had reached the most parsimonious, stable and well-fitting model possible.

I used an analogous procedure to analyse the correlates of physical activity, defining as 'physically active' any respondent who had reported a 'high' level of physical activity according to the IPAQ scoring protocol.

7.4 Regional area study

The Scottish Household Survey (SHS) is a continuous cross-sectional face-to-face interview survey of private households sampled using the PAF, with an achieved national sample of around 31,000 households over each two-year cycle. [436] SHS is said to provide a representative sample of private households (and of adults aged 16 and over living in private households) for the whole country each quarter, for the larger local authority areas (including Glasgow and South Lanarkshire, the local authorities through whose areas the new motorway is to run) each year, and for the smaller local authority areas every two years. The sampling method varies according to population density. In the more densely-populated local authorities such as Glasgow, a simple random sample is drawn. In the less densely-populated local authorities such as South Lanarkshire, a two-stage sampling method is used: a random sample of census enumeration districts is drawn (with a probability of selection proportional to the population of each district), then a random sample of households is drawn from each selected district. [436] The overall response rate in 2003-04 was 69%; the local authority area with the lowest response rate was Glasgow (60%). [437]

I obtained the latest available SHS dataset deposited in the UK Data Archive (covering the years 2003 and 2004) and ascertained that respondents' place of residence was coded in that dataset at the level of local authority area, but not at the level of any smaller administrative area. I therefore negotiated with the transport statistics branch of the Scottish Executive an agreement that they would supply me with travel diary data coded at the level of postcode sector for the years 2001 to 2004 inclusive. In exchange for the enhanced spatial detail, the specialised dataset which I received contained only a limited set of demographic, socioeconomic and health variables (Table 47). The dataset was supplied in 'long' format in which each stage of each trip constituted one record.

Domain	Variable
Characteristics of stage of trip	Survey year Stage number within trip Trip number to which stage belonged Mode of transport Purpose Duration (minutes) Postcode sector of origin and destination 'Quality' of origin and destination postcode*
Characteristics of respondent	Unique ID number Weighting factor† Sex Age‡ Working situation‡ Annual net household income‡ Cars available to household‡ Limiting long-term illness or disability Self-rated health‡

* This variable could take one of four values: 'home', 'work', 'definite' or 'notional', the latter category meaning that the location of the origin or destination could only be ascertained approximately
† Weighting factor to adjust for differences in selection probabilities between local authorities, between households of different sizes, and between days of the week
‡ Not supplied as raw variables but recoded into predefined groups

Table 47. Variables supplied in specialised SHS travel diary dataset

7.4.1 Restructuring of dataset

Using the SPSS function *Restructure: Cases into Variables*, I restructured the dataset from 'long' to 'wide' format, first merging the records for individual stages of trips into a trip-level dataset (one record per trip) and then merging the records for trips made by the same individual into an individual-level dataset (one record per person).

7.4.2 Derivation of variables

Spatial characteristics

For the purposes of this analysis, I defined an enlarged M74 'corridor' comprising those postcode sectors lying wholly or partly within a 500 metre buffer around the proposed route of the M74 motorway (postcode sectors G32 8, G32 9, G40 4, G41 1, G41 2, G42 0, G42 7, G42 8, G5 0, G5 8, G5 9, G51 1, G72 7, G73 1, G73 2 and G73 3) (Figure 17). I recoded all origins and destinations to larger aggregations of postcode sectors, either (a) the M74 corridor, (b) postcode districts within Glasgow (e.g. G1, G2), or (c) postcode areas outside Glasgow (e.g. AB for Aberdeen, ML for Motherwell). I assumed that 'notional' postcodes were sufficiently accurate for this purpose.

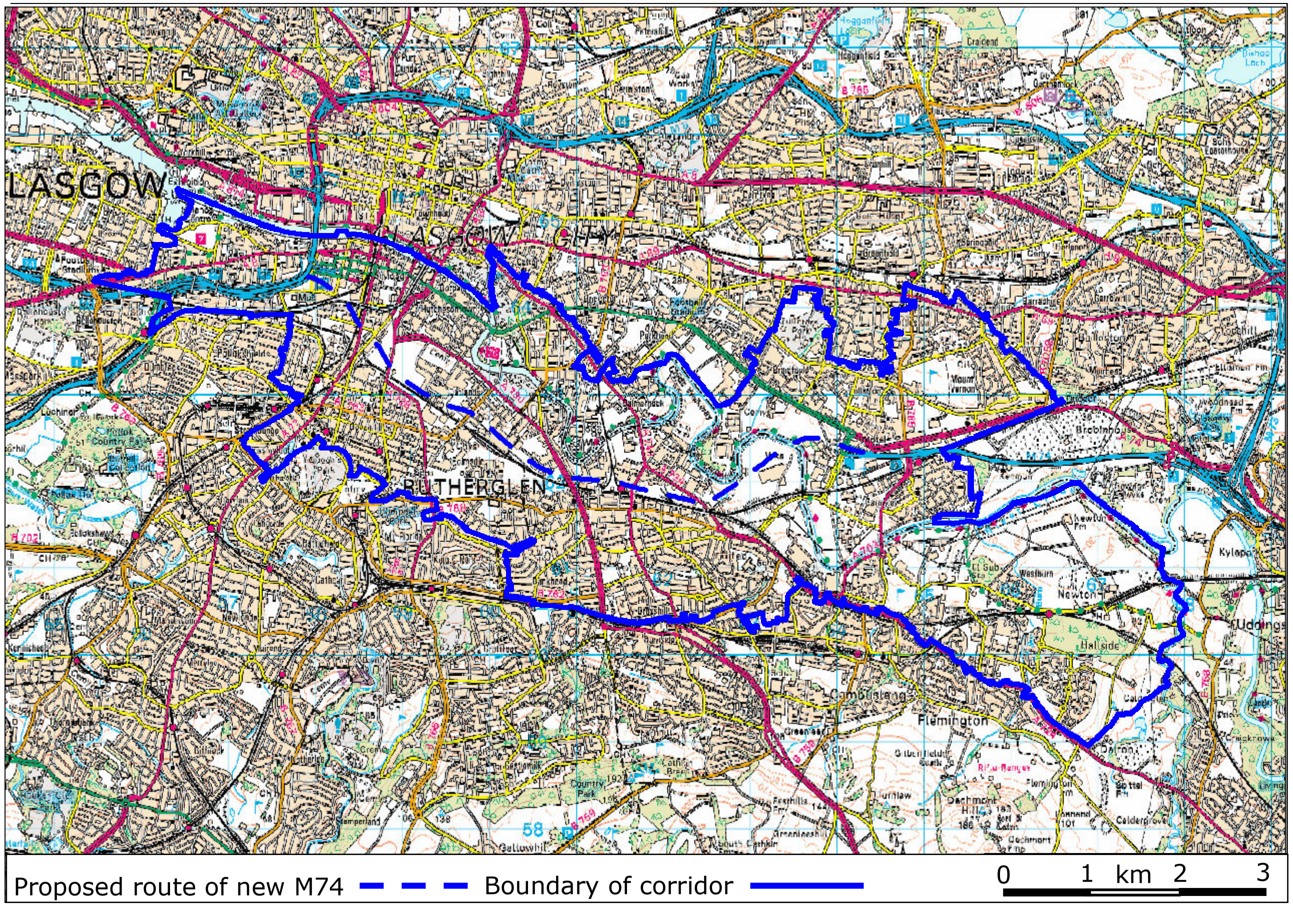

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Figure 17. M74 corridor defined in terms of postcode sectors for analysis of SHS travel diaries

Travel

I summed the reported travel time for each mode of transport, calculated a total travel time by active modes (walking plus cycling) and by all modes combined, and calculated the proportion of total travel time contributed by each mode of transport.

7.4.3 Analysis

Descriptive analysis

I described the distributions of the raw variables using frequency tables or bar charts for categorical variables and histograms, means and standard deviations, or medians and interquartile ranges for continuous variables as appropriate. I compared the results of these descriptive analyses with and without the application of the published weighting factors which are designed to correct for differences in selection probabilities between local authorities, between households of different sizes, and between days of the week. [436]

Spatial analysis of travel patterns

Using the restructured individual-level dataset and using origins and destinations of stages of trips defined as 'home' or 'work', I identified people living or working in the M74 corridor, described the spatial distributions of the other ends of their journeys to and from work, and compared the characteristics of people reporting these trips and their patterns of mode choice with those of the national sample.

Regression modelling of correlates of active travel

As in the local area study, I defined the primary outcome variable, 'active travel', as having been achieved by any respondent who had reported at least 30 minutes of travel by walking, cycling or both in their travel diary. I began to examine the relationships between putative explanatory variables and this primary outcome variable by cross-tabulating individual explanatory variables with active travel and entering each explanatory variable into a univariate logistic regression model in order to estimate the odds ratio (with 95% confidence interval) for active travel, and the associated P-value, for each category of the explanatory variable.

Also as in the local area study, I selected variables to be entered into multivariate modelling using the approach recommended by Hosmer and Lemeshow. [435] I examined the unadjusted estimates of the odds ratios and elected to enter all available variables as potential explanatory variables in a multivariate model. I then removed those which appeared to be insignificant in the multivariate model, then re-entered them one or two at a time in order to investigate the effect of removing variables on the model. Having identified the optimal interim model, I then investigated the effect of adding interaction terms and continued to remove variables and refit the model until I was satisfied I had reached the most parsimonious, stable and well-fitting model possible.

7.5 Ethical approval, data protection and research governance

The University of Glasgow Faculty of Medicine Ethics Committee approved the cross-sectional phase of the M74 study on 23 June 2005 (reference no. FM01304) with the data protection procedures described in Section 7.3.5, and approved the test–retest reliability study as an extension to the original approval on 26 January 2006 (Appendix 2). The study was then registered with the UK Data Archive as using Scottish Household Survey data (reference no. 18242). QualityMetric Incorporated granted a licence to use the SF-8 survey between 1 July 2005 and 2 July 2006 (licence no. R1-061005-22740). No licence was required to use the International Physical Activity Questionnaire.

I established a steering group for the study which met for the first time on 24 September 2004 and regularly thereafter. The steering group comprised me, Prof Mark Petticrew (PhD supervisor), Prof Nanette Mutrie (PhD adviser), and two collaborators from the Research Unit in Health Behaviour and Change at the University of Edinburgh: Prof Steve Platt and Dr Richard Mitchell.

8 M74 study: results

8.1 Overview of this chapter

In this chapter, I present the results of the cross-sectional (baseline) quantitative analysis of M74 study data in the following order:

1. The results of the pilot survey for the local area study
2. The results of the local area study itself
3. The results of the regional area study.

I have followed Altman's principles for presenting numerical data as given in the *British Medical Journal*: [438]

- Summary statistics such as means are reported to no more than one additional decimal place over the raw data
- Where raw frequencies are reported either in the text or in a table, percentages are given in the text as integers
- Test statistics such as χ^2 are given to no more than two decimal places
- P-values are given to no more than two significant figures.

I have also followed that journal's convention of using 'significance' to indicate 'statistical significance'. Unless otherwise stated, where I have described an association or a difference as 'significant' this should be taken to mean statistically significant at the conventional level of α=0.05 (two-sided).

8.2 Local area study: pilot survey

8.2.1 Response

12 of the 200 questionnaires were returned by the Royal Mail as undeliverable (no such address, gone away or deceased). By 20 August (four weeks after the reminder postcards were sent out, and six weeks after the original mailing), a total of 21 responses had been received — a response rate of 11% of all addresses sampled. Data from 19 of these respondents were received and entered in time to be included in the analysis. 13 respondents gave valid consent for telephone follow-up, and nine telephone interviews were successfully completed. A further 16 members of unit staff or students agreed to take part, of whom 14 completed test–retest follow-up. Retest data were collected between seven and 18 days after the original survey.

8.2.2 Comments on questionnaire

A variety of comments were made about specific items on the draft questionnaire, but with the exception of those made about the travel diary such comments were minor or were only made by one person. In the telephone interviews, I specifically asked all external respondents whether the draft questionnaire was too long or too complicated: none of them thought it was.

More comments were made about the travel diary than about other parts of the draft questionnaire. By far the most frequent comment (made by eight respondents) was that 'yesterday' — the day for which respondents were asked to record their travel — had been atypical and that their travel behaviour varied according to the day of the week. Five respondents made similar comments about their physical activity during the previous week. I probed respondents' travel diary entries to verify that they had understood what had been asked for. I identified only two potential problems with the travel diaries which had involved more than one respondent, and satisfied myself on both points after probing the responses. First, two respondents had recorded bus journeys with no associated walking. Both subsequently confirmed that the bus stop was immediately outside their house and the bus had taken them all the way to their destination. Second, two other respondents had recorded no journeys; both subsequently confirmed that they had indeed not gone out at all that day.

A few respondents commented on limitations of the SF-8 or IPAQ questionnaires, but I was unable to contemplate significant alterations to these instruments without compromising their validity and reliability already established in published studies.

8.2.3 Quantitative analysis

No questionnaire item had a large proportion of missing responses, and the distributions of the raw variables all appeared plausible. Respondents typically reported two or three journeys (mean 2.7, median 3.0, range 0 to 6) and a mean total of 58.5 minutes' travel per day, 21.1 minutes of which were on foot.

I briefly examined the test–retest reliability of the items on the neighbourhood scale by calculating Spearman's correlation coefficient (r_s) using data from the 23 respondents for whom repeated measures were available. The correlation coefficients for the individual items ranged from 0.55 to 0.89 with the exception of one item, 'There are no shops within walking distance' (r_s=0.21). I concluded that the poor test–retest correlation for this item might reflect potential ambiguity — for example between shops of any kind, food shops, or large shops — and some external respondents indicated difficulty with this question during their telephone retest. I therefore decided to reword this item to 'The nearest shops are too far to walk to'.

8.3 Local area study: response

Over the three-month period, 1345 households returned a completed questionnaire and 676 survey packs were returned to sender as undeliverable by the Royal Mail (520 in the first wave and a further 156 from different addresses in the second wave). I excluded 23 of the 1345 completed questionnaires in which the respondent had not given their age or sex, leaving 1322 valid responses to be entered into analysis. The final overall response rate, corrected to take account of the 676 addresses from which no response could reasonably have been expected, was therefore 1322 / (9000-676) = 15.9%. Approximately equal numbers of valid responses were received from the south (n=437), east (n=428) and north (n=457) study areas. Although the proportion of survey packs returned as undeliverable was slightly higher in the south study area than in the east and north study areas (Table 48), the response rates for the three study areas were not significantly different (χ^2=2.02, df=2; P=0.36).

	Study area		
	South	East	North
Addresses sampled	3000	3000	3000
Returned to sender as undeliverable	355	173	148
Valid addresses sampled	2645	2827	2852
Valid responses received	437	428	457
Response rate	16.5%	15.1%	16.0%

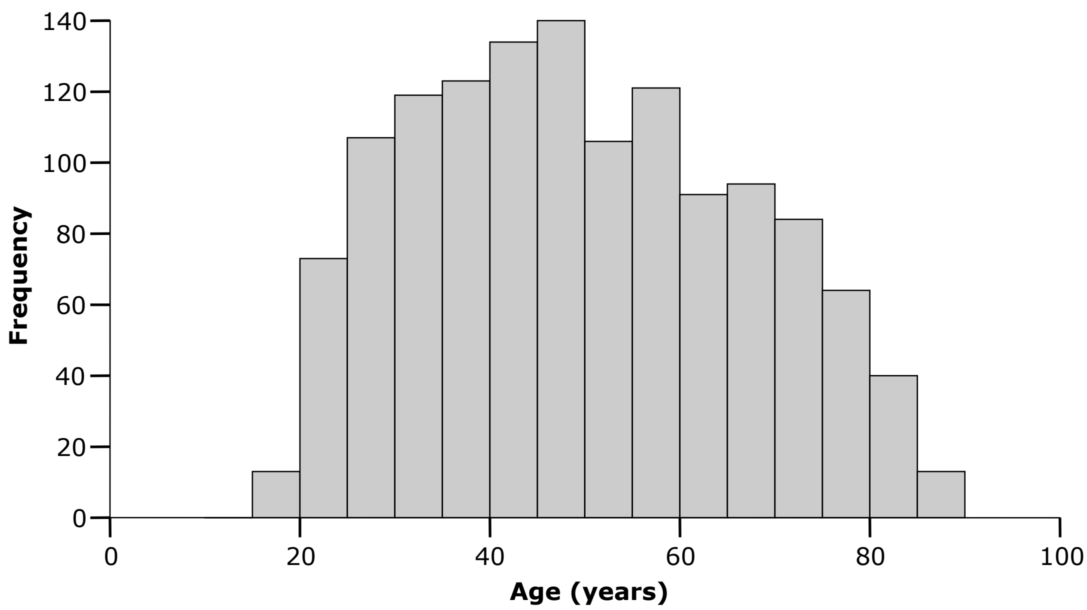
Table 48. Response rates by study area

8.4 Local area study: descriptive data

8.4.1 Demographic and socioeconomic characteristics

Age and sex

Respondents were aged between 16 and 89 years, with an average age of about 50 years (mean 49.2 years, median 48.0 years) (Figure 18, Table 49).



n=1322

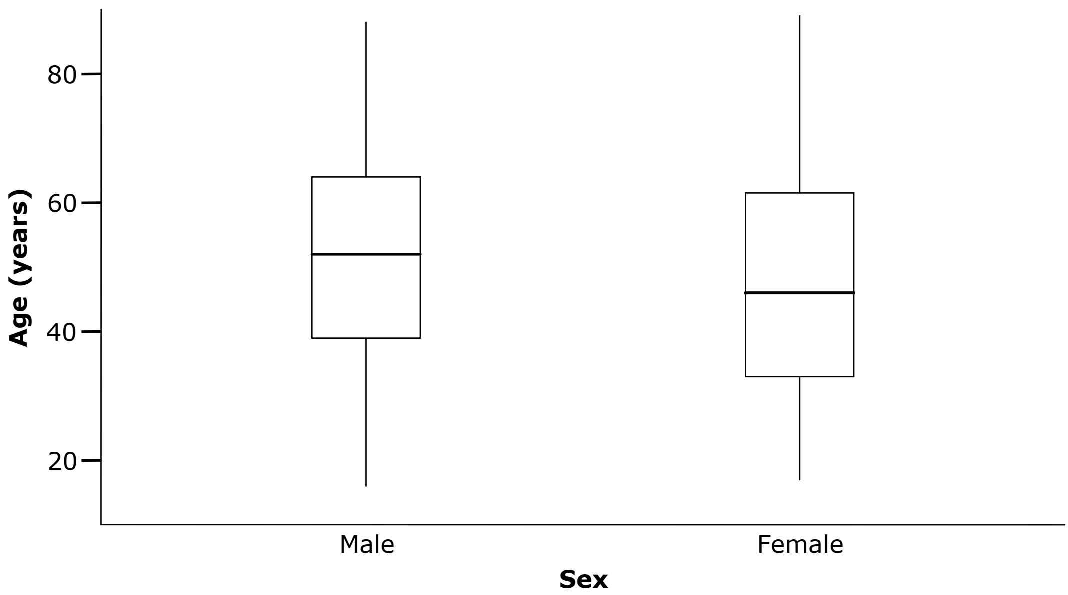
Figure 18. Ages of respondents

Age group	Frequency (%)
16 to 39	435 (32.9)
40 to 64	592 (44.8)
65 and over	295 (22.3)

n=1322. Cut-points for categories chosen to be consistent with those used in the Scottish Household Survey travel diary dataset (see Table 103 later in this chapter)

Table 49. Distribution of respondents by age group

804 (61%) of the 1322 respondents were women. Female respondents were significantly younger than male respondents, with a difference in mean age of 4.0 years (95% confidence interval 2.2 to 5.9; t=4.26, P<0.001) and a difference in median age of 6.0 years (Mann-Whitney U test: z=4.47, P<0.001) (Figure 19).



	Male	Female
Mean (years)	51.7	47.7
Median (years)	52.0	46.0
n	518	804

n=1322. Boxes indicate interquartile range divided by median, whiskers indicate range

Figure 19. Age distributions of male and female respondents

Work

In response to the question on working situation, 47% of respondents described themselves as doing paid work full-time or part-time (Table 50). I disregarded the working situation of the respondent's spouse or partner in analysis because of the large number of missing responses to this question (707; 54% of respondents). Of the 1244 (94%) respondents who gave valid responses to the items on distance to place of work or study, 546 (44%) described themselves either as not working or studying or as usually working at home or from home, for whom the items were therefore not applicable. This left 698 (56%) who did usually travel to a place of work or study; for these respondents (omitting 31 respondents who reported a distance of one mile or more but did not state the exact distance) the median reported distance was 3.5 miles (Table 51).

Household circumstances

70% of respondents described their household as finding it a strain to get by or having to be careful with money (Table 52). Just over half (52%) of respondents described their household as owner-occupied (Table 53), and a similar proportion reported that there was at least one car or van available for use by their household (Table 54), but only 21% of respondents (26% of men and 18% of women) reported having personal access to a bicycle (Table 55). I disregarded household composition in analysis because of the large number of missing responses to the questions on the numbers of children aged under five (590; 45% of respondents) or between five and 15 (546; 41% of respondents) living in the household.

Response	Frequency (%)
Doing paid work full-time*	511 (39.1)
Retired	333 (25.5)
Disabled, invalid or permanently sick†	129 (9.9)
Doing paid work part-time*	105 (8.0)
Unemployed†	84 (6.4)
Caring for home and family or dependants†	59 (4.5)
Full time student†	51 (3.9)
On a government training scheme†	6 (0.5)
Other†	28 (2.1)

n=1306 (16 respondents had missing data for this item)
* Categories combined into 'Employed' for subsequent analysis
† Categories combined into 'Other' for subsequent analysis

Table 50. Working situation

Response	Frequency (%)
Not applicable	546 (43.9)
Less than one mile*	85 (6.8)
1.0 to 1.9 miles*	49 (3.9)
2.0 to 2.9 miles*	105 (8.4)
3.0 to 3.9 miles*	96 (7.7)
4.0 to 4.9 miles†	77 (6.2)
5.0 to 5.9 miles†	54 (4.3)
6.0 to 9.9 miles†	86 (6.9)
10.0 miles or over†	115 (9.2)
One mile or over (not otherwise specified)‡	31 (2.5)

n=1244 (88 respondents had missing data for this item)
* Categories combined into 'Less than four miles' for subsequent analysis
† Categories combined into 'Four miles or more' for subsequent analysis
‡ Category recoded as missing for subsequent analysis

Table 51. Distance to place of work or study

Response	Frequency (%)
Find it a strain to get by from week to week	233 (17.9)
Have to be careful about money	680 (52.2)
Able to manage without much difficulty	299 (23.0)
Quite comfortably off	90 (6.9)

n=1302 (20 respondents had missing data for this item)

Table 52. Financial situation of households

Response	Frequency (%)
Owner-occupied	678 (51.6)
Social rented*	543 (41.3)
Private sector rented†	59 (4.5)
Part-owned, part-rented†	9 (0.7)
Other†	25 (1.9)

n=1314 (8 respondents had missing data for this item)
* Rented from a local authority, Scottish Homes, a housing association or a charity
† Categories combined into 'Other' for subsequent analysis

Table 53. Housing tenure

Response	Frequency (%)
None	629 (48.4)
One	525 (40.4)
Two*	123 (9.5)
Three*	19 (1.5)
Four*	4 (0.3)

n=1300 (22 respondents had missing data for this item)
* Categories combined into 'Two to four' for subsequent analysis

Table 54. Cars or vans available to households

Sex	Frequency (%) reporting access to a bicycle
Male	136 (26.4)
Female	145 (18.2)
Total	281 (21.4)

n=1312 (10 respondents had missing data for this item)

Table 55. Access to bicycles

8.4.2 Representativeness of achieved sample

A limited comparison of the characteristics of the achieved sample with the aggregate 2001 census data for the output areas which formed the sampling areas showed that women and owner-occupiers were over-represented, and younger adults and those without access to a car were under-represented, in the achieved sample compared with the expected profile of the local population as a whole (Table 56).

	Study area					
	South		East		North	
Data source	Census 2001	Survey 2005	Census 2001	Survey 2005	Census 2001	Survey 2005
Women	54%	56%	55%	63%	55%	63%
Aged 16-39	41%	33%	43%	33%	42%	33%
Aged 40-64	37%	46%	37%	44%	37%	46%
Aged 65 and over	22%	22%	20%	22%	20%	23%
Owner-occupiers	38%	51%	39%	54%	38%	50%
No access to car or van	66%	48%	66%	50%	64%	47%

Table 56. Comparison of survey respondents with census respondents

Relationships between demographic and socioeconomic characteristics

Tests of the strength of association between pairwise combinations of the categorical demographic and socioeconomic variables are shown in Table 57. There were significant associations between most of the variables considered except for sex, which was not significantly associated with working situation, financial situation, housing tenure, or access to a car.

Respondents in the oldest age group (65 and over) were less likely than those in younger age groups to live in owner-occupied accommodation. Access to a bicycle was associated with being younger, being male, being employed, being in a more favourable financial situation, living in owner-occupied accommodation, and having access to a car.

Other observed associations were in the directions expected. Most (91%) respondents in the oldest age group described themselves as retired. Respondents in employment were more likely than others to be in a favourable financial situation and to live in owner-occupied accommodation. Respondents in a more favourable financial situation were more likely to live in owner-occupied accommodation. Access to a car was associated with being in a more favourable financial situation, living in owner-occupied accommodation and being employed.

Variables compared		Test	Result
Working situation (unordered)	Housing tenure (unordered)	Chi-squared test	χ^2=221.71, df=4; $P<0.001$
Working situation (unordered)	Access to a bicycle (binary)	Chi-squared test	χ^2=68.34, df=2; $P<0.001$
Working situation (unordered)	Sex (binary)	Chi-squared test	χ^2=1.91, df=2; $P=0.38$
Housing tenure (unordered)	Access to a bicycle (binary)	Chi-squared test	χ^2=27.61, df=1; $P<0.001$
Housing tenure (unordered)	Sex (binary)	Chi-squared test	χ^2=2.98, df=2; $P=0.23$
Access to a bicycle (binary)	Sex (binary)	Chi-squared test	χ^2=12.33, df=1; $P<0.001$
Age group (ordered)	Access to a bicycle (binary)	Chi-squared test for linear trend	χ^2=11.70, df=1; $P<0.001$
Age group (ordered)	Sex (binary)	Chi-squared test for linear trend	χ^2=1.09, df=1; $P=0.30$
Financial situation (ordered)	Access to a bicycle (binary)	Chi-squared test for linear trend	χ^2=17.78, df=1; $P<0.001$
Financial situation (ordered)	Sex (binary)	Chi-squared test for linear trend	χ^2=0.25, df=1; $P=0.62$
Access to a car (ordered)	Access to a bicycle (binary)	Chi-squared test for linear trend	χ^2=76.75, df=1; $P<0.001$
Access to a car (ordered)	Sex (binary)	Chi-squared test for linear trend	χ^2=3.06, df=1; $P=0.08$
Age group (ordered)	Working situation (unordered)	Kruskal-Wallis test*	χ^2=382.35, df=2; $P<0.001$
Age group (ordered)	Housing tenure (unordered)	Kruskal-Wallis test*	χ^2=9.54, df=2; $P=0.008$
Financial situation (ordered)	Working situation (unordered)	Kruskal-Wallis test*	χ^2=149.64, df=2; $P<0.001$
Financial situation (ordered)	Housing tenure (unordered)	Kruskal-Wallis test*	χ^2=194.43, df=2; $P<0.001$
Access to a car (ordered)	Working situation (unordered)	Kruskal-Wallis test*	χ^2=208.88, df=2; $P<0.001$
Access to a car (ordered)	Housing tenure (unordered)	Kruskal-Wallis test*	χ^2=221.14, df=2; $P<0.001$
Age group (ordered)	Financial situation (ordered)	Spearman correlation coefficient*	r_s=0.07
Access to a car (ordered)	Financial situation (ordered)	Spearman correlation coefficient*	r_s=0.28
Access to a car (ordered)	Age group (ordered)	Spearman correlation coefficient*	r_s=−0.14

* Adjusted for ties. χ^2: chi-squared test. df: degrees of freedom. r_s: Spearman correlation coefficient

Table 57. Associations between demographic and socioeconomic characteristics

8.4.3 Health and wellbeing

When asked how they felt about their life, most respondents (63%) selected a response category more favourable than the midpoint of the seven-point rating scale (Table 58). 39% of respondents described themselves as having a limiting long-term illness, health problem or disability (hereafter referred to as a 'health problem') and 25% described themselves as having difficulty walking for a quarter of a mile (hereafter referred to as 'difficulty walking'). These latter variables were strongly associated with each other (χ^2=565.95, df=1; P<0.001): 94% of those who reported difficulty walking also reported a health problem (Table 59).

Response category on rating scale	Frequency (%)
1 (most favourable)	101 (7.8)
2	307 (23.8)
3	399 (30.9)
4	244 (18.9)
5	138 (10.7)
6	53 (4.1)
7 (least favourable)	49 (3.8)

n=1291 (31 respondents had missing data for this item)

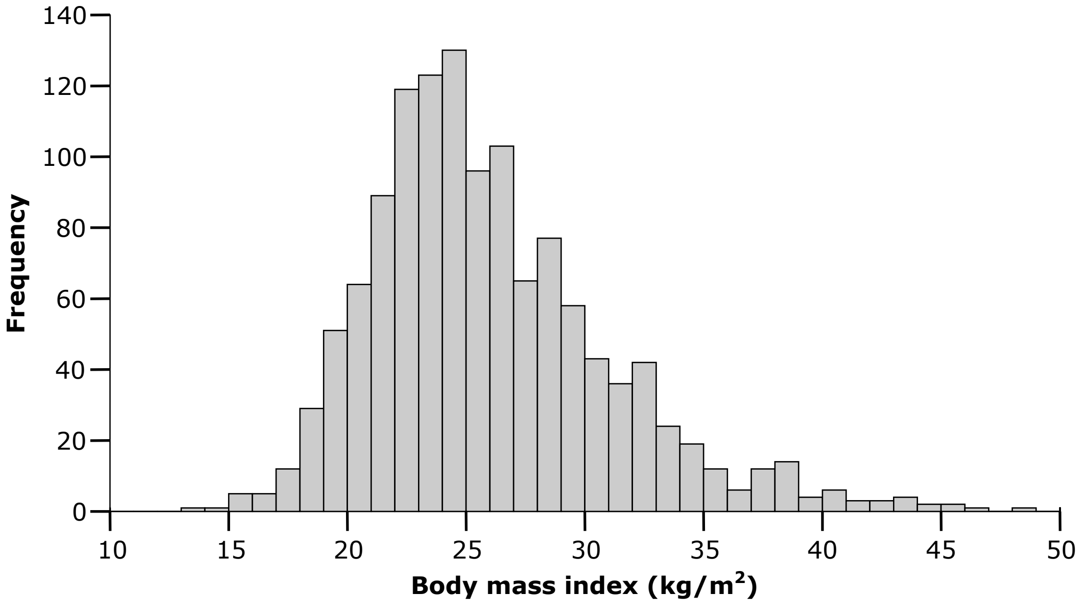
Table 58. How respondents felt about their life

Health problem	Difficulty walking*		
	Yes	No	Total
Yes	303 (94.1)	188 (19.6)	491 (38.3)
No	19 (5.9)	771 (80.4)	790 (61.7)
Total	322 (100.0)	959 (100.0)	1281 (100.0)

n=1281 (41 respondents had missing data for one or both items)
* Count (column %)

Table 59. Health and mobility problems

Half of respondents (636; 50%) had a body mass index greater than or equal to 25 (mean 26.1 kg/m^2, standard deviation 6.0; median 25.1 kg/m^2) (Figure 20).



n=1266 (56 respondents had missing data for height or weight)

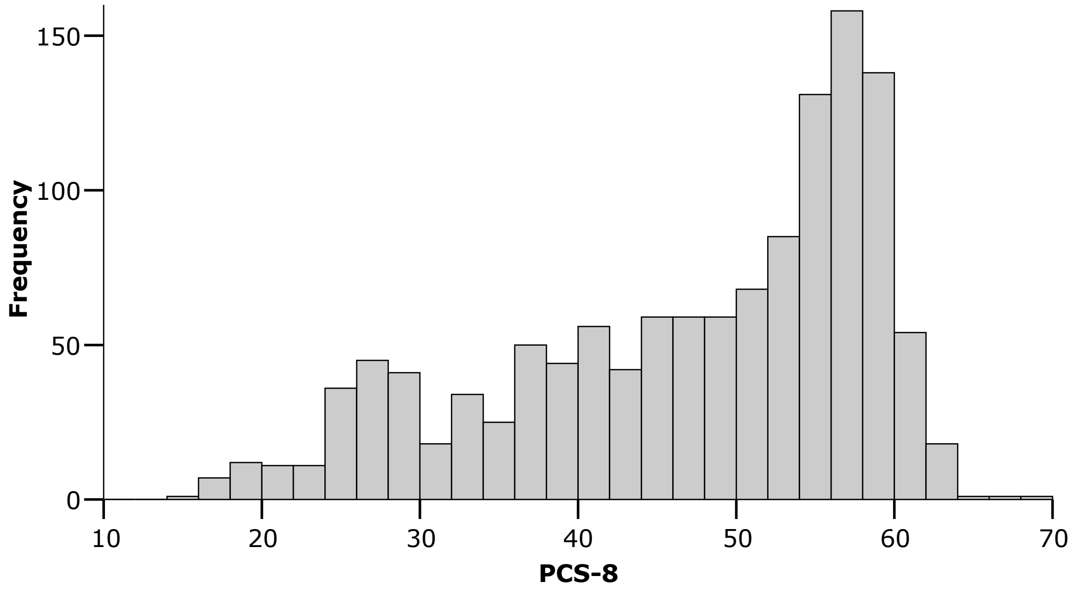
Figure 20. Distribution of body mass index

The physical and mental health summary scores calculated from responses to the SF-8 were moderately correlated with each other (r_s=0.40). The means of both summary scores were significantly less than 50, i.e. significantly less than the population norm (Table 60), but the medians were closer to 50 than the means, reflecting the marked negative skew in the distribution of both variables (Figure 21, Figure 22) which has also been reported in studies using the SF-36 in general population samples in the US and the UK; [429] the median physical health summary score was not significantly less than 50.

Summary score	Mean (sd)	95% CI for mean	Median (IQR)	95% CI for median
Physical (PCS-8)	47.0 (11.5)	46.4 to 47.7	50.9 (17.4)	49.6 to 51.7
Mental (MCS-8)	44.3 (11.5)	43.7 to 45.0	47.3 (17.3)	46.4 to 48.1

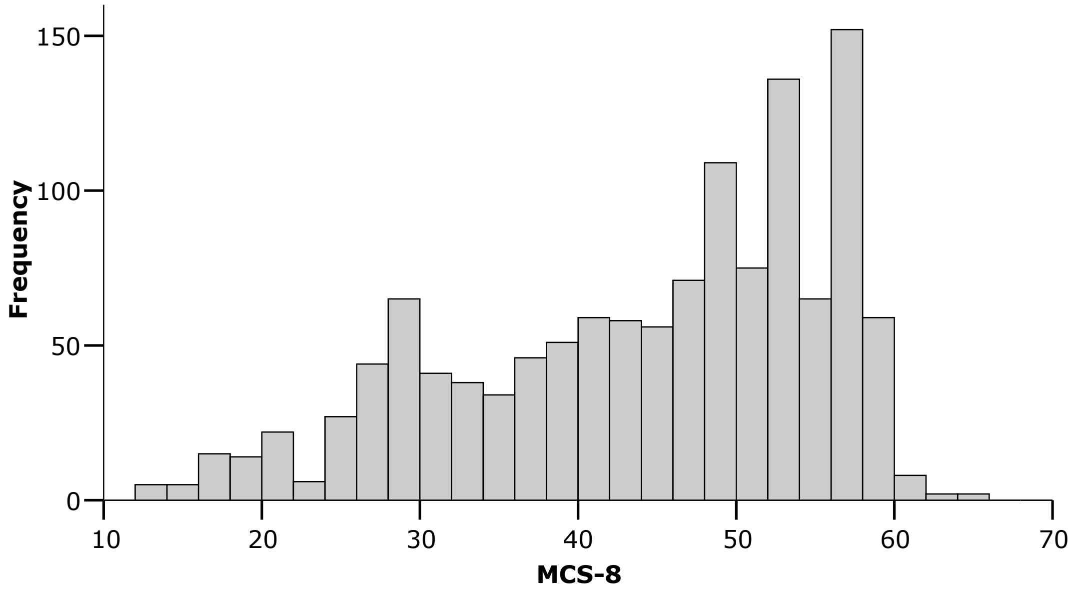
n=1265 (57 respondents had missing data for one or more items contributing to these summary scores). sd: standard deviation. 95% CI: 95% confidence interval. IQR: interquartile range

Table 60. Average physical and mental health summary scores



n=1265 (57 respondents had missing data for one or more items contributing to this summary score)

Figure 21. Distribution of physical health summary scores



n=1265 (57 respondents had missing data for one or more items contributing to this summary score)

Figure 22. Distribution of mental health summary scores

Relationships between health variables

Tests of the strength of association between pairwise combinations of the variables related to health and wellbeing are shown in Table 61. The associations between most of these variables were significant and in the expected directions except for body mass index, which tended to be higher in people who reported a health problem or difficulty walking but was not correlated with how people felt about their life or with the mental health summary score.

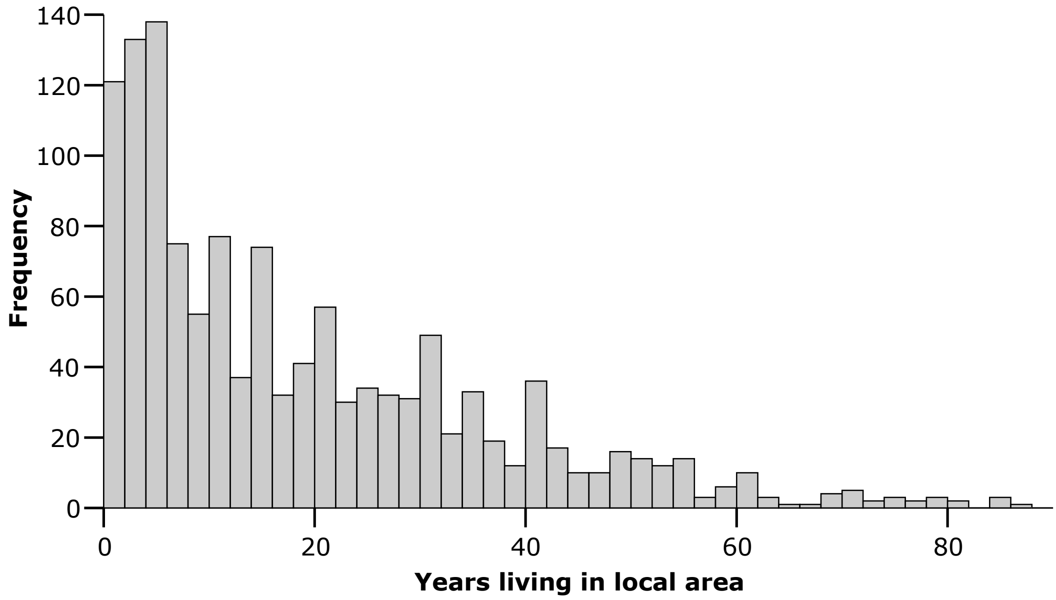
Variables compared		Test	Result
How they felt about life (ordered)	Health problem (binary)	Chi-squared test for linear trend	χ^2=126.62, df=1; $P<0.001$
How they felt about life (ordered)	Difficulty walking (binary)	Chi-squared test for linear trend	χ^2=92.05, df=1; $P<0.001$
Physical health (continuous)	Health problem (binary)	Mann-Whitney *U* test*	z=24.56, $P<0.001$
Physical health (continuous)	Difficulty walking (binary)	Mann-Whitney *U* test*	z=23.42, $P<0.001$
Mental health (continuous)	Health problem (binary)	Mann-Whitney *U* test*	z=15.19, $P<0.001$
Mental health (continuous)	Difficulty walking (binary)	Mann-Whitney *U* test*	z=13.16, $P<0.001$
Body mass index (continuous)	Health problem (binary)	Mann-Whitney *U* test*	z=4.49, $P<0.001$
Body mass index (continuous)	Difficulty walking (binary)	Mann-Whitney *U* test*	z=5.65, $P<0.001$
Physical health (continuous)	How they felt about life (ordered)	Spearman correlation coefficient*	r_s=−0.36
Physical health (continuous)	Body mass index (continuous)	Spearman correlation coefficient*	r_s=−0.16
How they felt about life (ordered)	Mental health (continuous)	Spearman correlation coefficient*	r_s=−0.60
How they felt about life (ordered)	Body mass index (continuous)	Spearman correlation coefficient*	r_s=0.05
Mental health (continuous)	Body mass index (continuous)	Spearman correlation coefficient*	r_s=−0.05

The associations between health problems and difficulty walking and between physical and mental health summary scores are given in the text
* Adjusted for ties. χ^2: chi-squared test. df: degrees of freedom. r_s: Spearman correlation coefficient

Table 61. Associations between health and wellbeing variables

8.4.4 Perceptions of local environment

Most respondents reported having lived in their local area for more than 10 years (median duration of residence 14 years) (Figure 23); as expected, duration of residence was correlated with age (r_s=0.56). When asked how they felt about living in their local area, most respondents (64%) selected a response category more favourable than the midpoint of the seven-point rating scale (Table 62).



n=1279 (43 respondents had missing data for this item)

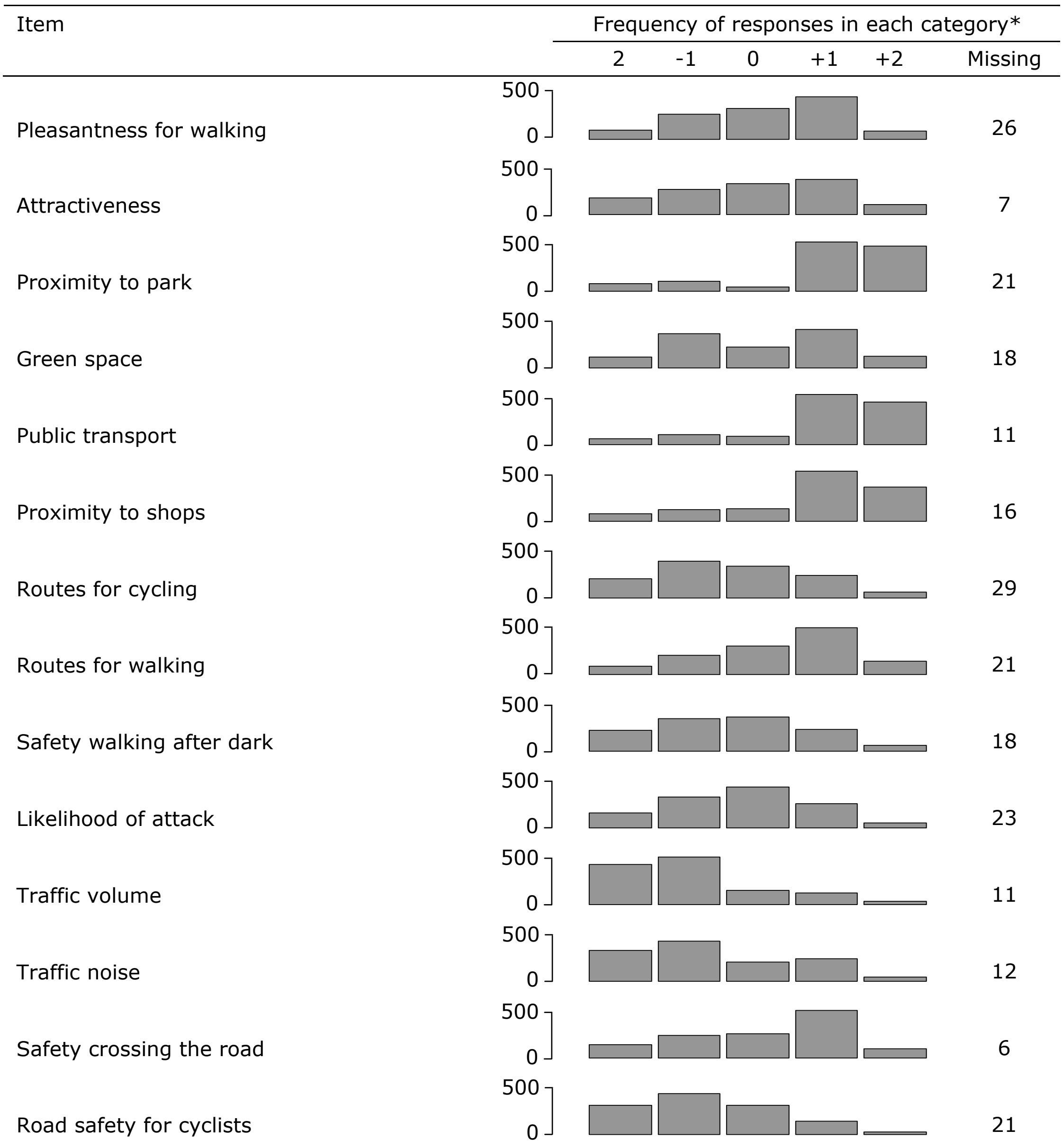
Figure 23. Distribution of duration of residence in local area

Response category on rating scale	Frequency (%)
1 (most favourable)	139 (10.5)
2	307 (23.3)
3	400 (30.3)
4	216 (16.4)
5	111 (8.4)
6	71 (5.4)
7 (least favourable)	74 (5.6)

n=1318 (4 respondents had missing data for this item)

Table 62. How respondents felt about living in their local area

The distributions of responses to each of the 14 items on the neighbourhood scale are summarised in the matrix of bar charts shown in Figure 24, responses to the negatively-worded items having been recoded so that for each item a value of +2 represents the most favourable response ('strongly agree' or 'strongly disagree', as appropriate), a value of -2 represents the least favourable response, and a value of zero represents a neutral response ('neither agree nor disagree'). The items which most often elicited the most favourable (+2) response were those on public transport and proximity to shops; the items which most often elicited the least favourable (-2) response were those on traffic volume, traffic noise and road safety for cyclists. The average summary neighbourhood score (the sum of these 14 individual items) was zero (mean score 0.2, standard deviation 7.2; median score 0.0, interquartile range 10.0). The cut-points defining the tertiles of the summary neighbourhood score were: upper tertile, +4 and above; middle tertile, -2 to +3 inclusive; lower tertile, -3 and below (Figure 25). There was a significant association between the tertile of summary neighbourhood score and the response to the question 'How do you feel about living in your local area?' (test for linear trend: χ^2=227.12, df=1; P<0.001) (Table 63).



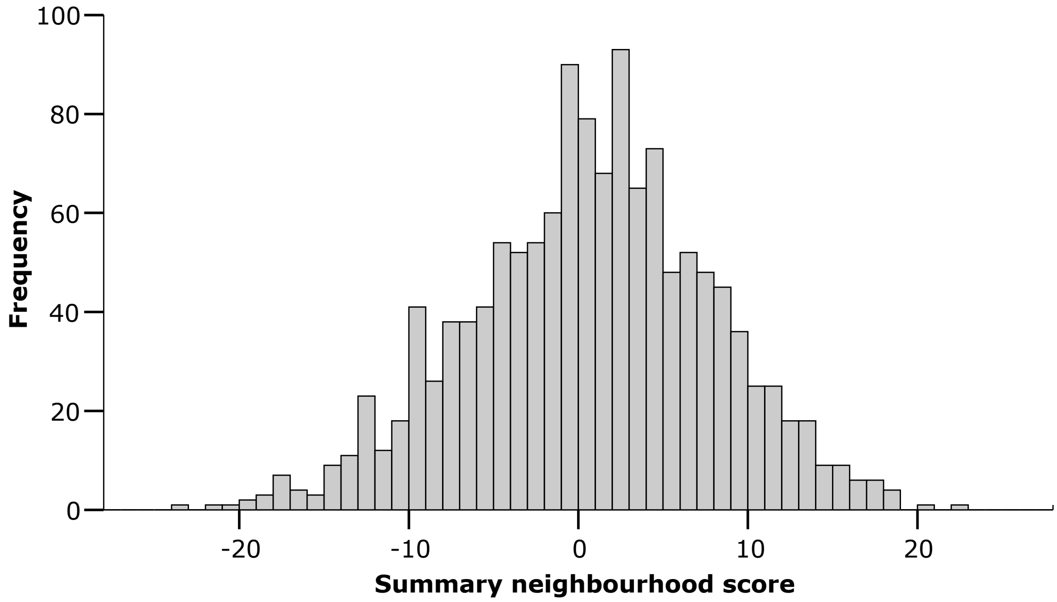
n=1322
* Items recoded such that +2 is the most favourable and -2 the least favourable response category for each item

Figure 24. Responses to individual items on neighbourhood scale

Tertile of summary neighbourhood score	'How do you feel about living in your local area?' Frequency (%) > midpoint of scale
Lowest	171/438 (39.0)
Middle	301/453 (66.4)
Highest	374/424 (88.2)

n=1315 (7 respondents had missing data for one or both items)

Table 63. Association between summary neighbourhood variables



n=1319 (3 respondents had missing data for all items contributing to this summary score)

Figure 25. Distribution of summary neighbourhood score

8.4.5 Travel diaries

77% of completed travel diaries were said to record journeys made on a weekday. Saturdays and Tuesdays appeared to be under-represented in the travel diaries compared to other days of the week (Table 64). 536 (41%) respondents described the day recorded in the travel diary as a normal working day; 452 (34%) considered this question inapplicable. The day of the week to which a respondent's travel diary was said to refer ('yesterday') was consistent with the numerical date on which the questionnaire was said to have been completed in 1069 (81%) of all 1322 responses.

Day of the week	Frequency (%)
Monday	195 (15.2)
Tuesday	126 (9.8)
Wednesday	203 (15.8)
Thursday	220 (17.2)
Friday	238 (18.6)
Saturday	96 (7.5)
Sunday	203 (15.8)

n=1281 (41 respondents had missing data for this item)

Table 64. Day of the week recorded in travel diaries

1232 (93%) of all 1322 respondents confirmed that they had been at home at some time on the day to which the travel diary referred. Ten responses were received in which a printing error had resulted in a partially or completely missing or illegible travel diary, and 33 responses contained travel diaries which I deemed implausible at the pre-coding stage on the grounds that the respondent appeared to have misinterpreted what was being asked (for example, recording what appeared to be a whole week's travel or a list of all regular journeys). I disregarded the travel diaries of all respondents who had not confirmed that they had been at home or who had returned a questionnaire with a missing, misprinted or implausible travel diary, leaving 1226 travel diaries suitable in principle for analysis.

Small numbers of respondents had recorded journeys whose purpose was either not stated (n=13) or outwith the scope of the travel diary: the latter group comprised journeys made in the course of work (n=8), shopping journeys in which walking around the shops appeared to have been included as part of the journey (n=14), going for a walk (n=19), or walking the dog (n=17). I deleted these journeys from the travel diaries before further analysis. After deletion of these ineligible journeys, the median number of journeys recorded by respondents was two; 10% of respondents reported no journeys, and 7% reported more than five journeys (Table 65).

Total number of journeys	Frequency (%)
None	125 (10.2)
One	235 (19.2)
Two	315 (25.7)
Three	207 (16.9)
Four	193 (15.7)
Five	68 (5.5)
Six to twelve	83 (6.8)

n=1226 (96 respondents returned travel diaries unsuitable for analysis)

Table 65. Total number of journeys recorded in travel diaries

Of these 1226 travel diaries, 583 (48%) included a shopping journey, 501 (41%) included a journey to or from the respondent's place of work or study and 108 (9%) included a journey escorting a child to or from school or childcare. Most respondents (673; 55%) recorded some travel on foot; nearly half of all respondents (595; 49%) recorded some travel by car; 463 (38%) recorded some travel by public transport; only 17 (1%) recorded any travel by bicycle.

Quantifying the amount of time spent travelling was complicated by the discovery that a small minority of respondents had misunderstood the instructions for the travel diary. For the purposes of travel time analysis, I disregarded the travel diaries of respondents who appeared to have recorded bus service numbers rather than the duration of travel by bus (n=34) or who had entered non-numeric data (usually ticks) rather than the duration of travel (n=98). This left 1099 travel diaries suitable for travel time analysis (the exclusion criteria were not mutually exclusive).

On average, respondents recorded about an hour's travel per day in total (mean 61.5 minutes, median 50.0 minutes), of which a minority was spent using active modes of transport (walking or cycling: mean 20.0 minutes, median 10.0 minutes) (Table 66). The distribution of travel time for each mode and for all modes combined showed a strong positive skew, such that the median travel time for most individual modes was zero. 304 respondents (28% of those returning travel diaries suitable for travel time analysis, or 31% excluding those who recorded no travel at all) recorded 30 minutes or more of active travel on the day of their travel diary. 294 (97%) of these 'active travellers' recorded at least 30 minutes of walking (with or without cycling in addition), whereas the remaining 10 recorded less than 30 minutes of walking but recorded sufficient cycling to bring their total active travel to at least 30 minutes. 506 respondents (46%, or 52% excluding the non-travellers) recorded a journey which involved walking for at least 10 minutes, whereas only 15 (1%) recorded a journey which involved cycling for at least 10 minutes. 90 (8%, or 9% excluding the non-travellers) recorded a car journey lasting five minutes or less, and 264 (24%, or 27% excluding the non-travellers) recorded a car journey lasting ten minutes or less.

Mode	All respondents reporting valid travel time data†			Excluding respondents who made no journeys‡		
	Mean (sd)	Median (IQR)	Proportion of total	Mean (sd)	Median (IQR)	Proportion of total
Car	24.4 (40.8)	0.0 (40.0)	39.7%	27.5 (42.3)	10.0 (43.0)	39.6%
Walking	19.2 (27.8)	10.0 (30.0)	31.2%	21.7 (28.6)	10.0 (31.0)	31.3%
Bus	14.6 (30.8)	0.0 (20.0)	23.7%	16.5 (32.2)	0.0 (20.0)	23.8%
Rail	1.8 (10.0)	0.0 (0.0)	2.9%	2.0 (10.6)	0.0 (0.0)	2.9%
Cycling	0.7 (7.3)	0.0 (0.0)	1.1%	0.8 (7.7)	0.0 (0.0)	1.2%
Motorcycle	0.1 (2.0)	0.0 (0.0)	0.2%	0.1 (2.1)	0.0 (0.0)	0.1%
Other	0.6 (9.4)	0.0 (0.0)	1.0%	0.7 (10.0)	0.0 (0.0)	1.0%
Active modes*	20.0 (28.5)	10.0 (30.0)	32.4%	22.5 (29.3)	10.0 (35.0)	32.4%
All modes combined	61.5 (53.2)	50.0 (63.0)	100.0%	69.4 (51.4)	60.0 (55.0)	100.0%

IQR: interquartile range. sd: standard deviation
* Walking and cycling combined
† n=1099 (223 respondents returned travel diaries unsuitable for travel time analysis)
‡ n=974 (125 of those returning travel diaries suitable for travel time analysis did not record any journeys on the day in question)

Table 66. Travel time by mode recorded in travel diaries

8.4.6 Physical activity

As specified in the IPAQ scoring protocol, I excluded from analysis 21 respondents who had reported more than 16 hours of physical activity per day, as well 468 respondents who had missing or internally inconsistent data on the frequency (days per week) or duration (hours or minutes per day) of any of the three components of physical activity (walking, moderate activity or vigorous activity). This left 833 respondents with physical activity data suitable for analysis. Also as specified in the IPAQ scoring protocol, I recoded reported durations of activity of less than 10 minutes to zero (n=6) and durations of greater than 180 minutes to 180 minutes (n=240). As with the travel time analysis, the distribution of IPAQ summary data showed a strong positive skew (Table 67, Figure 26, Figure 27). Only 38% of respondents with complete physical activity data were categorised as having reported 'sufficient' physical activity according to the IPAQ scoring protocol (those in the 'high' category) (Table 68).

Summary measure	Mean (sd)	Median (IQR)
Walking (min/week)	318.4 (366.1)	180.0 (375.0)
Total activity (MET-min/week)	3000.1 (3323.1)	1935.0 (3645.0)

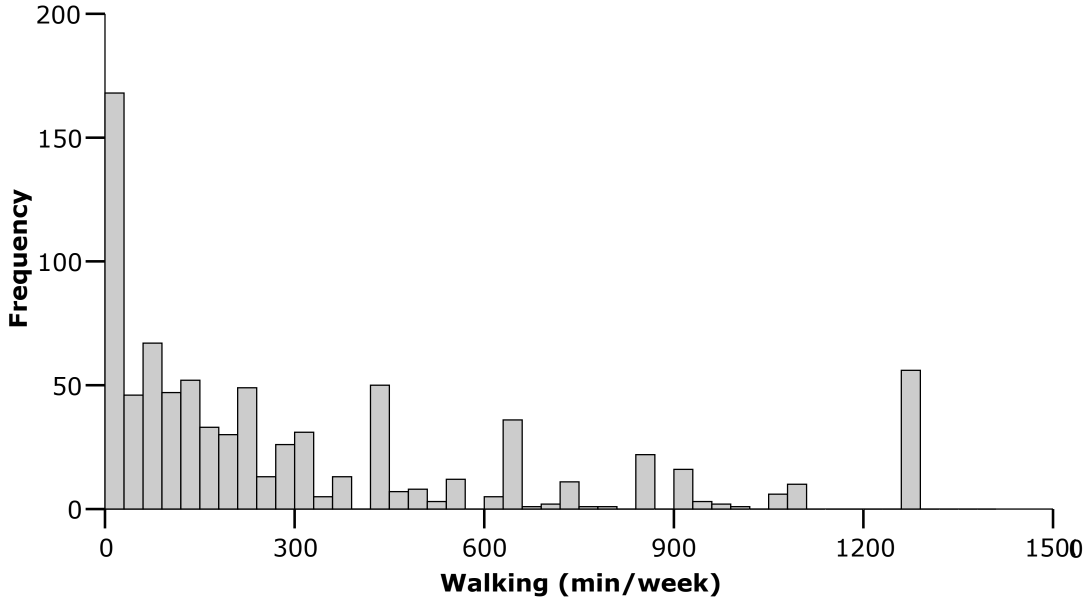
n=833 (489 respondents had missing, incomplete, internally inconsistent or implausible physical activity data)
IQR: interquartile range. sd: standard deviation

Table 67. Average time spent walking and overall physical activity

Physical activity category	Frequency (%)
Low	232 (27.9)
Moderate	285 (34.2)
High	316 (37.9)

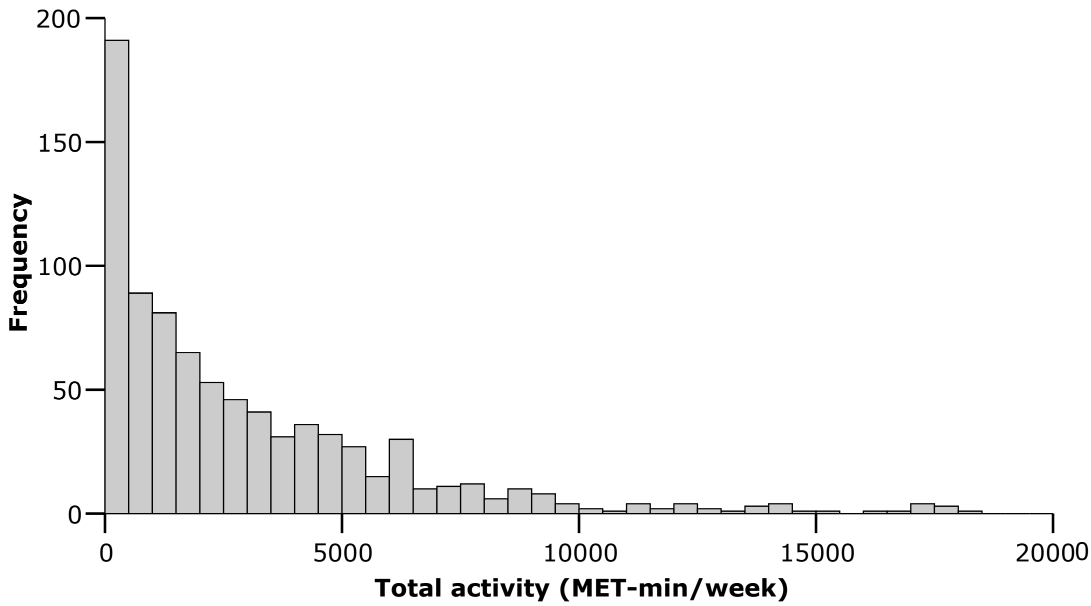
n=833 (489 respondents had missing, incomplete, internally inconsistent or implausible physical activity data)

Table 68. Categorisation of overall physical activity



n=833 (489 respondents had missing, incomplete, internally inconsistent or implausible physical activity data). The peak at 1260 min/week reflects the truncation of implausibly high reported quantities of walking at a maximum of 180 min/day as specified in the IPAQ scoring protocol

Figure 26. Distribution of time spent walking



n=833 (489 respondents had missing, incomplete, internally inconsistent or implausible physical activity data)

Figure 27. Distribution of overall physical activity

8.4.7 Estimating the contribution of active travel to physical activity

Overall, the mean time recorded in the travel diaries as having been spent travelling by active modes was 20 minutes per day, almost all of which was spent walking rather than cycling. Scaled up to a whole week, this suggested that walking as a mode of transport contributed about 40% of the total weekly time spent walking recorded using IPAQ, and that active travel accounted for an estimated mean weekly expenditure of 465 MET-minutes — about 15% of the mean total weekly MET-minutes recorded using IPAQ. For both walking and overall physical activity, the estimated proportional contribution of active travel was higher among women, younger people and those without access to a car (Table 69).

		Activity recorded using travel diary				Activity recorded using IPAQ			
		Walking		Active travel		Overall walking		Overall physical activity	
Group	N	Mean (min/day)	Mean (min/week)	Mean (min/day)	Estimated mean (MET-min/week)	Mean (min/week)	Estimated contribution of active travel	Mean (MET-min/week)	Estimated contribution of active travel
All	717	19.2	134.2	20.1	465.4	317.8	42.2%	3036.2	15.3%
Sex									
Male	301	16.2	113.7	18.3	423.9	344.7	33.0%	3213.4	13.2%
Female	416	21.3	149.0	21.4	495.5	298.3	49.9%	2907.9	17.0%
Age group									
16-39	281	25.1	175.6	26.8	619.7	303.3	57.9%	2999.0	20.7%
40-64	316	15.9	111.4	16.6	382.7	329.5	33.8%	3221.5	11.9%
65+	120	13.9	97.0	13.9	322.1	320.9	30.2%	2634.9	12.2%
Cars available to household									
None	301	26.9	188.2	27.6	638.2	336.1	56.0%	2756.1	23.2%
One	322	14.5	101.4	15.8	364.8	309.9	32.7%	3204.2	11.4%
Two or more	89	10.5	73.5	11.2	258.3	289.8	25.4%	3477.4	7.4%

n=717 (605 respondents had data unsuitable for travel time analysis, physical activity analysis or both)

Table 69. Estimated contribution of active travel to overall walking and overall physical activity

8.5 Local area study: comparison of study areas

8.5.1 Characteristics of respondents

A comparison of the distribution of the characteristics of respondents in the three study areas showed few differences. The null hypothesis of no difference between study areas in average age and duration of residence was supported irrespective of the choice between parametric (ANOVA) and non-parametric (Kruskal-Wallis) tests (Table 70). The null hypothesis of no difference between study areas in the distribution of characteristics represented by categorical variables (sex, distance to work or study, access to a bicycle, housing tenure, cars available, working situation, financial situation, health problem and difficulty walking) was supported except in the case of housing tenure (Table 71). Respondents in the east control area were less likely to be social tenants than those in the other two study areas; the association between housing tenure and study area was of borderline significance (χ^2=12.41, df=6; P=0.053) and was in the same direction as that expected from the aggregate census data used to select the study areas (Table 43 in Chapter 7).

Variable	ANOVA			Kruskal-Wallis test		
	F	df	P	χ^2	df	P
Age	0.15	2	0.87	0.22	2	0.90
Years living in local area	0.14	2	0.87	0.27	2	0.87

ANOVA: analysis of variance. *F*: F test. χ^2: chi-squared test. df: degrees of freedom

Table 70. Comparison of responses from the three study areas (1)

Variable	Category	Study area			Test result			
		South*	East*	North*	n	χ^2	df	P
Sex	Male	190 (43.5)	158 (36.9)	170 (37.2)	1322	5.06‡	2	0.08
Distance to work or study	Not applicable†	173 (43.4)	178 (45.4)	195 (46.2)	1213	0.53§	2	0.77
	Less than four miles†	114 (28.6)	109 (27.8)	112 (26.5)				
	Four miles or more†	112 (28.1)	105 (26.8)	115 (27.3)				
Access to a bicycle		94 (21.7)	82 (19.3)	105 (23.2)	1322	1.99‡	2	0.37
Housing tenure	Social rented	186 (42.9)	155 (36.6)	202 (44.2)	1314	9.34‡	4	0.053
	Owner-occupied	220 (50.7)	228 (53.9)	230 (50.3)				
	Other†	28 (6.5)	40 (9.5)	25 (5.5)				
Cars available	None	206 (48.4)	210 (49.8)	213 (47.1)	1300	0.73§	2	0.69
	One	163 (38.3)	169 (40.0)	193 (42.7)				
	Two or more†	57 (13.4)	43 (10.2)	46 (10.2)				
Working situation	Employed†	211 (49.2)	184 (43.4)	221 (48.8)	1306	6.36‡	4	0.17
	Retired	105 (24.5)	107 (25.2)	121 (26.7)				
	Other†	113 (26.3)	133 (31.4)	111 (24.5)				
Financial situation	Strain	71 (16.5)	79 (18.6)	83 (18.5)	1302	3.31§	2	0.19
	Careful	217 (50.5)	227 (53.5)	236 (52.7)				
	Manage	107 (24.9)	96 (22.6)	96 (21.4)				
	Comfortable	35 (8.1)	22 (5.2)	33 (7.4)				
Health problem	Yes	160 (37.4)	175 (42.0)	164 (36.7)	1292	2.95‡	2	0.23
Difficulty walking	Yes	108 (25.3)	115 (27.4)	102 (22.8)	1293	2.47‡	2	0.29

* Count (column %)
† Category created by collapsing original responses into fewer categories
‡ Simple chi-squared test
§ Kruskal-Wallis test to take account of ordering of categories
n: total number of respondents. $\chi2$: chi-squared test. df: degrees of freedom

Table 71. Comparison of responses from the three study areas (2)

8.5.2 Proximity to motorways and major roads

Most respondents had a unit postcode whose centroid lay within 300 metres of a major non-motorway road (an A- or B-class road) (Table 72). Respondents in the south study area were most likely to live close to an A or B road while those in the north study area were least likely to do so, reflecting the fact that the north area was defined by its proximity to a quiet suburban railway rather than to major roads.

In the east study area (the control area containing existing motorways) about a quarter of respondents had a unit postcode whose centroid lay within 200 metres of the route of a motorway and about 10% lived within an equivalent distance of a motorway access point. Respondents in this control area tended to live closer to a motorway (and, especially, closer to a motorway access point) than respondents in the intervention area did to the proposed route of or access points to the new motorway, reflecting the different spatial distributions of residential and non-residential development in the different study areas. Nonetheless, about three-quarters of respondents in the intervention area had a unit postcode whose centroid lay within 500 metres of the proposed route of the new motorway.

All respondents in the north study area had a unit postcode which lay more than 500 metres from both existing and proposed motorway infrastructure, confirming the correct spatial specification of this non-motorway control area.

	Study area		
	South*	East*	North*
Proximity to A or B road			
Within 100 metres	208 (47.6)	132 (30.8)	83 (18.2)
101-200 metres	141 (32.3)	98 (22.9)	91 (19.9)
201-300 metres	53 (12.1)	76 (17.8)	63 (13.8)
301-400 metres	16 (3.7)	44 (10.3)	67 (14.7)
401-500 metres	0 (0.0)	19 (4.4)	34 (7.4)
Over 500 metres	19 (4.3)	59 (13.8)	119 (26.0)
Total	437 (100.0)	428 (100.0)	457 (100.0)
Proximity to route of proposed† or existing‡ motorway			
Within 100 metres	5 (1.1)	34 (7.9)	—
101-200 metres	37 (8.5)	83 (19.4)	—
201-300 metres	91 (20.8)	74 (17.3)	—
301-400 metres	69 (15.8)	73 (17.1)	—
401-500 metres	123 (28.1)	99 (23.1)	—
Over 500 metres	112 (25.6)	65 (15.2)	457 (100.0)
Total	437 (100.0)	428 (100.0)	457 (100.0)
Proximity to proposed† or existing‡ motorway access point			
Within 100 metres	—	10 (2.3)	—
101-200 metres	1 (0.2)	33 (7.7)	—
201-300 metres	13 (3.0)	61 (14.3)	—
301-400 metres	12 (2.7)	60 (14.0)	—
401-500 metres	20 (4.6)	81 (18.9)	—
Over 500 metres	391 (89.5)	183 (42.8)	457 (100.0)
Total	437 (100.0)	428 (100.0)	457 (100.0)

n=1322
* Count (column %)
† Applies only to south study area
‡ Applies only to east and north study areas

Table 72. Proximity of respondents' homes to motorways and major roads

8.5.3 Travel diaries

About three-quarters of the usable travel diaries returned from each study area were said to record travel undertaken on a weekday (Table 73). There was no association between study area and the proportion of weekday responses (χ^2=1.72, df=2; P=0.42).

Study area	Frequency (%) of travel diaries completed on a weekday
South	258 (77.7)
East	243 (73.4)
North	252 (74.8)

n=1000, comprising respondents who both returned a travel diary suitable in principle for analysis (n=1226) and reported a day of the week consistent with the numerical date on their questionnaire (n=1069) (see Section 8.4.5)

Table 73. Travel diaries returned from the three study areas

8.6 Local area study: neighbourhood scale

Collinearity of items

A cross-tabulation of the Pearson correlation coefficients between the individual items on the neighbourhood scale showed little evidence of collinearity between the items: no pair of items had a correlation coefficient greater than 0.5, and most pairwise correlation coefficients were less than 0.2 (Table 74).

	Pleasantness for walking	Attractiveness	Proximity to park	Green space	Public transport	Proximity to shops	Routes for cycling	Routes for walking	Safety walking after dark	Likelihood of attack	Traffic volume	Traffic noise	Safety crossing the road
Attractiveness	0.48												
Proximity to park	0.23	0.16											
Green space	0.18	0.26	0.26										
Public transport	0.19	0.10	0.16	0.01									
Proximity to shops	0.06	0.09	0.19	0.16	0.16								
Routes for cycling	0.24	0.15	0.14	0.09	0.04	-0.06							
Routes for walking	0.29	0.33	0.23	0.29	0.13	0.29	0.17						
Safety walking after dark	0.37	0.27	0.18	0.10	0.15	0.05	0.22	0.13					
Likelihood of attack	0.33	0.38	0.06	0.21	0.04	0.06	0.15	0.24	0.42				
Traffic volume	0.18	0.08	-0.05	0.06	-0.14	-0.16	0.19	-0.03	0.16	0.13			
Traffic noise	0.11	0.18	-0.02	0.13	-0.17	-0.03	0.08	0.08	0.08	0.20	0.50		
Safety crossing the road	0.21	0.15	0.19	0.11	0.12	0.03	0.18	0.13	0.25	0.18	0.29	0.22	
Road safety for cyclists	0.14	0.18	-0.02	0.12	-0.08	-0.01	0.22	0.15	0.12	0.27	0.28	0.40	0.27

Table 74. Correlation matrix for neighbourhood scale items

Maximum-likelihood explanatory factor analysis

I specified that first one factor should be extracted, then two factors, and so on in an iterative fashion. I had to continue until eight latent factors had been extracted until the goodness-of-fit test ceased to indicate that the null hypothesis of adequate fit should be rejected (i.e. P>0.05) (Table 75). I decided that eight factors were too many to be useful and therefore disregarded these factors in subsequent analysis.

Number of factors extracted	Goodness-of-fit test		
	X^2	df	P
1	1412.72	77	<0.001
2	673.18	64	<0.001
3	420.89	52	<0.001
4	275.03	41	<0.001
5	156.99	31	<0.001
6	98.46	22	<0.001
7	50.60	14	<0.001
8	4.88	7	0.67

X^2: chi-squared test. df: degrees of freedom

Table 75. Results of maximum-likelihood exploratory factor analysis

Principal components analysis

To begin with, I ran a principal components analysis without specifying the number of components (factors) to be extracted. The program therefore extracted 14 components and returned satisfactory values for the tests to confirm that the data were suitable for principal components analysis: a value of 0.76 for the Kaiser-Meyer-Olkin measure of sampling adequacy, and a value of χ^2=3222.14 (df=91, P<0.001) for Bartlett's test of sphericity. [431] I then examined the eigenvalues associated with the extracted components (Table 76 and Figure 28).

Component number	Eigenvalue	Proportion of total variance explained	
		Individual	Cumulative
1	3.21	23.0%	23.0%
2	1.91	13.7%	36.6%
3	1.23	8.8%	45.4%
4	1.07	7.7%	53.1%
5	0.95	6.8%	59.8%
6	0.88	6.3%	66.1%
7	0.80	5.7%	71.8%
8	0.72	5.2%	77.0%
9	0.66	4.7%	81.7%
10	0.62	4.4%	86.1%
11	0.56	4.0%	90.1%
12	0.51	3.7%	93.8%
13	0.47	3.4%	97.1%
14	0.40	2.9%	100.0%

Table 76. Eigenvalues associated with principal components

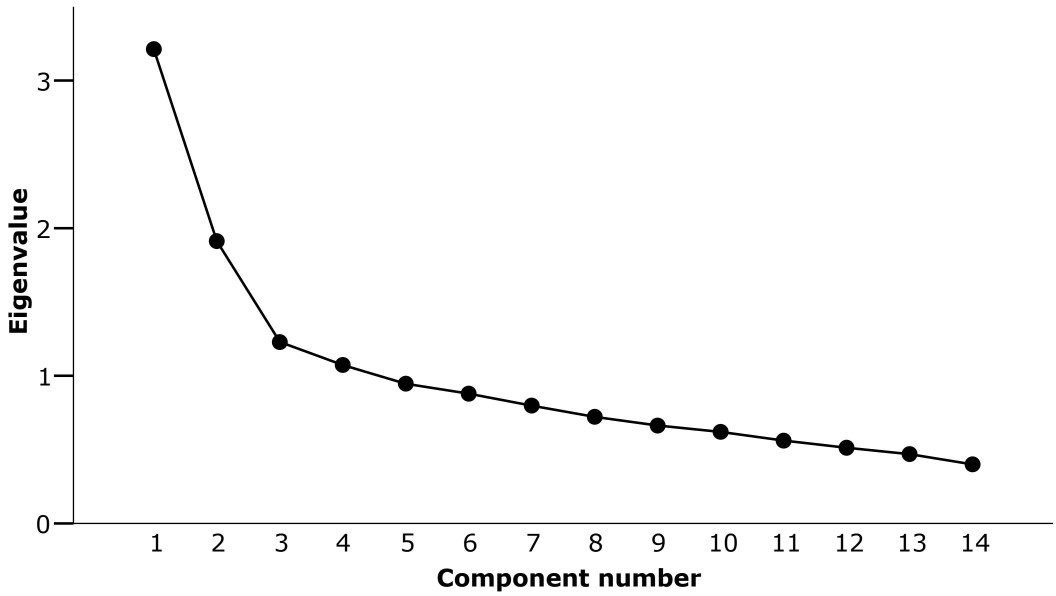


Figure 28. Scree plot of eigenvalues associated with principal components

I considered these data against three alternative criteria for selecting factors from this analysis: [431] (a) the scree plot showed a flattening of the eigenvalue curve after the first three factors, which together explained 45% of the variance; (b) the first four factors had an eigenvalue greater than 1, and together explained 53% of the variance; or (c) the first eight factors each explained at least 5% of the total variance, and together explained 77% of the variance. I decided that eight factors were too many to be useful and therefore chose to pursue a three- or four-factor solution.

I then repeated the analysis, specifying first a three- and then a four-factor solution and applying Varimax rotation to identify which variables were most strongly correlated with ('loaded on') the extracted factors. The rotated component matrices for the two solutions are shown in Table 77.

	Three-factor solution			Four-factor solution			
	Component number			Component number			
Item	1	2	3	1	2	3	4
Pleasantness for walking	0.69			0.67			
Attractiveness	0.49		0.42	0.70			
Proximity to park			0.45			0.49	0.53
Green space			0.64			0.62	
Public transport		-0.50			-0.43		0.52
Proximity to shops			0.66			0.68	
Routes for cycling	0.49						0.46
Routes for walking			0.70			0.65	
Safety walking after dark	0.73			0.63			
Likelihood of attack	0.54			0.74			
Traffic volume		0.67			0.72		
Traffic noise		0.79			0.80		
Safety crossing the road	0.49						0.66
Road safety for cyclists		0.64			0.65		

Correlation coefficients (loading factors) with absolute values of less than 0.4 omitted in the interests of clarity

Table 77. Varimax-rotated component matrices

I compared the rotated three- and four-factor solutions and concluded that, on balance, the first three factors of the four-factor solution constituted the most satisfactory set of factors for the following reasons:

1. There was no cross-loading of items between factors (in the three-factor solution, attractiveness 'loaded significantly' onto both the first and third factors)

2. The four items which 'loaded significantly' onto the first factor of the four-factor solution formed a more meaningful group of items than the six items which 'loaded significantly' onto the first factor of the three-factor solution.

I therefore defined the three principal components (factors) as comprising the groups of items listed in Table 78. I labelled the three factors to reflect the items which contributed to them as follows: factor 1, 'Safe and pleasant surroundings'; factor 2, 'Low traffic', and factor 3, 'Convenience for walking'.

Factor	Items contributing to factor	Direction of correlation
1	Pleasantness for walking	Positive
	Attractiveness	Positive
	Safety walking after dark	Positive
	Likelihood of attack	Positive
2	Public transport	Negative
	Traffic volume	Positive
	Traffic noise	Positive
	Road safety for cyclists	Positive
3	Proximity to park	Positive
	Green space	Positive
	Proximity to shops	Positive
	Routes for walking	Positive

Table 78. Neighbourhood factors identified using principal components analysis

I then calculated summary scores for each factor (subscale) by summing the scores for the individual items in each subscale, except that in calculating the summary score for factor (subscale) 2, I took the negative of the score for public transport because the correlation coefficient for that item was negative. I also calculated Cronbach's α as a measure of the internal consistency of each subscale (Table 79); by way of comparison, Cronbach's α for the summary neighbourhood score was 0.72. For research applications, values of 0.7 to 0.8 for Cronbach's α are regarded as satisfactory. [439] The Pearson correlation coefficients for the relationships between the summary scores for the subscales and the summary neighbourhood score are shown in Table 80.

Factor	Label	Mean (sd)	Median (IQR)	α
1	Safe and pleasant surroundings	-0.5 (3.2)	0.0 (5.0)	0.70
2	Low traffic	-3.2 (2.9)	-4.0 (4.0)	0.58
3	Convenience for walking	2.1 (3.0)	2.0 (4.0)	0.55

α: Cronbach's α. IQR: interquartile range. sd: standard deviation.

Table 79. Summary scores for neighbourhood subscales

Scale or subscale	Factor 1	Factor 2	Factor 3
Factor 2	0.17		
Factor 3	0.34	-0.03	
Overall score	0.79	0.37	0.65

Table 80. Correlation matrix for neighbourhood subscales

Cluster analysis

Two-step cluster analysis identified three clusters with or without an additional outlier cluster (Table 81).

Cluster number	Without outlier cluster*	With outlier cluster*
1	539 (40.8)	270 (20.4)
2	438 (33.1)	413 (31.2)
3	345 (26.1)	465 (35.2)
Outlier	—	174 (13.2)
Total	1322 (100.0)	1322 (100.0)

* Count (column %)

Table 81. Distribution of cluster membership

I decided to investigate further the simpler of the alternative outputs from the cluster analysis: the three-cluster model without an additional outlier cluster. Using the SPSS function *Variable Importance Plot*, I ranked the importance (χ^2 statistic) of each item on the neighbourhood scale in defining each cluster and summed these ranks across the three clusters. This showed that two variables, safety walking after dark and attractiveness of surroundings, appeared consistently as the first, second or third most important variable in defining each cluster.

I then compared the distribution of these variables between the three clusters. With respect to safety walking after dark, clusters 1 and 2 were dominated by more moderate responses (tending to the negative in cluster 1 and to the positive in cluster 2), whereas cluster 3 was characterised by more extreme responses at either end of the spectrum; with respect to attractiveness of surroundings, cluster 1 was dominated by moderate responses tending to the negative, cluster 2 by positive responses and cluster 3 by negative responses (Table 82).

Item	Proportion of responses by cluster				
	-2	-1	0	+1	+2
Safety walking after dark					
Cluster 1	19.7%	59.7%	56.8%	15.7%	9.0%
Cluster 2	2.9%	16.6%	38.6%	80.2%	22.4%
Cluster 3	77.3%	23.8%	4.7%	4.0%	68.7%
Attractiveness					
Cluster 1	16.9%	62.5%	59.2%	31.0%	2.7%
Cluster 2	5.3%	9.4%	25.5%	61.1%	65.5%
Cluster 3	77.8%	28.2%	15.3%	7.9%	31.8%

Table 82. Distribution of neighbourhood scale items between clusters

Test–retest reliability

660 respondents met the eligibility criteria and constituted the sampling frame for the test–retest survey. The cumulative frequency distribution for this group of respondents showed that the cut-points for the tertiles of age occurred at 38 years and 54 years. A stratified random sample of 200 members of this sampling frame received the retest questionnaire. Of these, 125 (63%) returned retest questionnaires in which every item had been answered and in which they had confirmed that they still lived at the same address. The achieved sample contained a balanced representation of men (n=63) and women (n=62) with an age distribution similar to that of the initial sample (mean 47.9 years, median 47.0 years).

The test–retest characteristics of each item on the neighbourhood scale are summarised in Table 83. The proportion of respondents who gave exactly the same response to a particular item at test and retest ranged from 40% (for the item ‘There is little green space’) to 66% (for the item ‘There is convenient public transport’). The constructs (pairs of items) most likely to elicit exactly the same response at retest were those concerned with access to amenities and with traffic; the constructs least likely to elicit a consistent response were those concerned with road safety and personal safety.

Test–retest correlation coefficients for each item ranged from 0.33 to 0.70 (Pearson), from 0.38 to 0.66 (Spearman), or from 0.34 to 0.70 (intraclass). The choice of method made little difference to the estimates of the coefficients; irrespective of method, the constructs (pairs of items) with the strongest test–retest correlations were those concerned with aesthetics and access to amenities; the constructs with the weakest correlations were those concerned with green space and convenience of routes.

The unweighted value of Cohen's κ for the chance-adjusted test–retest agreement for each item ranged from 0.18 to 0.50. Thirteen items had a value of κ of at least 0.20 ('fair' agreement), while three had a value of κ of at least 0.40 ('moderate' agreement): these were the two items concerned with access to amenities (both κ=0.50) and 'There is little traffic' (κ=0.40). After collapsing the five response categories into three categories (positive, neutral and negative), the recalculated values of Cohen's κ ranged from 0.24 to 0.59, with 8 of the 14 items having a recalculated value of κ of at least 0.40 ('moderate' agreement).

Item	Measure of test–retest agreement					
		Correlation coefficient			Cohen's κ	
	Exact agreement*	Pearson	Spearman	Intraclass	Original categories	Collapsed categories
Pleasantness for walking	62 (49.6)	0.64	0.63	0.64	0.32	0.44
Attractiveness	67 (53.6)	0.58	0.60	0.58	0.38	0.47
Proximity to park	75 (60.0)	0.54	0.54	0.54	0.38	0.47
Green space	50 (40.0)	0.36	0.38	0.36	0.18	0.24
Public transport	83 (66.4)	0.70	0.66	0.70	0.50	0.59
Proximity to shops	82 (65.6)	0.51	0.55	0.50	0.50	0.53
Routes for cycling	56 (44.8)	0.53	0.54	0.52	0.26	0.39
Routes for walking	66 (52.8)	0.33	0.40	0.34	0.34	0.36
Safety walking after dark	61 (48.8)	0.42	0.46	0.42	0.38	0.41
Likelihood of attack	62 (49.6)	0.68	0.66	0.67	0.32	0.42
Traffic volume	73 (58.4)	0.47	0.56	0.48	0.40	0.35
Traffic noise	68 (54.4)	0.63	0.64	0.62	0.38	0.53
Safety crossing the road	57 (45.6)	0.52	0.47	0.52	0.20	0.32
Road safety for cyclists	59 (47.2)	0.45	0.49	0.45	0.28	0.37

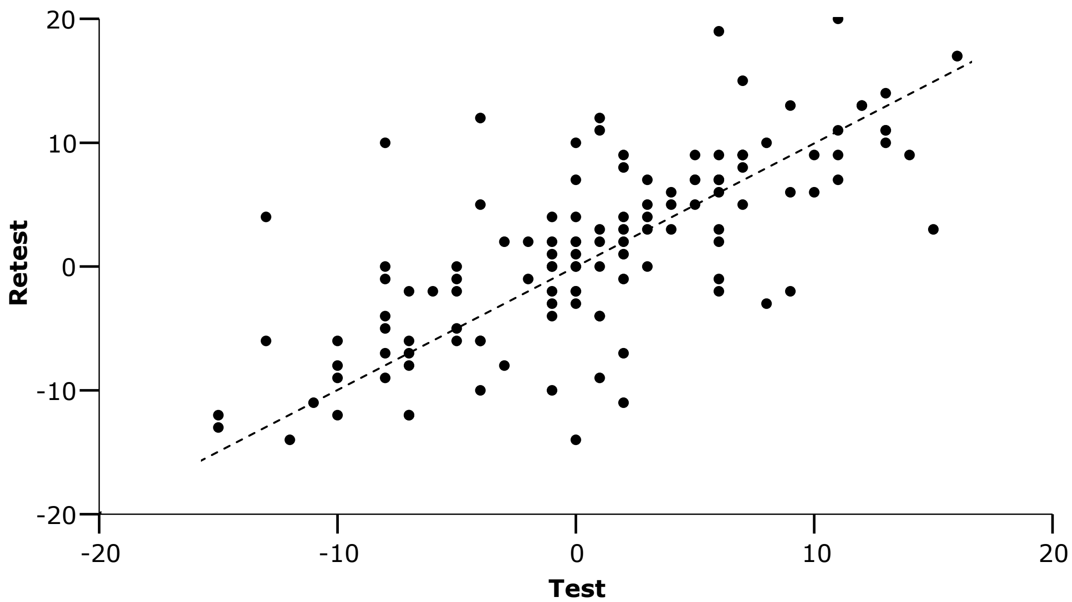
n=125
* Count (%)

Table 83. Test–retest relationships of items in neighbourhood scale

Test–retest comparison of responses on the seven-point rating scale to the question 'Which face shows best how you feel about living in your local area?' showed exact agreement in 63/125 (50.2%) cases and an unweighted Cohen's κ of 0.38. The test–retest correlation coefficients for this rating scale, and for the summary neighbourhood score and its subscales, are summarised in Table 84 and Figure 29.

Scale or subscale	Test–retest correlation coefficient		
	Pearson	Spearman	Intraclass
Which face shows best how you feel about living in your local area?			
Seven-point scale	0.80	0.78	0.80
Summary neighbourhood score			
Factor 1	0.75	0.72	0.75
Factor 2	0.75	0.76	0.75
Factor 3	0.57	0.59	0.57
Overall score	0.73	0.73	0.73

Table 84. Test–retest relationships of summary neighbourhood score and subscales



Dotted line indicates line of equality

Figure 29. Test and retest values for summary neighbourhood score

8.7 Local area study: regression modelling

8.7.1 Modelling the correlates of active travel

Model incorporating personal characteristics

Univariate relationships

I began with a series of univariate logistic regression analyses to examine the relationship between the dichotomous outcome of whether a respondent had reported 30 minutes or more of active travel in their travel diary (hereafter referred to as 'active travel') and each of the putative explanatory variables related to the demographic or socioeconomic characteristics of respondents or to their health and wellbeing, as well as two variables (whether they had recorded their travel on a weekday or at the weekend, and the study area of residence) to control for possible effects of sampling variations. The results of these analyses are summarised in Table 85.

Variable	n or frequency (%)*	OR (95% CI)	P
Demographic and socioeconomic			
Age	1099	0.98 (0.97, 0.99)	<0.001
Sex			
Male (0)	116/431 (26.9)	1.00	
Female (1)	188/668 (28.1)	1.06 (0.81, 1.40)	0.66
Housing tenure			
Social renter (0)	109/443 (24.6)	1.00	
Owner-occupier (1)	162/578 (28.0)	1.19 (0.90, 1.58)	0.22
Other (2)	33/74 (44.6)	2.47 (1.49, 4.09)	<0.001
Financial situation			
Comfortable (0)	20/77 (26.0)	1.00	
Manage (3)	64/257 (24.9)	0.95 (0.53, 1.69)	0.85
Careful (2)	164/557 (29.4)	1.19 (0.69, 2.04)	0.53
Strain (1)	56/194 (28.9)	1.16 (0.64, 2.10)	0.63
Working situation			
Retired (0)	55/260 (21.2)	1.00	
Employed (1)	150/531 (28.2)	1.47 (1.03, 2.09)	0.033
Other (2)	99/297 (33.3)	1.86 (1.27, 2.73)	0.001
Distance to work or study			
Four miles or more (0)	66/284 (23.2)	1.00	
Less than four miles (2)	109/288 (37.8)	2.01 (1.40, 2.90)	<0.001
Not applicable (1)	118/449 (26.3)	1.18 (0.83, 1.67)	0.36
Access to bicycle			
No (0)	218/848 (25.7)	1.00	
Yes (1)	86/244 (35.2)	1.57 (1.16, 2.13)	0.004
Cars available			
Two to four (0)	22/124 (17.7)	1.00	
One (2)	96/447 (21.5)	1.27 (0.76, 2.12)	0.36
None (1)	185/515 (35.9)	2.60 (1.59, 4.26)	<0.001

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 85. Active travel: proportions and unadjusted odds ratios (1)

Variable	n or frequency (%)*	OR (95% CI)	P
Health and wellbeing			
How they felt about their life	1083	0.87 (0.79, 0.96)	0.005
Physical health summary score (PCS-8)	1065	1.03 (1.02, 1.05)	<0.001
Mental health summary score (MCS-8)	1065	1.02 (1.00, 1.03)	0.014
Body mass index (BMI)	1063	0.99 (0.96, 1.01)	0.33
Quintile of BMI			
Highest (0)	49/204 (24.0)	1.00	
Second highest (4)	57/215 (26.5)	1.14 (0.73, 1.77)	0.56
Middle (3)	62/218 (28.4)	1.26 (0.81, 1.94)	0.30
Second lowest (2)	57/216 (26.4)	1.13 (0.73, 1.76)	0.58
Lowest (1)	70/210 (33.3)	1.58 (1.03, 2.43)	0.037
Long-term health problem			
Yes (0)	81/406 (20.0)	1.00	
No (1)	221/681 (32.5)	1.93 (1.44, 2.58)	<0.001
Difficulty walking			
Yes (0)	30/254 (11.8)	1.00	
No (1)	271/827 (32.8)	3.64 (2.42, 5.47)	<0.001
Control variables			
Day of travel diary			
Weekend (0)	43/220 (19.5)	1.00	
Weekday (1)	212/686 (30.9)	1.84 (1.27, 2.67)	0.001
Study area			
South (0)	111/374 (29.7)	1.00	
East (1)	97/347 (28.0)	0.92 (0.67, 1.27)	0.61
North (2)	96/378 (25.4)	0.81 (0.59, 1.11)	0.19

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 85. Active travel: proportions and unadjusted odds ratios (1) (continued)

From the results of these univariate analyses, using the generous criterion of P<0.25 recommended by Hosmer and Lemeshow [435] I selected the following variables for entry to the multivariate model: age, housing tenure, working situation, distance to work or study, access to a bicycle, and cars available, as well as two variables representing day of travel diary and study area to control for possible effects of sampling variation. Financial situation did not appear to be significantly associated with active travel. Body mass index (BMI) was not significantly associated with active travel when treated as a continuous variable, but there was a significant difference in the odds of active travel between the highest and lowest quintiles of BMI; I therefore also entered quintile of BMI in the multivariate model. From the other variables pertaining to health and wellbeing, which I had previously shown to be associated with each other, I selected difficulty walking for entry to the multivariate model, since this was the variable associated with a larger crude odds ratio (3.64) than any other categorical variable under consideration and was also the 'health' variable with the strongest intuitive association with active travel. I also entered sex because the associations between walking and environmental characteristics have been shown to vary between the sexes in some studies. [20]

Multivariate model

When I entered all of these provisionally-significant variables in a multivariate model, four variables (sex, working situation, quintile of BMI, and study area of residence) did not appear to be significant after adjustment for the other variables (Table 86). I therefore removed these four variables and refitted the model including only age, housing tenure, distance to work or study, access to a bicycle, cars available and difficulty walking, along with the control variable representing day of travel diary (Table 87).

Variable	ß	se	Wald	df	OR (95% CI)	P
Age	-0.016	0.008	3.884	1	0.98 (0.97, 1.00)	0.049
Sex (reference: male)						
Female (1)	-0.006	0.175	0.001	1	0.99 (0.71, 1.40)	0.97
Housing tenure (reference: social renter)						
Owner-occupier (1)	0.681	0.218	9.777	1	1.98 (1.29, 3.03)	0.002
Other (2)	0.594	0.370	2.568	1	1.81 (0.88, 3.74)	0.11
Working situation (reference: retired)						
Employed (1)	-0.168	0.428	0.154	1	0.85 (0.37, 1.95)	0.69
Other (2)	0.252	0.348	0.526	1	1.29 (0.65, 2.54)	0.47
Distance to work or study (reference: four miles or more)						
Less than four miles (2)	0.496	0.220	5.087	1	1.64 (1.07, 2.52)	0.024
Not applicable (1)	0.435	0.386	1.269	1	1.55 (0.72, 3.30)	0.26
Access to bicycle (reference: no)						
Yes (1)	0.531	0.210	6.416	1	1.70 (1.13, 2.57)	0.011
Cars available (reference: two to four)						
One (2)	0.411	0.301	1.870	1	1.51 (0.84, 2.72)	0.17
None (1)	1.592	0.330	23.343	1	4.91 (2.58, 9.38)	<0.001
Difficulty walking (reference: yes)						
No (1)	1.241	0.287	18.658	1	3.46 (1.97, 6.07)	<0.001
Quintile of BMI (reference: highest)						
Second highest (4)	0.327	0.283	1.340	1	1.39 (0.80, 2.42)	0.25
Middle (3)	0.016	0.289	0.003	1	1.02 (0.58, 1.79)	0.95
Second lowest (2)	0.127	0.287	0.194	1	1.14 (0.65, 1.99)	0.66
Lowest (1)	0.295	0.287	1.059	1	1.34 (0.77, 2.36)	0.30
Day of travel diary (reference: weekend)						
Weekday (1)	0.692	0.214	10.419	1	2.00 (1.31, 3.04)	0.001
Study area (reference: south)						
East (1)	-0.269	0.209	1.664	1	0.76 (0.51, 1.15)	0.20
North (2)	-0.301	0.204	2.173	1	0.74 (0.50, 1.10)	0.14

n=809. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 86. Partially-adjusted multivariate model for active travel (1)

Variable	ß	se	Wald	df	OR (95% CI)	P
Age	-0.022	0.006	12.320	1	0.98 (0.97, 0.99)	<0.001
Housing tenure (reference: social renter)						
Owner-occupier (1)	0.584	0.209	7.822	1	1.79 (1.19, 2.70)	0.005
Other (2)	0.486	0.350	1.923	1	1.62 (0.82, 3.23)	0.17
Distance to work or study (reference: four miles or more)						
Less than four miles (2)	0.519	0.216	5.778	1	1.68 (1.10, 2.56)	0.016
Not applicable (1)	0.708	0.262	7.310	1	2.03 (1.22, 3.39)	0.007
Access to bicycle (reference: no)						
Yes (1)	0.513	0.203	6.363	1	1.67 (1.12, 2.49)	0.012
Cars available (reference: two to four)						
One (2)	0.434	0.296	2.154	1	1.54 (0.86, 2.76)	0.14
None (1)	1.599	0.321	24.878	1	4.95 (2.64, 9.28)	<0.001
Difficulty walking (reference: yes)						
No (1)	1.180	0.269	19.299	1	3.25 (1.92, 5.51)	<0.001
Day of travel diary (reference: weekend)						
Weekday (1)	0.679	0.210	10.477	1	1.97 (1.31, 2.97)	0.001

n=831. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 87. Partially-adjusted multivariate model for active travel (2)

Interaction terms

I considered the possibility of interaction between the two variables reflecting access to particular modes of transport (bicycles and cars) and between each of those variables and age, distance to work or study, and difficulty walking. I added interaction terms for each pairwise combination of these variables to the model, one at a time. The P-values for six of these seven interaction terms were all greater than 0.1, but one interaction term appeared potentially significant when added to the model: the interaction between the number of cars available and difficulty walking (P=0.054), although adding this interaction term made little difference to the estimated odds ratios for the other variables included in the model. In order to aid interpretation, I collapsed this pair of interacting variables into a single 2 x 2 composite variable and refitted the model (Table 88). This final best model of the personal correlates of active travel provided satisfactory goodness-of-fit (Hosmer and Lemeshow test: χ^2=13.04, df=8; P=0.11) and explained nearly one-fifth of the total variance in active travel (Nagelkerke's R^2=18.7%).

Variable	ß	se	Wald	df	OR (95% CI)	P
Age	-0.022	0.006	12.398	1	0.98 (0.97, 0.99)	<0.001
Housing tenure (reference: social renter)						
Owner-occupier (1)	0.580	0.209	7.708	1	1.79 (1.19, 2.69)	0.005
Other (2)	0.492	0.349	1.988	1	1.64 (0.83, 3.24)	0.159
Distance to work or study (reference: four miles or more)						
Less than four miles (2)	0.565	0.214	6.945	1	1.76 (1.16, 2.68)	0.008
Not applicable (1)	0.750	0.262	8.173	1	2.12 (1.27, 3.54)	0.004
Access to bicycle (reference: no)						
Yes (1)	0.461	0.200	5.304	1	1.59 (1.07, 2.35)	0.021
Composite variable (reference: access to car and difficulty walking)						
Car, no difficulty (3)	1.438	0.552	6.792	1	4.21 (1.43, 12,43)	0.009
No car, difficulty (2)	1.536	0.582	6.961	1	4.65 (1.48, 14.54)	0.008
No car, no difficulty (1)	2.643	0.544	23.639	1	14.06 (4.84, 40.80)	<0.001
Day of travel diary (reference: weekend)						
Weekday (1)	0.674	0.209	10.371	1	1.96 (1.32, 3.00)	0.001

n=831. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 88. Partially-adjusted multivariate model for active travel (3)

Model incorporating environmental characteristics

Univariate relationships

I continued with a series of univariate logistic regression analyses to examine the relationship between active travel and each of the putative explanatory variables related to the objective or subjective characteristics of respondents' environments. The results of these analyses are summarised in Table 89.

Following the same principles as I applied for the personal variables, I selected the following variables for entry to the multivariate model: proximity to any major road; four individual items from the neighbourhood scale (attractiveness, proximity to a park, proximity to shops, and road safety for cyclists); tertile of summary neighbourhood score; the neighbourhood subscale scores derived from the principal components analysis; and the cluster memberships derived from the second two-step cluster analysis. Proximity to a motorway, how people felt about living in their local area on the seven-point rating scale, and the summary neighbourhood score treated as a continuous variable did not appear to be significantly associated with active travel.

Variable	n or frequency (%)*	OR (95% CI)	P
Objective			
Proximity to any existing motorway infrastructure			
Within 100 m (0)	9/30 (30.0)	1.00	
101-200 m (1)	14/64 (21.9)	0.65 (0.25, 1.74)	0.39
201-300 m (2)	20/61 (32.8)	1.14 (0.44, 2.93)	0.79
301-400 m (3)	21/62 (33.9)	1.20 (0.47, 3.06)	0.71
400-500 m (4)	18/80 (22.5)	0.68 (0.26, 1.74)	0.42
Over 500 m (5)	222/802 (27.7)	0.89 (0.40, 1.98)	0.78
Proximity to any existing major road infrastructure			
Within 100 m (0)	112/375 (29.9)	1.00	
101-200 m (1)	84/302 (27.8)	0.90 (0.65, 1.26)	0.56
201-300 m (2)	42/149 (28.2)	0.92 (0.61, 1.40)	0.70
301-400 m (3)	24/99 (24.2)	0.75 (0.45, 1.25)	0.27
401-500 m (4)	8/54 (14.8)	0.41 (0.19, 0.89)	0.025
Over 500 m (5)	34/120 (28.3)	0.93 (0.59, 1.46)	0.75

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 89. Active travel: proportions and unadjusted odds ratios (2)

Variable	n or frequency (%)*	OR (95% CI)	P
Subjective			
How they felt about their local area	1097	1.02 (0.94, 1.11)	0.58
Individual items in neighbourhood scale			
Pleasantness for walking	1099	0.97 (0.85, 1.10)	0.60
Attractiveness	1099	0.92 (0.83, 1.03)	0.16
Proximity to park	1099	1.13 (1.00, 1.28)	0.052
Green space	1099	1.03 (0.92, 1.15)	0.63
Public transport	1099	1.07 (0.95, 1.22)	0.26
Proximity to shops	1099	1.29 (1.14, 1.47)	<0.001
Routes for cycling	1099	1.03 (0.91, 1.16)	0.68
Routes for walking	1099	1.04 (0.92, 1.18)	0.55
Safety walking after dark	1099	1.06 (0.94, 1.19)	0.35
Likelihood of attack	1099	1.01 (0.89, 1.15)	0.87
Traffic volume	1099	0.97 (0.85, 1.11)	0.69
Traffic noise	1099	0.95 (0.85, 1.07)	0.38
Safety crossing the road	1099	1.02 (0.91, 1.15)	0.74
Road safety for cyclists	1099	0.88 (0.77, 1.00)	0.056
Summary neighbourhood score	1099	1.01 (0.99, 1.03)	0.44
Tertile of summary neighbourhood score			
Lowest (0)	92/366 (25.1)	1.00	
Middle (1)	106/365 (29.0)	1.22 (0.88, 1.69)	0.24
Highest (2)	106/367 (28.9)	1.21 (0.87, 1.68)	0.25
Neighbourhood subscale summary scores			
Factor 1	1099	0.99 (0.95, 1.04)	0.75
Factor 2	1099	0.96 (0.92, 1.01)	0.11
Factor 3	1099	1.07 (1.02, 1.12)	0.007
Cluster membership (without outlier cluster)			
Third cluster (0)	74/277 (26.7)	1.00	
First cluster (1)	118/446 (26.5)	0.99 (0.70, 1.39)	0.94
Second cluster (2)	112/376 (29.8)	1.16 (0.82, 1.64)	0.39
Cluster membership (with outlier cluster)			
Third cluster (0)	129/406 (31.8)	1.00	
First cluster (2)	55/229 (24.0)	0.68 (0.47, 0.98)	0.039
Second cluster (3)	90/336 (26.8)	0.79 (0.57, 1.08)	0.14
Outlier cluster (1)	30/128 (23.4)	0.66 (0.42, 1.04)	0.073

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 89. Active travel: proportions and unadjusted odds ratios (2) (continued)

Contribution to multivariate model

I added each of these environmental variables to the multivariate model, one at a time. In most cases (attractiveness, proximity to a park, tertile of summary neighbourhood score, cluster membership, and the subscale summary scores for factors 1 and 3), the P-values for these variables when added to the model were greater than 0.1, or in other words, these variables were no longer signficantly associated with active travel after adjusting for personal characteristics. I identified four variables worthy of further consideration for addition to the final model: proximity to any major road, proximity to shops, road safety for cyclists, and the subscale summary score for factor 2 (Table 90). However, the 'significant' result for proximity to any major road was confined to the comparison between one small category (401 to 500 metres) and the reference category (within 100 metres); there was no suggestion of a linear trend in the odds ratio with increasing distance. Furthermore, the P-values for the single neighbourhood scale items (proximity to shops, P=0.030; road safety for cyclists, P=0.023) were substantially smaller than that for the subscale summary score for factor 2 (P=0.086), and road safety for cyclists was one of the variables included in factor 2. I therefore concluded that only two environmental variables — proximity to shops, and road safety for cyclists — should be entered in the final model.

Variable	ß	se	Wald	df	OR (95% CI)	P
Proximity to any existing major road infrastructure (reference: within 100 m)						
101-200 m (1)	-0.013	0.208	0.004	1	0.99 (0.66, 1.48)	0.95
201-300 m (2)	-0.019	0.253	0.006	1	0.98 (0.60, 1.61)	0.94
301-400 m (3)	-0.235	0.328	0.513	1	0.79 (0.42, 1.50)	0.47
401-500 m (4)	-1.370	0.577	5.642	1	0.25 (0.08, 0.79)	0.018
Over 500 m (5)	-0.029	0.292	0.010	1	0.97 (0.55, 1.72)	0.92
Individual items in neighbourhood scale						
Proximity to shops	0.181	0.083	4.715	1	1.20 (1.02, 1.41)	0.030
Road safety for cyclists	-0.191	0.084	5.147	1	0.83 (0.70, 0.97)	0.023
Neighbourhood subscale summary scores						
Factor 2	-0.051	0.030	2.956	1	0.95 (0.90, 1.01)	0.086

Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 90. Regression coefficients for individual environmental variables added to model including personal variables

Final model

I therefore fitted a final model containing the following variables: age, housing tenure, distance to work or study, access to a bicycle, the composite variable reflecting the interaction between cars available and difficulty walking, day of travel diary, proximity to shops, and road safety for cyclists (Table 91). This final best model of the personal and environmental correlates of active travel provided satisfactory goodness-of-fit (Hosmer and Lemeshow test: χ^2=10.61, df=8; P=0.23) and explained slightly more of the total variance in active travel than did the personal model alone (Nagelkerke's R^2=20.1%). In order to aid the interpretation of the interaction term and to examine any potential interaction between the two selected environmental variables and car availability, I also partitioned the dataset into two strata ('No car available' and 'Car available') and refitted the final model separately to each stratum of the dataset (Table 92). In order to show how multivariate adjustment influenced the estimated odds ratios for each variable, I also refitted the earlier stages of the model to the subset of respondents with non-missing data for all variables included in the final model (Table 93).

Variable	ß	se	Wald	df	OR (95% CI)	P
Age	-0.021	0.006	11.052	1	0.98 (0.97, 0.99)	0.001
Housing tenure (reference: social renter)						
Owner-occupier (1)	0.532	0.211	6.348	1	1.70 (1.13, 2.58)	0.012
Other (2)	0.480	0.353	1.848	1	1.62 (0.81, 3.23)	0.17
Distance to work or study (reference: four miles or more)						
Less than four miles (2)	0.591	0.216	7.470	1	1.81 (1.18, 2.76)	0.006
Not applicable (1)	0.765	0.264	8.386	1	2.15 (1.28, 3.61)	0.004
Access to bicycle (reference: no)						
Yes (1)	0.451	0.201	5.033	1	1.57 (1.06, 2.33)	0.025
Composite variable (reference: access to car and difficulty walking)						
Car, no difficulty (3)	1.328	0.556	5.703	1	3.77 (1.27, 11.23)	0.017
No car, difficulty (2)	1.486	0.585	6.449	1	4.42 (1.40, 13.92)	0.011
No car, no difficulty (1)	2.556	0.547	21.804	1	12.88 (4.41, 37.67)	<0.001
Individual items in neighbourhood scale						
Proximity to shops	0.179	0.083	4.644	1	1.20 (1.02, 1.41)	0.031
Road safety for cyclists	-0.191	0.085	5.074	1	0.83 (0.70, 0.98)	0.024
Day of travel diary (reference: weekend)						
Weekday (1)	0.647	0.211	9.381	1	1.91 (1.26, 2.89)	0.002

Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio.

Table 91. Fully-adjusted multivariate model for active travel

Variable	ß	se	Wald	df	OR (95% CI)	P
No car available						
Age	-0.018	0.008	4.762	1	0.98 (0.97, 1.00)	0.029
Housing tenure (reference: social renter)						
Owner-occupier (1)	0.454	0.265	2.934	1	1.57 (0.94, 2.65)	0.087
Other (2)	0.397	0.453	0.766	1	1.49 (0.61, 3.62)	0.38
Distance to work or study (reference: four miles or more)						
Less than four miles (2)	0.184	0.379	0.235	1	1.20 (0.57, 2.53)	0.63
Not applicable (1)	0.002	0.381	0.000	1	1.00 (0.48, 2.11)	1.00
Access to bicycle (reference: no)						
Yes (1)	0.775	0.348	4.969	1	2.17 (1.10, 4.29)	0.026
Difficulty walking (reference: yes)						
No (1)	0.911	0.310	8.619	1	2.49 (1.35, 4.57)	0.003
Individual items in neighbourhood scale						
Proximity to shops	0.096	0.112	0.738	1	1.10 (0.88, 1.37)	0.39
Road safety for cyclists	-0.118	0.117	1.021	1	0.89 (0.71, 1.12)	0.31
Day of travel diary (reference: weekend)						
Weekday (1)	0.203	0.278	0.532	1	1.22 (0.71, 2.11)	0.47
Car available						
Age	-0.028	0.010	7.132	1	0.97 (0.95, 0.99)	0.008
Housing tenure (reference: social renter)						
Owner-occupier (1)	0.570	0.369	2.391	1	1.77 (0.86, 3.64)	0.12
Other (2)	0.496	0.598	0.689	1	1.64 (0.51, 5.30)	0.41
Distance to work or study (reference: four miles or more)						
Less than four miles (2)	0.672	0.277	5.904	1	1.96 (1.14, 3.37)	0.015
Not applicable (1)	1.577	0.402	15.362	1	4.84 (2.20, 10.66)	<0.001
Access to bicycle (reference: no)						
Yes (1)	0.358	0.259	1.912	1	1.43 (0.86, 2.38)	0.17
Difficulty walking (reference: yes)						
No (1)	1.722	0.595	8.367	1	5.60 (1.74, 17.98)	0.004
Individual items in neighbourhood scale						
Proximity to shops	0.290	0.135	4.619	1	1.34 (1.03, 1.74)	0.032
Road safety for cyclists	-0.264	0.127	4.319	1	0.77 (0.06, 0.99)	0.038
Day of travel diary (reference: weekend)						
Weekday (1)	1.201	0.367	10.697	1	3.32 (1.62, 6.82)	0.001

Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio.

Table 92. Stratified fully-adjusted multivariate model for active travel

Variable	Estimated odds ratio: Crude	Partially-adjusted model*	Fully-adjusted model†	P†
Age	0.98	0.98	0.98	0.001
Housing tenure (reference: social renter)				
Owner-occupier (1)	1.12	1.79	1.70	0.012
Other (2)	1.82	1.64	1.62	0.17
Distance to work or study (reference: four miles or more)				
Less than four miles (2)	2.01	1.76	1.81	0.006
Not applicable (1)	1.18	2.12	2.15	0.004
Access to bicycle (reference: no)				
Yes (1)	1.55	1.59	1.57	0.025
Composite variable (reference: access to car and difficulty walking)				
Car, no difficulty (3)	5.48	4.21	3.77	0.017
No car, difficulty (2)	3.63	4.65	4.42	0.011
No car, no difficulty (1)	14.68	14.06	12.88	<0.001
Individual items in neighbourhood scale				
Proximity to shops	1.31	—	1.20	0.031
Road safety for cyclists	0.87	—	0.83	0.024
Day of travel diary (reference: weekend)				
Weekday (1)	1.85	1.96	1.91	0.002
Summary measures of performance of model				
Nagelkerke's R^2		18.7%	20.1%	
Omnibus test		P<0.001	P<0.001	
Goodness-of-fit‡		P=0.11	P=0.23	

n=831. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables
* Model including and adjusting for all other personal characteristics and day of travel but not perceptions of the local environment
† Final model including and adjusting for all other personal characteristics, day of travel, and perceptions of the local environment
‡ Hosmer and Lemeshow test

Table 93. Effect of multivariate adjustment on estimated odds ratios for active travel

Summary of regression model for active travel

Respondents were almost twice as likely (estimated odds ratio 1.91) to be classified as active travellers if they had recorded their travel diary on a weekday rather than at the weekend. After adjustment for day of travel, study area of residence and personal characteristics, the final model indicated that active travel was significantly associated with younger age (estimated odds ratio 1.02 per one-year decrease in age); living in owner-occupied accommodation (estimated odds ratio 1.70 compared with social-rented accommodation); travelling less than four miles, or not travelling at all, to a place of work or study (estimated odds ratios 1.81 and 2.15 respectively compared with travelling four miles or more); having access to a bicycle (estimated odds ratio 1.57); perceiving that the nearest shops were within walking distance (estimated odds ratio 1.20 per unit of five-point rating scale); and perceiving that the local roads were dangerous for cyclists (estimated odds ratio 1.20 per unit of five-point rating scale). Including these latter two measures of perceptions of the local environment contributed a small increase in the proportion of the total variance in active travel explained by the model, from 18.7% to 20.1%. Multivariate adjustment somewhat enhanced the strength of association with owner-occupied housing tenure and not travelling to work or study compared with the crude odds ratios associated with those characteristics.

Active travel was also significantly associated with not having access to a car and with not reporting difficulty walking for a quarter of a mile; an interaction of borderline signficance (P=0.054) was found between these two explanatory variables in the multivariate model. The odds of active travel were highest among respondents with neither access to a car nor difficulty walking (estimated odds ratio 12.88 compared with those who had access to a car and reported difficulty walking). The odds of active travel in the intermediate categories — respondents who had access to a car and reported no difficulty walking, or who reported difficulty walking but had no access to a car — were lower but of comparable magnitude to each other (estimated odds ratios 3.77 and 4.42 respectively). Multivariate adjustment somewhat attenuated the strength of association with difficulty walking compared with the crude odds ratio associated with that characteristic.

After partitioning the dataset, it became apparent that the subset of respondents with no access to a car accounted for the significant overall relationship between active travel and access to a bicycle, whereas those with access to a car accounted for the significant overall relationships with distance to work or study, day of travel, and perceptions of the local environment; the relationship with difficulty walking was also stronger in this group than in those without access to a car (estimated odds ratios 5.60 and 2.49 respectively).

Active travel did not appear to be significantly associated with sex, household financial situation, body mass index, study area of residence, proximity to motorway infrastructure or any major road, or the summary measures of perceptions of the local environment after adjustment for other personal characteristics.

8.7.2 Modelling the correlates of physical activity

Model incorporating personal characteristics

Univariate relationships

Following the same principles as those followed in the local area study, I began with a series of univariate logistic regression analyses to examine the relationship between physical activity and each of the putative explanatory variables available in the dataset, defining respondents as 'physically active' if they met the IPAQ criteria for 'high' overall physical activity (Table 94). From the results of these univariate analyses, I selected the following variables for entry to the multivariate model: age, housing tenure, working situation, distance to work or study, access to a bicycle, difficulty walking, body mass index (as a continuous variable) and the control variable representing day of travel diary. I also entered sex because the associations between walking and environmental characteristics have been shown to vary between the sexes in some studies. [20] Study area of residence, financial situation and the number of cars available did not appear to be significantly associated with physical activity.

Variable	n or frequency (%)*	OR (95% CI)	P
Demographic and socioeconomic			
Age	833	0.99 (0.98, 1.00)	0.026
Sex			
Male (0)	129/355 (36.3)	1.00	
Female (1)	187/478 (39.1)	1.13 (0.85, 1.50)	0.41
Housing tenure			
Social renter (0)	114/318 (35.8)	1.00	
Owner-occupier (1)	170/451 (37.7)	1.08 (0.80, 1.46)	0.60
Other (2)	32/64 (50.0)	1.79 (1.04, 3.07)	0.035
Financial situation			
Comfortable (0)	26/67 (38.8)	1.00	
Manage (3)	83/210 (39.5)	1.03 (0.59, 1.81)	0.92
Careful (2)	152/402 (37.8)	0.96 (0.56, 1.63)	0.88
Strain (1)	53/147 (36.1)	0.89 (0.49, 1.61)	0.70
Working situation			
Retired (0)	69/227 (30.4)	1.00	
Employed (1)	55/174 (31.6)	1.71 (1.18, 2.48)	0.005
Other (2)	189/428 (44.2)	0.94 (0.62, 1.45)	0.80
Distance to work or study			
Four miles or more (0)	94/234 (40.2)	1.00	
Less than four miles (2)	103/228 (45.2)	1.23 (0.85, 1.78)	0.28
Not applicable (1)	101/318 (31.8)	0.69 (0.49, 0.99)	0.041
Access to bicycle			
No (0)	221/632 (35.0)	1.00	
Yes (1)	95/198 (48.0)	1.72 (1.24, 2.37)	0.001
Cars available			
Two to four (0)	45/104 (43.3)	1.00	
One (2)	138/369 (37.4)	0.78 (0.50, 1.22)	0.28
None (1)	132/353 (37.4)	0.78 (0.50, 1.22)	0.28

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 94. Physical activity: proportions and unadjusted odds ratios (1)

Variable	n or frequency (%)*	OR (95% CI)	P
Health and wellbeing			
How they felt about their life	825	0.83 (0.75, 0.92)	<0.001
Physical health summary score (PCS-8)	833	1.05 (1.04, 1.07)	<0.001
Mental health summary score (MCS-8)	833	1.03 (1.02, 1.05)	<0.001
Body mass index (BMI)	814	0.94 (0.91, 0.97)	<0.001
Quintile of BMI			
Highest (0)	38/149 (25.5)	1.00	
Second highest (4)	63/162 (38.9)	1.86 (1.14, 3.02)	0.012
Middle (3)	67/160 (41.9)	2.1 (1.30, 3.41)	0.003
Second lowest (2)	70/172 (40.7)	2.00 (1.24, 3.23)	0.004
Lowest (1)	73/171 (42.7)	2.18 (1.35, 3.51)	0.001
Long-term health problem			
Yes (0)	66/291 (22.7)	1.00	
No (1)	246/530 (46.4)	2.95 (2.14, 4.08)	<0.001
Difficulty walking			
Yes (0)	27/193 (14.0)	1.00	
No (1)	286/629 (45.5)	5.13 (3.32, 7.93)	<0.001
Control variables			
Travel diary day			
Weekend (0)	77/173 (44.5)	1.00	
Weekday (1)	191/533 (35.8)	0.70 (0.49, 0.99)	0.042
Study area			
South (0)	108/278 (38.8)	1.00	
East (1)	106/264 (40.2)	1.06 (0.75, 1.49)	0.76
North (2)	102/291 (35.1)	0.85 (0.60, 1.19)	0.35

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 94. Physical activity: proportions and unadjusted odds ratios (1) (continued)

Multivariate model

When I entered all of these provisionally-significant variables in a multivariate model, five variables (age, sex, working situation, distance to work or study, and access to a bicycle) did not appear to be significant after adjustment for the other variables (Table 95). I therefore removed these five variables and refitted the model including only housing tenure, difficulty walking and body mass index, along with the control variable representing day of travel diary (Table 96).

Variable	ß	se	Wald	df	OR (95% CI)	P
Age	0.009	0.008	1.076	1	1.01 (0.99, 1.03)	0.30
Sex (reference: male)						
Female (1)	0.040	0.180	0.050	1	1.04 (0.73, 1.48)	0.82
Housing tenure (reference: social renter)						
Owner-occupier (1)	-0.474	0.215	4.849	1	0.62 (0.41, 0.95)	0.028
Other (2)	0.425	0.376	1.279	1	1.53 (0.73, 3.19)	0.26
Working situation (reference: retired)						
Employed (1)	0.392	0.442	0.786	1	1.48 (0.62, 3.52)	0.38
Other (2)	-0.173	0.364	0.225	1	0.84 (0.41, 1.72)	0.64
Distance to work or study (reference: four miles or more)						
Less than four miles (2)	0.308	0.215	2.062	1	1.36 (0.89, 2.07)	0.15
Not applicable (1)	0.454	0.391	1.349	1	1.57 (0.73, 3.39)	0.25
Access to bicycle (reference: no)						
Yes (1)	0.130	0.202	0.415	1	1.14 (0.77, 1.69)	0.52
Difficulty walking (reference: yes)						
No (1)	1.800	0.307	34.294	1	6.05 (3.31, 11.05)	<0.001
Body mass index	-0.040	0.018	4.706	1	0.96 (0.93, 1.00)	0.03
Travel diary day (reference: weekend)						
Weekday (1)	-0.496	0.202	6.066	1	0.61 (0.41, 0.90)	0.014

n=639. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio.

Table 95. Partially-adjusted multivariate model for physical activity (1)

Variable	ß	se	Wald	df	OR (95% CI)	P
Housing tenure (reference: social renter)						
Owner-occupier (1)	-0.390	0.185	4.431	1	0.68 (0.47, 0.97)	0.035
Other (2)	0.291	0.343	0.721	1	1.34 (0.68, 2.62)	0.40
Difficulty walking (reference: yes)						
No (1)	1.858	0.271	46.88	1	6.41 (3.77, 10.92)	<0.001
Body mass index	-0.041	0.018	5.274	1	0.96 (0.93, 0.99)	0.022
Travel diary day (reference: weekend)						
Weekday (1)	-0.451	0.193	5.474	1	0.64 (0.44, 0.93)	0.019

n=684. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 96. Partially-adjusted multivariate model for physical activity (2)

Interaction terms

In view of the small number of variables remaining in the model, I added interaction terms for each pairwise combination of these variables to the model, one at a time. The P-values for five of these six interaction terms were all greater than 0.1, but one interaction term appeared potentially significant when added to the model: the interaction between difficulty walking and body mass index (P=0.066), although adding this interaction term made little difference to the estimated odds ratios for the other variables included in the model. In order to aid interpretation, I collapsed this pair of interacting variables into a single 2 x 2 composite variable and refitted the model (Table 97). This final best model of the personal correlates of physical activity provided satisfactory goodness-of-fit (Hosmer and Lemeshow test: χ^2=3.89, df=7; P=0.89) and explained about one-sixth of the total variance in physical activity (Nagelkerke's R^2=15.9%).

Variable	ß	se	Wald	df	OR (95% CI)	P
Housing tenure (reference: social renter)						
Owner-occupier (1)	-0.406	0.185	4.833	1	0.67 (0.46, 0.96)	0.028
Other (2)	0.346	0.347	0.993	1	1.41 (0.72, 2.79)	0.32
Composite variable (reference: BMI≥25 and difficulty walking)						
BMI<25, no difficulty (1)	1.704	0.313	29.536	1	5.49 (2.97, 10.16)	<0.001
BMI<25, difficulty (2)	-1.145	0.592	3.747	1	0.32 (0.1, 1.01)	0.053
BMI≥25, no difficulty (3)	1.368	0.317	18.591	1	3.93 (2.11, 7.32)	<0.001
Travel diary day (reference: weekend)						
Weekday (1)	-0.452	0.193	5.461	1	0.64 (0.44, 0.93)	0.019

n=684. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. BMI: body mass index. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 97. Partially-adjusted multivariate model for physical activity (3)

Model incorporating environmental characteristics

Univariate relationships

I continued with a series of univariate logistic regression analyses to examine the relationship between physical activity and each of the putative explanatory variables related to the objective or subjective characteristics of respondents' environments (Table 98).

Following the same principles as I applied for the personal variables, I selected the following variables for entry to the multivariate model: proximity to existing motorway infrastructure; proximity to any major road; seven individual items from the neighbourhood scale (pleasantness for walking, proximity to a park, public transport, proximity to shops, routes for cycling, traffic volume, and safety crossing the road); summary neighbourhood score; tertile of summary neighbourhood score; the neighbourhood subscale scores derived from the principal components analysis; and the cluster memberships derived from both the first and the second two-step cluster analysis.

Variable	n or frequency (%)*	OR (95% CI)	P
Objective			
Proximity to any existing motorway infrastructure			
Within 100 m (0)	7/21 (33.3)	1.00	
101-200 m (1)	20/45 (44.4)	1.60 (0.54, 4.72)	0.39
201-300 m (2)	21/51 (41.2)	1.40 (0.48, 4.06)	0.54
301-400 m (3)	22/45 (48.9)	1.91 (0.65, 5.63)	0.24
401-500 m (4)	22/63 (34.9)	1.07 (0.38, 3.05)	0.90
Over 500 m (5)	224/608 (36.8)	1.17 (0.46, 2.93)	0.74
Proximity to any existing major road infrastructure			
Within 100 m (0)	103/288 (35.8)	1.00	
101-200 m (1)	83/230 (36.1)	1.01 (0.71, 1.46)	0.94
201-300 m (2)	51/117 (43.6)	1.39 (0.90, 2.15)	0.14
301-400 m (3)	30/67 (44.8)	1.46 (0.85, 2.50)	0.17
401-500 m (4)	13/37 (35.1)	0.97 (0.48, 1.99)	0.94
Over 500 m (5)	36/94 (38.3)	1.11 (0.69, 1.80)	0.66

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 98. Physical activity: proportions and unadjusted odds ratios (2)

Variable	N or frequency (%)*	OR (95% CI)	P
Subjective			
How they felt about their local area	832	0.97 (0.89, 1.06)	0.97
Individual items in neighbourhood scale			
Pleasantness for walking	833	1.09 (0.95, 1.24)	0.21
Attractiveness	833	1.00 (0.89, 1.12)	0.98
Proximity to park	833	1.19 (1.04, 1.35)	0.008
Green space	833	1.05 (0.93, 1.18)	0.40
Public transport	833	1.11 (0.96, 1.27)	0.15
Proximity to shops	833	1.10 (0.97, 1.24)	0.14
Routes for cycling	833	1.10 (0.97, 1.25)	0.13
Routes for walking	833	1.03 (0.91, 1.17)	0.63
Safety walking after dark	833	0.99 (0.87, 1.12)	0.84
Likelihood of attack	833	0.93 (0.81, 1.06)	0.28
Traffic volume	833	0.91 (0.78, 1.05)	0.19
Traffic noise	833	0.95 (0.84, 1.07)	0.39
Safety crossing the road	833	1.09 (0.97, 1.23)	0.17
Road safety for cyclists	833	1.03 (0.90, 1.18)	0.67
Summary neighbourhood score	833	1.01 (0.99, 1.03)	0.22
Tertile of summary neighbourhood score			
Lowest (0)	95/269 (35.3)	1.00	
Middle (1)	102/279 (36.6)	1.06 (0.74, 1.50)	0.76
Highest (2)	119/285 (41.8)	1.31 (0.93, 1.85)	0.12
Neighbourhood subscale summary scores			
Factor 1	833	1.00 (0.96, 1.04)	1.00
Factor 2	833	0.97 (0.92, 1.02)	0.24
Factor 3	833	1.05 (1.00, 1.10)	0.036
Cluster membership (without outlier cluster)			
Third cluster (0)	81/212 (38.2)	1.00	
First cluster (1)	106/318 (33.3)	0.81 (0.56, 1.16)	0.25
Second cluster (2)	129/303 (42.6)	1.20 (0.84, 1.72)	0.32
Cluster membership (with outlier cluster)			
Third cluster (0)	124/307 (40.4)	1.00	
First cluster (2)	73/182 (40.1)	0.99 (0.68, 1.44)	0.95
Second cluster (3)	84/251 (33.5)	0.74 (0.52, 1.05)	0.093
Outlier cluster (1)	35/93 (37.6)	0.89 (0.55, 1.44)	0.63

For categorical variables, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes
* For continuous variables, total number of respondents; for categorical variables, frequency (%) of respondents in each category
OR: odds ratio. 95% CI: 95% confidence interval

Table 98. Physical activity: proportions and unadjusted odds ratios (2) (continued)

Contribution to multivariate model

I added each of these environmental variables to the model, one at a time. In most cases, the P-values for these variables when added to the model were greater than 0.1, or in other words, these variables were no longer signficantly associated with physical activity after adjusting for personal characteristics. I identified five variables worthy of further consideration for addition to the final model: proximity to existing motorway infrastructure, tertile of summary neighbourhood score, traffic volume, and cluster membership with or without an outlier cluster (Table 99). However, the 'significant' results for proximity to existing motorway infrastructure and tertile of summary neighbourhood score were confined to the comparison between one category and the reference category; in neither case was there a suggestion of a linear trend in the odds ratio. I compared the characteristics of the models including one each of the three other variables (traffic volume, cluster membership without an outlier cluster, and cluster membership with an outlier cluster). All three models provided satisfactory goodness-of-fit (P=0.87, P=0.98 and P=0.83 respectively), but the model including cluster membership without an outlier cluster explained slightly more of the overall variance in physical activity than the other two models (17.2% compared with 16.6% and 16.9% respectively).

Variable	ß	se	Wald	df	OR (95% CI)	P
Proximity to any existing motorway infrastructure (reference: within 100 m)						
101-200 m (1)	1.083	0.808	1.799	1	2.95 (0.61, 14.39)	0.18
201-300 m (2)	0.901	0.787	1.311	1	2.46 (0.53, 11.52)	0.25
301-400 m (3)	1.428	0.798	3.202	1	4.17 (0.87, 19.92)	0.074
401-500 m (4)	0.565	0.787	0.516	1	1.76 (0.38, 8.22)	0.47
Over 500 m (5)	0.728	0.727	1.004	1	2.07 (0.50, 8.61)	0.32
Individual items in neighbourhood scale						
Traffic volume	-0.178	0.091	3.837	1	0.84 (0.70, 1.00)	0.050
Tertile of summary neighbourhood score (reference: lowest)						
Middle (1)	-0.358	0.217	2.715	1	0.70 (0.46, 1.07)	0.099
Highest (2)	-0.116	0.214	0.294	1	0.89 (0.59, 1.35)	0.59
Cluster membership (without outlier cluster) (reference: third cluster)						
First cluster (1)	-0.582	0.227	6.549	1	0.56 (0.36, 0.87)	0.01
Second cluster (2)	-0.253	0.227	1.247	1	0.78 (0.50, 1.21)	0.26
Cluster membership (with outlier cluster) (reference: third cluster)						
First cluster (2)	0.460	0.234	3.865	1	1.58 (1.00, 2.50)	0.049
Second cluster (3)	-0.094	0.210	0.201	1	0.91 (0.60, 1.37)	0.65
Outlier cluster (1)	0.106	0.299	0.126	1	1.11 (0.62, 2.00)	0.72

Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 99. Regression coefficients for individual environmental variables added to model including personal variables

Final model

I therefore fitted a final model containing the following variables: housing tenure, the composite variable reflecting the interaction between body mass index and difficulty walking, and cluster membership, along with the control variable representing day of travel diary (Table 100). This final best model of the personal and environmental correlates of physical activity provided satisfactory goodness-of-fit (Hosmer and Lemeshow test: χ^2=2.08, df=8; P=0.98) and explained slightly more of the total variance in active travel than did the personal model alone (Nagelkerke's R^2=17.2%). In order to aid the interpretation of the interaction term and to examine any potential interaction between cluster membership and the variables in that interaction term, I also partitioned the dataset by difficulty walking and by body mass index (less than 25, or 25 or over) and refitted the final model separately to each stratum of the dataset (Table 101). In order to show how multivariate adjustment influenced the estimated odds ratios for each variable, I also refitted the earlier stages of the model to the subset of respondents with non-missing data for all variables included in the final model (Table 102).

Variable	ß	se	Wald	df	OR (95% CI)	P
Housing tenure (reference: social renter)						
Owner-occupier (1)	-0.432	0.189	5.202	1	0.65 (0.45, 0.94)	0.023
Other (2)	0.376	0.351	1.152	1	1.46 (0.73, 2.90)	0.283
Composite variable (reference: BMI≥25 and difficulty walking)						
BMI<25, no difficulty (1)	1.744	0.316	30.469	1	5.72 (3.08, 10.63)	<0.001
BMI<25, difficulty (2)	-1.220	0.594	4.212	1	0.30 (0.09, 0.95)	0.04
BMI≥25, no difficulty (3)	1.401	0.320	19.217	1	4.06 (2.17, 7.60)	<0.001
Cluster membership (without outlier cluster) (reference: third cluster)						
First cluster (1)	-0.582	0.227	6.549	1	0.56 (0.36, 0.87)	0.01
Second cluster (2)	-0.253	0.227	1.247	1	0.78 (0.50, 1.21)	0.264
Travel diary day (reference: weekend)						
Weekday (1)	-0.480	0.195	6.044	1	0.62 (0.42, 0.91)	0.014

n=684. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 100. Fully-adjusted multivariate model for physical activity

Variable	Estimated odds ratio for subgroup			
	Difficulty walking		Body mass index	
	No	Yes	BMI<25	BMI≥25
Housing tenure (reference: social renter)				
Owner-occupier (1)	0.61*	0.73	0.64	0.65
Other (2)	1.36	2.65	1.43	1.50
Difficulty walking (reference: yes)				
No (1)	—	—	21.19***	3.95***
Body mass index (reference: BMI≥25)				
BMI<25 (1)	0.71	3.97*	—	—
Cluster (reference: third cluster)				
First cluster (1)	0.59	0.45	0.46*	0.66
Second cluster (2)	0.89	0.22	0.58	1.03
Travel diary day (reference: weekend)				
Weekday (1)	0.64*	0.45	0.83	0.46**

95% confidence intervals omitted in the interests of clarity. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. 95% confidence intervals for asterisked odds ratios excluded unity: * P<0.05; ** P<0.01; *** P<0.001

Table 101. Stratified fully-adjusted estimated odds ratios for physical activity

Variable	Estimated odds ratio			P†
	Crude	Partially-adjusted model*	Fully-adjusted model†	
Housing tenure (reference: social renter)				
Owner-occupier (1)	0.99	0.67	0.65	0.023
Other (2)	2.00	1.41	1.46	0.283
Composite variable (reference: BMI≥25 and difficulty walking)				
BMI<25, no difficulty (1)	5.06	5.49	5.72	<0.001
BMI<25, difficulty (2)	0.35	0.32	0.30	0.04
BMI≥25, no difficulty (3)	3.54	3.93	4.06	<0.001
Cluster (reference: third cluster)				
First cluster (1)	0.78	—	0.56	0.01
Second cluster (2)	1.09	—	0.78	0.264
Day of travel diary (reference: weekend)				
Weekday (1)	0.70	0.64	0.62	0.014
Summary measures of performance of model				
Nagelkerke's R^2		15.9%	17.2%	
Omnibus test		P<0.001	P<0.001	
Goodness-of-fit‡		P=0.79	P=0.98	

n=684. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables
* Including all other personal characteristics and day of travel but not cluster membership
† Including all other personal characteristics, day of travel and cluster membership
‡ Hosmer and Lemeshow test

Table 102. Effect of multivariate adjustment on estimated odds ratios for physical activity

Summary of regression model for physical activity

In contrast to the likelihood of active travel, respondents were more likely (estimated odds ratio 1.61) to be classified as physically active if they had recorded their travel diary at the weekend rather than on a weekday. After adjustment for day of travel and personal characteristics, the final model indicated that physical activity was significantly associated with living in social-rented accommodation (estimated odds ratio 1.54 compared with owner-occupied accommodation) and with cluster membership based on a two-step cluster analysis of the individual items in the neighbourhood scale (estimated odds ratio 1.79 between the first and third cluster, with an intermediate estimated odds ratio of 1.28 for the second cluster). Including cluster membership contributed a small increase in the proportion of the total variance in physical activity explained by the model, from 15.9% to 17.2%. Multivariate adjustment enhanced the strength of all these associations compared with the crude odds ratios associated with those characteristics. An alternative multivariate model including perceived traffic volume explained less (16.6%) of the total variance in physical activity explained by the model including cluster membership: in this model, physical activity was associated with perceiving that there was a large volume of traffic (estimated odds ratio 1.19 per unit of five-point rating scale).

Physical activity was also significantly associated with not being overweight and with not reporting difficulty walking for a quarter of a mile; an interaction of borderline significance (P=0.066) was found between these two explanatory variables in the multivariate model. The odds of being physically active were highest among respondents who neither were overweight nor reported difficulty walking (estimated odds ratio 5.72 compared with those who were overweight and reported difficulty walking). Multivariate adjustment somewhat enhanced the strength of this association compared with the crude odds ratios associated with those combinations of characteristics.

After partitioning the dataset, it became apparent that the association between physical activity and difficulty walking was highly significant irrespective of whether respondents were overweight, although the association was much stronger among those who were not overweight (ratio of estimated odds ratios 5.36). On the other hand, the association between physical activity and being overweight was significant among respondents who reported difficulty walking (estimated odds ratio 3.97) but not among those who did not report difficulty walking. The significance of the overall assocation between physical activity and cluster membership was not maintained in subgroups defined by the presence of absence of difficulty walking or of overweight, except for the subgroup who were not overweight.

Physical activity did not appear to be significantly associated with age, sex, working situation, financial situation, study area of residence or proximity to a motorway or any major road after adjustment for other personal characteristics.

8.8 Regional area study: descriptive data

8.8.1 Characteristics of sample

The dataset received contained 116511 records, each record representing either a single trip or a single stage of a multi-stage trip. Home addresses accounted for the origins of 50701 (44%) of the stages and the destinations of 49802 (43%) of the stages; work addresses accounted for the origins of 13484 (12%) of the stages and the destinations of 13484 (12%) of the stages. About a quarter of all origins (28919; 25%) and destinations (28679; 25%) were assigned only 'notional' postcodes.

By restructuring the dataset from stage-level to trip-level and then from trip-level to individual-level, I ascertained that these 116511 records represented 109385 trips, each trip involving between one and five stages, and that the 109385 trips were recorded by 39067 individual respondents, each respondent having recorded between one and 14 trips on the day of their travel diary. Data from approximately equal numbers of respondents were obtained in each of the four survey years 2001 (n=10163), 2002 (n=9610), 2003 (n=9499) and 2004 (n=9795). By combining the data for the origin and destination of each stage recorded by each respondent I was able to identify the area of residence for 38760 (99.2%) of the respondents, of whom 502 (1.3%) lived in the area defined as the M74 corridor and 7280 (18.8%) lived elsewhere in the Glasgow (G) postcode area.

Table 103 summarises the distribution of socioeconomic characteristics in the dataset as a whole and in two subsets of respondents — those living within the M74 corridor and those living outside it. There was a significant association between area of residence (M74 corridor versus elsewhere in Scotland) and all socioeconomic characteristics except for sex. Compared with those living elsewhere in Scotland, respondents living in the M74 corridor were more likely to be in a younger age group (test for linear trend: χ^2=4.29, df=1; P=0.038), not to be employed (χ^2=16.52, df=2; P<0.001), to live in a household with no access to a car (test for linear trend: χ^2=93.79, df=1; P<0.001), to live in a household in a lower income band (test for linear trend: χ^2=38.74, df=1; P<0.001), and to have a long-term health problem (χ^2=18.45, df=1; P<0.001). Respondents were also asked to rate their health over the past 12 months ('good', 'fairly good' or 'not good'), but data for this variable were missing for nearly half (19303; 49.4%) of all respondents; I therefore disregarded this variable in analysis. Among the entire sample, there was a small but significant decrease from 2001 to 2004 in the proportion of respondents who reported that their household had no access to a car (test for linear trend: χ^2=11.41, df=1; P=0.001); it was not possible to discern any clear trend within the much smaller sample of respondents living in the M74 corridor (test for linear trend: χ^2=0.05, df=1; P=0.82) (Table 104).

Weighting responses by the published travel diary weighting factors made little difference to these findings. Significant associations remained between area of residence and all socioeconomic characteristics except for sex. Compared with those living elsewhere in Scotland, respondents living in the M74 corridor were more likely to be in a younger age group (test for linear trend: χ^2=7.06, df=1; P=0.008), not to be employed (χ^2=22.6, df=2; P<0.001), to live in a household with no access to a car (test for linear trend: χ^2=121.15, df=1; P<0.001), to live in a household in a lower income band (test for linear trend: χ^2=56.97, df=1; P<0.001), and to have a long-term health problem (χ^2=6.62, df=1; P=0.01). Among the entire sample, there remained a small but significant decrease from 2001 to 2004 in the proportion of respondents who reported that their household had no access to a car (test for linear trend: χ^2=16.39, df=1; P<0.001); it was not possible to discern any clear trend among respondents living in the M74 corridor (test for linear trend: χ^2=0.17, df=1; P=0.68).

Area of residence	Unweighted data			Weighted data		
	M74 corridor*	Rest of Scotland*	All*	M74 corridor*	Rest of Scotland*	All*
Sex						
Male	222 (44.2)	16969 (44.0)	17191 (44.0)	261 (43.6)	18382 (45.6)	18643 (45.6)
Age group						
16 to 39	223 (44.4)	14361 (37.2)	14584 (37.3)	282 (47.1)	15446 (38.3)	15728 (38.5)
40 to 64	175 (34.9)	16327 (42.3)	16502 (42.2)	211 (35.2)	18105 (44.9)	18316 (44.8)
65 and over	104 (20.7)	7877 (20.4)	7981 (20.4)	106 (17.7)	6738 (16.7)	6844 (16.7)
Working situation						
Employed	251 (50.0)	21930 (56.9)	22181 (56.8)	316 (52.7)	24275 (60.3)	24591 (60.1)
Retired	120 (23.9)	9248 (24.0)	9368 (24.0)	121 (20.2)	8103 (20.1)	8224 (20.1)
Other	131 (26.1)	7387 (19.2)	7518 (19.2)	163 (27.2)	7912 (19.6)	8075 (19.7)
Cars available to household						
None	221 (44.0)	10395 (27.0)	10616 (27.2)	226 (37.7)	8882 (22.0)	9108 (22.3)
One	228 (45.4)	18619 (48.3)	18847 (48.2)	287 (47.9)	18680 (46.4)	18967 (46.4)
Two or more	53 (10.6)	9551 (24.8)	9604 (24.6)	86 (14.4)	12728 (31.6)	12814 (31.3)
Annual net household income						
Up to £10,000	177 (35.3)	9994 (25.9)	10171 (26.0)	173 (28.9)	8180 (20.3)	8353 (20.4)
£10,000 to £20,000	195 (38.8)	13626 (35.3)	13821 (35.4)	241 (40.2)	13429 (33.3)	13670 (33.4)
Over £20,000	130 (25.9)	14945 (38.8)	15075 (38.6)	185 (30.9)	18679 (46.4)	18864 (46.1)
Long-term health problem						
Yes	130 (25.9)	7095 (18.4)	7225 (18.5)	121 (20.2)	6559 (16.3)	6680 (16.3)

Unweighted n=502 (M74 corridor), n=38565 (rest of Scotland), n=39067 (all)
* Count (column %)

Table 103. Characteristics of SHS respondents

Area of residence	Frequency (%) of respondents with no access to a car			
	2001	2002	2003	2004
Unweighted data				
All of Scotland	2910 (28.6)	2613 (27.2)	2468 (26.0)	2625 (26.8)
M74 corridor	55 (42.0)	78 (48.1)	34 (41.0)	54 (42.9)
Weighted data				
All of Scotland	2458 (23.3)	2341 (23.4)	2066 (20.7)	2243 (21.7)
M74 corridor	56 (35.9)	78 (41.5)	41 (37.6)	51 (34.9)

Unweighted n=502 (M74 corridor), n=39067 (all)

Table 104. Trends in household car access by survey year

8.8.2 Distribution of home and work addresses

Of the 502 respondents identified as living in the M74 corridor, only 145 (29%) had a postcode sector for a place of work recorded in their travel diary. Most of these respondents worked within the Glasgow postcode area but outside the M74 corridor (Table 105). Only one worked outside the west of Scotland (the Glasgow, Motherwell and Paisley postcode areas).

Of the 39067 respondents throughout Scotland, 12013 (31%) had a postcode sector for a place of work recorded in their travel diary, of whom 224 (1.9%) had a place of work within the M74 corridor and 222 also had a postcode sector recorded for their home address. Most of these respondents working within the M74 corridor lived within the Glasgow (G) postcode area but outside the M74 corridor (Table 106). Only four lived outside the west of Scotland (the Glasgow, Kilmarnock, Motherwell and Paisley postcode areas).

Place of work	Frequency (%)
Within the Glasgow (G) postcode area	
Within M74 corridor	27 (18.6)
Central Glasgow*	45 (31.0)
Elsewhere in the Glasgow (G) postcode area	65 (44.8)
Elsewhere in the west of Scotland	
Motherwell (ML) postcode area	4 (2.8)
Paisley (PA) postcode area	3 (2.1)
Elsewhere in Scotland	1 (0.7)

n=145
* Postcode areas G1 to G5 inclusive, excluding those parts of G5 within the M74 corridor

Table 105. Places of work of respondents living in M74 corridor

Home address	Frequency (%)
Within the Glasgow (G) postcode area	
Within M74 corridor	27 (12.2)
Central Glasgow*	1 (0.5)
Elsewhere in the Glasgow (G) postcode area	150 (67.6)
Elsewhere in the west of Scotland	
Motherwell (ML) postcode area	17 (7.7)
Paisley (PA) postcode area	17 (7.7)
Kilmarnock (KA) postcode area	6 (2.7)
Elsewhere in Scotland	4 (1.8)

n=222
* Postcode areas G1 to G5 inclusive, excluding those parts of G5 within the M74 corridor

Table 106. Home addresses of respondents working in M74 corridor

8.8.3 Travel diaries

88 (18%) of the respondents living in the M74 corridor recorded 30 minutes or more of active travel on the day of their travel diary, of whom all but one reported at least 30 minutes of walking (with or without cycling in addition). The proportions of residents who recorded at least 30 minutes of active travel or at least 30 minutes of walking were slightly higher in the M74 corridor than in the rest of Scotland (for active travel: χ^2=2.98, df=1, P=0.085; for walking: χ^2=4.15, df=1, P=0.042) (Table 107).

As in the local area study, the distribution of travel time for each mode and for all modes combined showed a strong positive skew, such that the median travel time for most individual modes was zero. On average, respondents reported a somewhat higher total duration of travel per day — a mean of 75.6 minutes and a median of 57.0 minutes (Table 108) — than those in the local area study, who recorded a mean of 61.5 minutes and a median of 50.0 minutes (Table 66 earlier in this chapter). However, in the regional area study, residents of the M74 corridor reported a lower total duration of travel per day than respondents living elsewhere in Scotland (Table 108); although the difference in total duration of travel was not significant (Mann-Whitney *U* test: *z*=1.15, P=0.25), residents of the M74 corridor did report spending significantly less time travelling by car (*z*=7.51, P<0.001) and significantly more time travelling by bus (*z*=6.36, P<0.001), by rail (*z*=5.30, P<0.001), on foot (*z*=2.76, P=0.006) and by active modes combined (*z*=2.28, P=0.022); the difference in time spent cycling was not significant (*z*=1.85, P=0.064). Furthermore, all respondents in the regional area study had recorded at least one trip, whereas 10% of respondents in the local area study had not recorded any travel (Table 65 earlier in this chapter). The average total duration of travel per day among local area study respondents who had recorded any travel was similar to that of regional area study respondents living in the M74 corridor (mean 69.4 and 69.7 minutes respectively, median 60.0 and 56.0 minutes respectively) (Table 66 earlier in this chapter and Table 108).

Weighting responses by the published travel diary weights made modest differences to these findings. There remained no significant difference in total duration of travel between residents of the M74 corridor and respondents living elsewhere in Scotland (Mann-Whitney *U* test: z=0.52, P=0.60), although there were changes in the pattern of differences by mode: in weighted analysis, residents of the M74 corridor reported spending significantly less time travelling by car (z=7.36, P<0.001) and significantly more time travelling by bus (z=7.06, P<0.001), by rail (z=4.55, P<0.001), on foot (z=1.98, P=0.048) and by bike (z=2.08, P=0.038), but the difference in time spent travelling by active modes combined was no longer significant (z=1.48, P=0.14). The proportions of residents who recorded at least 30 minutes of active travel or at least 30 minutes of walking remained slightly higher in the M74 corridor than in the rest of Scotland (for active travel: χ^2=2.69, df=1, P=0.10; for walking: χ^2=3.97, df=1, P=0.046).

Area of residence	M74 corridor*	Rest of Scotland*	All*
Unweighted data			
Recorded 30 minutes or more of active travel	88 (17.5)	5699 (14.8)	5787 (14.8)
Recorded 30 minutes or more of walking	87 (17.3)	5452 (14.1)	5539 (14.2)
Weighted data			
Recorded 30 minutes or more of active travel	97 (16.2)	5583 (13.9)	5680 (13.9)
Recorded 30 minutes or more of walking	96 (16.0)	5335 (13.2)	5431 (13.3)

n=502 (M74 corridor), n=38565 (rest of Scotland), n=39067 (all)
* Frequency (%)

Table 107. Active travel recorded in SHS travel diaries

Area of residence	Average daily travel time by mode								
	M74 corridor			Rest of Scotland			All		
	Mean (sd)	Median (IQR)	Proportion of total	Mean (sd)	Median (IQR)	Proportion of total	Mean (sd)	Median (IQR)	Proportion of total
Unweighted data									
Car	35.2 (68.1)	17.5 (48.0)	50.5%	50.1 (69.3)	31.0 (68.0)	66.2%	49.9 (69.3)	30.0 (68.0)	66.0%
Walking	13.0 (28.4)	0.0 (17.0)	18.7%	10.8 (30.2)	0.0 (0.0)	14.3%	10.8 (30.2)	0.0 (0.0)	14.3%
Bus	16.9 (38.2)	0.0 (13.0)	24.2%	9.8 (31.9)	0.0 (0.0)	12.9%	9.9 (32.0)	0.0 (0.0)	13.1%
Rail	3.4 (16.8)	0.0 (0.0)	4.9%	2.2 (20.8)	0.0 (0.0)	2.9%	2.3 (20.7)	0.0 (0.0)	3.0%
Cycling	0.1 (1.4)	0.0 (0.0)	0.1%	0.5 (6.9)	0.0 (0.0)	0.7%	0.5 (6.8)	0.0 (0.0)	0.7%
Motorcycle	0.0 (—)	0.0 (0.0)	0.0%	0.2 (6.0)	0.0 (0.0)	0.3%	0.2 (6.0)	0.0 (0.0)	0.3%
Other	1.1 (15.7)	0.0 (0.0)	1.6%	2.0 (24.6)	0.0 (0.0)	2.6%	2.0 (24.5)	0.0 (0.0)	2.6%
Active modes*	13.1 (28.4)	0.0 (17.0)	18.8%	11.3 (30.9)	0.0 (0.0)	14.9%	11.3 (30.9)	0.0 (0.0)	14.9%
All modes combined	69.7 (70.5)	56.0 (55.0)	100.0%	75.7 (76.1)	57.0 (61.0)	100.0%	75.6 (76.0)	57.0 (61.0)	100.0%
Weighted data									
Car	38.4 (70.3)	20.0 (60.0)	53.3%	52.1 (70.6)	33.0 (70.0)	67.3%	51.9 (70.6)	33.0 (70.0)	67.1%
Walking	11.5 (26.7)	0.0 (0.0)	16.0%	10.1 (29.1)	0.0 (0.0)	13.0%	10.1 (29.1)	0.0 (0.0)	13.1%
Bus	16.0 (35.6)	0.0 (11.0)	22.2%	10.1 (32.3)	0.0 (0.0)	13.0%	10.2 (32.3)	0.0 (0.0)	13.2%
Rail	3.8 (17.4)	0.0 (0.0)	5.3%	2.3 (20.5)	0.0 (0.0)	3.0%	2.4 (20.4)	0.0 (0.0)	3.1%
Cycling	0.1 (1.3)	0.0 (0.0)	0.1%	0.5 (6.8)	0.0 (0.0)	0.6%	0.5 (6.7)	0.0 (0.0)	0.6%
Motorcycle	0.0 (—)	0.0 (0.0)	0.0%	0.2 (6.9)	0.0 (0.0)	0.3%	0.2 (6.8)	0.0 (0.0)	0.3%
Other	2.3 (21.3)	0.0 (0.0)	3.2%	2.1 (25.6)	0.0 (0.0)	2.7%	2.1 (25.5)	0.0 (0.0)	2.7%
Active modes*	11.6 (26.7)	0.0 (0.0)	16.1%	10.6 (29.9)	0.0 (0.0)	13.7%	10.6 (29.8)	0.0 (0.0)	13.7%
All modes combined	72.1 (72.1)	60.0 (58.0)	100.0%	77.4 (77.0)	59.0 (63.0)	100.0%	77.3 (76.9)	59.0 (63.0)	100.0%

Unweighted n=502 (M74 corridor), n=38565 (rest of Scotland), n=39067 (all)
* Walking and cycling combined
IQR: interquartile range. sd: standard deviation

Table 108. Travel time by mode recorded in SHS travel diaries

Relationships between categorical variables

Tests of the strength of association between pairwise combinations of the categorical variables are shown in Table 109. There were significant associations between most of the variables considered except for sex, which was not significantly associated with age group or health problems, and survey year, which was not correlated with age group, income or the number of cars available. Respondents in later survey years (2003 and 2004) were more likely than those in earlier years to report a health problem. Men were more likely than women to report a higher level of income and to report having access to a car.

Other associations between personal characteristics were in the expected directions. Most (93%) respondents in the oldest age group described themselves as retired. Respondents in employment were more likely than others to be male, to have a higher income and to have access to a car. Health problems were associated with being older, with not being employed, with having a lower income, and with having no access to a car. Access to a car was associated with a higher income.

Variables compared		Test	Result
Sex (binary)	Working situation (unordered)	Chi-squared test	χ^2=419.45, df=2; P<0.001
Sex (binary)	Health problem (binary)	Chi-squared test	χ^2=0.95, df=2; P=0.33
Working situation (unordered)	Health problem (binary)	Chi-squared test	χ^2=5448.11, df=2; P<0.001
Survey year (ordered)	Health problem (binary)	Chi-squared test for linear trend	χ^2=18.40, df=1; P<0.001
Age group (ordered)	Health problem (binary)	Chi-squared test for linear trend	χ^2=2799.36, df=1; P<0.001
Access to a car (ordered)	Health problem (binary)	Chi-squared test for linear trend	χ^2=1861.51, df=1; P<0.001
Household income (ordered)	Health problem (binary)	Chi-squared test for linear trend	χ^2=2409.96, df=1; P<0.001
Survey year (ordered)	Sex (binary)	Chi-squared test for linear trend	χ^2=2.16, df=1; P=0.84
Age group (ordered)	Sex (binary)	Chi-squared test for linear trend	χ^2=1.51, df=1; P=0.22
Access to a car (ordered)	Sex (binary)	Chi-squared test for linear trend	χ^2=316.18, df=1; P<0.001
Household income (ordered)	Sex (binary)	Chi-squared test for linear trend	χ^2=233.35, df=1; P<0.001
Survey year (ordered)	Working situation (unordered)	Kruskal-Wallis test*	χ^2=6.10, df=2; P=0.047
Age group (ordered)	Working situation (unordered)	Kruskal-Wallis test*	χ^2=19080.50, df=2; P<0.001
Access to a car (ordered)	Working situation (unordered)	Kruskal-Wallis test*	χ^2=4480.81, df=2; P<0.001
Household income (ordered)	Working situation (unordered)	Kruskal-Wallis test*	χ^2=10230.07, df=2; P<0.001
Survey year (ordered)	Age group (ordered)	Spearman correlation coefficient*	r_s=0.01
Survey year (ordered)	Household income (ordered)	Spearman correlation coefficient*	r_s=0.05
Age group (ordered)	Household income (ordered)	Spearman correlation coefficient*	r_s=−0.28
Access to a car (ordered)	Household income (ordered)	Spearman correlation coefficient*	r_s=0.55
Survey year (ordered)	Access to a car (ordered)	Spearman correlation coefficient*	r_s=0.04
Age group (ordered)	Access to a car (ordered)	Spearman correlation coefficient*	r_s=−0.14

* Adjusted for ties
χ^2: chi-squared test. df: degrees of freedom. r_s: Spearman correlation coefficient

Table 109. Associations between categorical variables

8.9 Regional area study: regression modelling

8.9.1 Modelling the correlates of active travel

Following the same principles as those followed in the local area study, I began with a series of univariate logistic regression analyses to examine the relationship between active travel and each of the putative explanatory variables available in the dataset, including a variable representing residence within the M74 corridor (Table 110). Finding that all the P-values were small ($P<0.1$), I entered all the available explanatory variables into the multivariate model. Household income and living in the M74 corridor did not appear to be significant after adjustment for the other variables (Table 111). I therefore removed these two variables and refitted the model including only age, sex, working situation, number of cars available and presence of a health problem, along with a control variable representing survey year (Table 112).

Variable	Frequency (%)	OR (95% CI)	P
Demographic and socioeconomic			
Age group			
65 and over (0)	1262/7981 (15.8)	1.00	
40 to 64 (2)	2062/16502 (12.5)	0.76 (0.70, 0.82)	<0.001
16 to 39 (1)	2463/14584 (16.9)	1.08 (1.00, 1.17)	0.037
Sex			
Female (0)	3335/21876 (15.2)	1.00	
Male (1)	2452/17191 (14.3)	0.93 (0.87, 0.98)	0.007
Annual net household income			
Over £20,000 (0)	1464/15075 (9.7)	1.00	
£10,000 to £20,000 (2)	2102/13821 (15.2)	1.67 (1.55, 1.79)	<0.001
Up to £10,000 (1)	2221/10171 (21.8)	2.60 (2.42, 2.79)	<0.001
Working situation			
Employed (0)	2463/22181 (11.1)	1.00	
Retired (1)	1518/9368 (16.2)	1.55 (1.44, 1.66)	<0.001
Other (2)	1806/7518 (24.0)	2.53 (2.37, 2.71)	<0.001
Cars available			
Two to four (0)	619/9604 (6.4)	1.00	
One (2)	2116/18847 (11.2)	1.84 (1.67, 2.02)	<0.001
None (1)	3052/10616 (28.7)	5.86 (5.34, 6.42)	<0.001
Health problem			
Yes (0)	1131/7225 (15.7)	1.00	
No (1)	4654/31828 (14.6)	0.92 (0.86, 0.99)	0.026
Environmental			
Resident of M74 corridor			
No (0)	5699/38565 (14.8)	1.00	
Yes (1)	88/502 (17.5)	1.23 (0.97, 1.55)	0.085
Control variable			
Survey year			
2004 (0)	1337/9795 (13.6)	1.00	
2003 (3)	1311/9499 (13.8)	1.01 (0.93, 1.10)	0.76
2002 (2)	1467/9610 (15.3)	1.14 (1.05, 1.23)	0.001
2001 (1)	1672/10163 (16.5)	1.25 (1.15, 1.35)	<0.001

For each variable, the first category listed (0) is the reference category; numbers in parentheses indicate assignment of dummy variable codes. OR: odds ratio. 95% CI: 95% confidence interval

Table 110. Active travel in SHS: proportions and unadjusted odds ratios

Variable	ß	se	Wald	df	OR (95% CI)	P
Age group (reference: 65 and over)						
40 to 64 (2)	0.318	0.064	24.752	1	1.37 (1.21, 1.56)	<0.001
16 to 39 (1)	0.540	0.071	57.749	1	1.72 (1.49, 1.97)	<0.001
Sex (reference: female)						
Male (1)	0.108	0.030	12.599	1	1.11 (1.05, 1.18)	<0.001
Annual net household income (reference: over £20,000)						
£10—£20,000 (2)	-0.066	0.042	2.471	1	0.94 (0.86, 1.02)	0.12
Up to £10,000 (1)	-0.046	0.049	0.880	1	0.95 (0.87, 1.05)	0.35
Working situation (reference: employed)						
Retired (1)	0.503	0.066	58.447	1	1.65 (1.45, 1.88)	<0.001
Other (2)	0.621	0.041	234.557	1	1.86 (1.72, 2.01)	<0.001
Cars available (reference: two to four)						
One (2)	0.625	0.050	155.462	1	1.87 (1.69, 2.06)	<0.001
None (1)	1.756	0.055	1001.80	1	5.79 (5.20, 6.46)	<0.001
Health problem (reference: yes)						
No (1)	0.391	0.041	92.181	1	1.48 (1.37, 1.60)	<0.001
Resident of M74 corridor (reference: no)						
Yes (1)	-0.082	0.123	0.444	1	0.92 (0.72, 1.17)	0.51
Survey year (reference: 2004)						
2003 (3)	0.022	0.043	0.267	1	1.02 (0.94, 1.11)	0.61
2002 (2)	0.110	0.042	6.767	1	1.12 (1.03, 1.21)	0.009
2001 (1)	0.176	0.041	17.973	1	1.19 (1.10, 1.29)	<0.001

n=39053. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 111. Partially-adjusted multivariate model for active travel in SHS (1)

Variable	ß	se	Wald	df	OR (95% CI)	P
Age group (reference: 65 and over)						
40 to 64 (2)	0.317	0.064	24.756	1	1.37 (1.21, 1.56)	<0.001
16 to 39 (1)	0.540	0.071	58.005	1	1.72 (1.49, 1.97)	<0.001
Sex (reference: female)						
Male (1)	0.108	0.030	12.701	1	1.11 (1.05, 1.18)	<0.001
Working situation (reference: employed)						
Retired (1)	0.493	0.064	59.155	1	1.64 (1.44, 1.86)	<0.001
Other (2)	0.613	0.038	254.667	1	1.85 (1.71, 1.99)	<0.001
Cars available (reference: two to four)						
One (2)	0.603	0.048	157.576	1	1.83 (1.66, 2.01)	<0.001
None (1)	1.724	0.049	1221.74	1	5.61 (5.09, 6.17)	<0.001
Health problem (reference: yes)						
No (1)	0.393	0.041	93.366	1	1.48 (1.37, 1.61)	<0.001
Survey year (reference: 2004)						
2003 (3)	0.022	0.043	0.261	1	1.02 (0.94, 1.11)	0.61
2002 (2)	0.109	0.042	6.601	1	1.12 (1.03, 1.21)	0.010
2001 (1)	0.174	0.041	17.644	1	1.19 (1.10, 1.29)	<0.001

n=39053. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 112. Partially-adjusted multivariate model for active travel in SHS (2)

I then considered the possibility of interaction between the number of cars available and three other variables: age, sex, and presence of a health problem. I added interaction terms for each pairwise combination of these variables to the model, one at a time. The P-values for two of these three interaction terms were greater than 0.1, but one interaction term appeared potentially significant when added to the model: the interaction between the number of cars available and sex ($P<0.001$), although adding this interaction term made little difference to the estimated odds ratios for the other variables included in the model. In order to aid interpretation, I collapsed this pair of interacting variables into a single 2 x 2 composite variable and refitted the model (Table 113).

This final best model of the personal correlates of active travel provided satisfactory goodness-of-fit (Hosmer and Lemeshow test: $\chi^2=14.59$, df=8; $P=0.068$) and explained about half as much of the total variance in active travel as was explained by the model using the data from the local area study (Nagelkerke's $R^2=11.0\%$). In order to aid the interpretation of the interaction term, I also partitioned the dataset into two strata ('No car available' and 'Car available') and refitted the final model separately to each stratum of the dataset (Table 114). In order to show how multivariate adjustment influenced the estimated odds ratios for each variable, I also refitted the earlier stages of the model to the subset of respondents with non-missing data for all variables included in the final model (Table 115).

Variable	ß	se	Wald	df	OR (95% CI)	P
Age group (reference: 65 and over)						
40 to 64 (2)	0.278	0.064	18.880	1	1.32 (1.16, 1.50)	<0.001
16 to 39 (1)	0.518	0.071	53.148	1	1.68 (1.46, 1.93)	<0.001
Working situation (reference: employed)						
Retired (1)	0.540	0.064	71.120	1	1.72 (1.51, 1.95)	<0.001
Other (2)	0.624	0.038	265.433	1	1.87 (1.73, 2.01)	<0.001
Composite variable (reference: male with access to a car)						
Male, no car (3)	1.487	0.048	973.233	1	4.42 (4.03, 4.85)	<0.001
Female, car (2)	0.055	0.041	1.842	1	1.06 (0.98, 1.15)	0.18
Female, no car (1)	1.180	0.043	750.556	1	3.25 (2.99, 3.54)	<0.001
Health problem (reference: yes)						
No (1)	0.380	0.041	86.559	1	1.46 (1.35, 1.58)	<0.001
Survey year (reference: 2004)						
2003 (3)	0.022	0.043	0.250	1	1.02 (0.94, 1.11)	0.62
2002 (2)	0.120	0.042	8.018	1	1.13 (1.04, 1.23)	0.005
2001 (1)	0.190	0.041	21.106	1	1.21 (1.11, 1.31)	<0.001

n=39053. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 113. Fully-adjusted multivariate model for active travel in SHS

Variable	ß	se	Wald	df	OR (95% CI)	P
No car available						
Age group (reference: 65 and over)						
40 to 64 (2)	0.179	0.096	3.514	1	1.20 (0.99, 1.44)	0.061
16 to 39 (1)	0.424	0.106	15.835	1	1.53 (1.24, 1.88)	<0.001
Sex (reference: female)						
Male (1)	0.285	0.045	39.963	1	1.33 (1.22, 1.45)	<0.001
Working situation (reference: employed)						
Retired (1)	0.235	0.101	5.397	1	1.27 (1.04, 1.54)	0.020
Other (2)	0.428	0.055	59.516	1	1.53 (1.38, 1.71)	<0.001
Health problem (reference: yes)						
No (1)	0.337	0.052	41.876	1	1.40 (1.27, 1.55)	<0.001
Survey year (reference: 2004)						
2003 (3)	0.012	0.064	0.035	1	1.01 (0.89, 1.15)	0.85
2002 (2)	0.157	0.062	6.359	1	1.17 (1.04, 1.32)	0.012
2001 (1)	0.220	0.060	13.307	1	1.25 (1.11, 1.40)	<0.001
Car available						
Age group (reference: 65 and over)						
40 to 64 (2)	0.302	0.086	12.212	1	1.35 (1.14, 1.60)	<0.001
16 to 39 (1)	0.534	0.096	31.026	1	1.71 (1.41, 2.06)	<0.001
Sex (reference: female)						
Male (1)	-0.043	0.041	1.101	1	0.96 (0.88, 1.04)	0.29
Working situation (reference: employed)						
Retired (1)	0.721	0.081	78.933	1	2.06 (1.75, 2.41)	<0.001
Other (2)	0.762	0.053	204.852	1	2.14 (1.93, 2.38)	<0.001
Health problem (reference: yes)						
No (1)	0.401	0.066	36.949	1	1.49 (1.31, 1.70)	<0.001
Survey year (reference: 2004)						
2003 (3)	0.028	0.059	0.228	1	1.03 (0.92, 1.15)	0.63
2002 (2)	0.083	0.058	2.068	1	1.09 (0.97, 1.22)	0.15
2001 (1)	0.162	0.057	8.165	1	1.18 (1.05, 1.31)	0.004

n=39053. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables. ß: Estimated regression coefficient. se: Standard error. Wald: Wald statistic. df: Degrees of freedom. OR: Exponent of estimated regression coefficient, i.e. estimated odds ratio. 95% CI: 95% confidence interval for estimated odds ratio

Table 114. Stratified fully-adjusted multivariate model for active travel in SHS

Variable	Estimated odds ratio		P*
	Crude	Fully-adjusted model*	
Age group (reference: 65 and over)			
40 to 64 (2)	0.76	1.32	<0.001
16 to 39 (1)	1.08	1.68	<0.001
Working situation (reference: employed)			
Retired (1)	1.55	1.72	<0.001
Other (2)	2.53	1.87	<0.001
Composite variable (reference: male with access to a car)			
Male, no car (3)	4.89	4.42	<0.001
Female, car (2)	1.14	1.06	0.18
Female, no car (1)	3.65	3.25	<0.001
Long-term health problem (reference: yes)			
No (1)	0.92	1.46	<0.001
Survey year (reference: 2004)			
2003 (3)	1.01	1.02	0.62
2002 (2)	1.14	1.13	0.005
2001 (1)	1.25	1.21	<0.001
Summary measures of performance of model			
Nagelkerke's R^2		11.0%	
Omnibus test		P<0.001	
Goodness-of-fit†		P=0.068	

n=39053. Numbers in parentheses indicate assignment of dummy variable codes for categorical variables
* Final model including and adjusting for all other variables
† Hosmer and Lemeshow test

Table 115. Effect of multivariate adjustment on estimated odds ratios for active travel in SHS

Summary of regression model for active travel

The odds of respondents being classifed as active travellers decreased over the period studied (estimated odds ratio 1.21 for 2001 compared with 2004). After adjustment for survey year and personal characteristics, the final model indicated that active travel was significantly associated with being in a younger age group (estimated odds ratios 1.68 and 1.32 respectively for the 16-39 and 40-64 year-old age groups compared with those aged 65 and over); not being in employment (estimated odds ratios 1.72 and 1.87 respectively for those describing themselves as retired or in one of a number of 'other' categories compared with those in employment); and not having a health problem (estimated odds ratio 1.46). The estimated odds ratios associated with age group and presence of a health problem, but not with survey year, were substantially altered by multivariate adjustment.

Active travel was also significantly associated with not having access to a car and with being male; a significant interaction ($P<0.001$) was found between these two explanatory variables in the multivariate model. Both men and women were more likely to be active travellers if they did not have access to a car (estimated odds ratios 4.42 and 3.25 respectively compared with men with access to a car). After partitioning the dataset, it became apparent that men were significantly more likely than women to be active travellers if they did not have access to a car (estimated odds ratio 1.33), but there was no significant difference between the sexes in active travel among those who did have access to a car. The strength of the relationship between active travel and working situation was weaker (but still highly significant) among respondents without access to a car than among those with access to a car.

Active travel did not appear to be significantly associated with household income or residence in the M74 corridor after adjustment for other personal characteristics.

9 M74 study: discussion

9.1 Overview of this chapter

In this chapter, I discuss the results of the cross-sectional (baseline) quantitative analysis of M74 study data.

In the first part of the chapter, I discuss the findings from the perspective of the methodological problem of how to design and conduct intervention studies in this field. I consider the strengths and weaknesses of the methods I used, the quality and representativeness of the data obtained, and the interpretation of methodological findings such as the performance of the neighbourhood scale.

In the second part of the chapter, I discuss the main 'results' of the cross-sectional analysis as such. These constitute the substantive findings about the characteristics of the study populations in the local and regional area studies, the descriptive epidemiology of travel behaviour and physical activity in these study populations, and the modelling of the correlates of active travel and physical activity.

The analyses undertaken for the thesis constitute no more than an initial foray into the datasets involved. In the final part of the chapter, I discuss how the work done so far lays the foundations for a longitudinal intervention study and outline a set of further analyses which could be conducted on the baseline datasets.

The overall conclusions for the thesis as a whole, encompassing both the systematic review and the M74 study, are presented in Chapter 10.

9.2 Methodological findings

9.2.1 Pilot survey for local area study

I used the pilot survey to test my proposed arrangements for administering the survey and to confirm whether a written questionnaire was capable of eliciting data of acceptable quality from respondents.

The response rate to the postal component of the pilot survey (11%) was disappointing. I attributed this partly to the time of year — I had no realistic choice but to distribute the pilot survey during the summer school holidays — but I assumed that this alone could not account for the poor response rate. I therefore made several changes before distributing the main survey, all of which were comparatively inexpensive and had been shown to have a significant effect on response rates to postal surveys in a meta-analysis: [427] notifiying recipients in advance, using white envelopes, printing the university crest on the envelopes, and printing some of the survey materials on coloured paper.

With hindsight, the comparatively small pilot dataset provided somewhat false reassurance about the quality of the data elicited, certainly with respect to the travel diaries. Although the aggregate travel data obtained in the pilot survey were comparable both with the data subsequently obtained in the main survey and with what I expected from other travel surveys, the misunderstandings evident in a minority of responses to the main survey — such as entering ticks or bus service numbers in the travel diaries — did not occur in the pilot survey. Had they done so, I may have been able to clarify the instructions on the questionnaire. However, the pilot survey did identify one item on the questionnaire with which respondents had difficulty and which had poor test–retest reliability: the item asking about proximity to shops. I therefore reworded this item for the main survey. Compared with the other items in the neighbourhood scale, the reliability of the reworded item was at least comparable with (r_s=0.55) — if not better than (κ=0.50) — that of most of the other items, which suggests that the decision to modify the item in light of the pilot results was justified.

9.2.2 Response and representativeness

Achieved sample

The final response rate achieved in the main survey for the local area study (16%) was higher than that in the pilot survey — an improvement which might be attributable to the time of year, the modifications made to the survey methods, or both — but was still comparatively low. There are several possible explanations for the low response rate. These explanations reflect problems at different stages in the chronology of the survey and are therefore not mutually exclusive.

The first explanation to be considered is that not all selected households received the survey materials. Although the final response rates did not differ significantly between study areas, the number of surveys returned to sender as undeliverable was noticeably higher in one study area (the south) than in the others. This may reflect the genuine impossibility of delivering mail to addresses in buildings or streets which had been abandoned or were being redeveloped at the time of the survey. However, a recent study for Postwatch Scotland has identified other problems with the delivery of mail to occupied flats in tenement buildings, including inconsistent numbering of flats and postal workers' difficulties in gaining access through controlled entry doors. [440] This suggests an alternative, although unverifiable, explanation that some survey packs might never have been delivered to their intended recipients.

The second explanation is that householders ignored the survey. One disadvantage of using the Postcode Address File (PAF) as a sampling frame is that survey packs have to be addressed impersonally — in this case, to 'The Householder' — rather than to a named recipient. I tried to prevent recipients from assuming the survey packs were unsolicited marketing materials by sending them a postcard in advance of the main survey (assuming that a postcard was more likely to be read than the contents of an envelope) and by marking the survey packs clearly with the university crest. Nonetheless, many people may have chosen simply to ignore the survey.

The third explanation is that potential respondents chose not to participate because, having seen the survey materials, they considered the survey uninteresting, irrelevant or too onerous to complete. With the approval of the ethics committee, I decided not to mention the M74 project, or even motorways in general, in the survey materials — partly because I did not want responses (particularly about the local environment) to be biased by knowledge of the underlying hypotheses of the longitudinal intervention study, and partly to avoid discouraging responses from the north control area, which had neither existing nor planned motorway infrastructure. However, this studious avoidance of introducing bias through the survey materials may also have had the effect of reducing the response rate, thereby introducing a different form of respondent bias. As for the burden of completing the survey, interviews in the pilot survey did not suggest that respondents had found the survey excessively burdensome, but naturally these views were obtained only from people who had completed the survey; others may not have responded because they found the questionnaire too onerous. The most complex part of the questionnaire was the travel diary; although I did my best to devise a travel diary which was substantially simpler than those used in the routine national travel surveys, it was still more complex than many items typically found in a postal questionnaire.

Realistic aspirations

The main concern about a low response rate to a survey is the possibility of respondent bias: that those who choose to respond to a survey differ in a systematic way from those who do not and therefore constitute a biased sample of the population of interest. This is particularly important if the object of the survey is to estimate the prevalence of, and trends in, particular characteristics or conditions in a population. These are key objectives of large-scale national population surveys such as the Scottish Health Survey or the Scottish Household Survey (SHS); compared with the response rates achieved in those surveys, the response rate achieved in the local area study is poor.

However, such a direct comparison is inappropriate for two reasons. First, the resources available for recruitment and data collection in those surveys are much greater than those which were available for the M74 study. Second, the ultimate objective of the M74 study is not to estimate prevalence or trends in the general population but to investigate the effects of an intervention in a specific, comparatively deprived urban population. It is recognised that response rates are often lower in more deprived areas and that considerable effort may be required to recruit respondents, particularly because of a high prevalence of demolished or unoccupied addresses in those areas. [441] It is not surprising that surveys such as the SHS should have achieved higher response rates using interviewers making repeated calls in person than I was able to achieve using a postal survey.

While it would clearly be desirable to have achieved a sample which could be shown to be representative of the study population, this is not necessarily either a realistic expectation or a *sine qua non* for an intervention study of this kind which aims to compare changes observed in an intervention area with those observed in one or more control areas and to explore how these changes are distributed in the population. A recent population-based study of a somewhat similar intervention — the opening of a new food superstore — in a similarly deprived area of Glasgow also achieved a response rate of 15%, despite non-respondents having been sent two reminders. [442] Although my achieved sample contained a higher proportion of respondents from owner-occupied and car-owning households than would have been predicted from the 2001 census data for the same output areas, these differences may be partly accounted for by a rising background trend in owner-occupation and car ownership between 2001 and 2005. Furthermore, for the purposes of a population-based intervention study of this kind, it may be at least as important to show that the samples obtained in the different study areas are comparable with each other and include respondents from different social strata of interest. I was able to show both that the aggregate demographic and socioeconomic characteristics of the samples achieved in each of the three study areas were comparable and that they contained, for example, approximately equal numbers of owner-occupied and non-owner-occupied households and of households with and without access to a car.

Alternative approaches

I considered and rejected the possibilities of conducting the survey using the telephone or internet. In 2003, 12% of adults living in areas of 'high deprivation' in the UK had no fixed (landline) telephone [443] and in 2005, only 30% of households in the lowest quintile of the Scottish Index of Multiple Deprivation had access to the internet — less than half the proportion in the highest quintile. [444] There is no obvious way of constructing a sampling frame of either mobile telephone numbers or email addresses based on place of residence. I also considered and rejected the possibility of offering larger monetary incentives for completing the survey, partly because of the resource implications but also because the ethics committee might not have sanctioned an incentive which could have been seen as an excessive inducement to participate. However, within the resources available for this study two more realistic alternative strategies for recruiting respondents might have been considered.

First, I could have used the edited electoral register as the sampling frame instead of the PAF. The advantage of the edited electoral register is that survey packs can be addressed to named recipients. However, most large population surveys (such as the SHS) use the PAF because it is more complete; the edited electoral register (the version available to third parties for purposes other than elections) excludes not only those who have chosen not to register as electors but also those registered electors who have opted out of the edited register in order to avoid receiving unsolicited mail. The National Centre for Social Research (NatCen) reports that 32% of adults had opted out of the edited register by 2005 and that young people, graduates and people living in rented accommodation were under-represented in the edited register; on the basis of these findings, NatCen does not recommend the edited register as a sampling frame. [445] I therefore chose the PAF in preference to the edited electoral register in order to limit respondent bias, but it is possible that using the edited electoral register may have resulted in a larger (although not necessarily a more representative) sample.

Second, I could have used the same resources to survey a smaller number of households more intensively, for example by using fieldworkers to follow up the postal survey with house calls to encourage completion of, and to collect, the questionnaires. Although this strategy would probably have resulted in a higher response rate, it would have been difficult to achieve a sample of comparable size distributed over a comparable area without deploying a large number of fieldworkers.

9.2.3 Data quality

In general, the quality of the data obtained appeared acceptable. For most of the items on demographic, socioeconomic, health and environmental topics, the number of missing responses was small and the range and distribution of responses were in keeping with expectations, as were the aggregate data on travel and physical activity (see below). However, responses to certain items were characterised by a large number of missing or inconsistent responses.

Demographic and socioeconomic characteristics

For each of the items on household composition and the working situation of the respondent's spouse or partner, between 40% and 55% of responses were missing. These items were adapted from those used in previous surveys and do not appear particularly intrusive or difficult to understand, so there is no obvious explanation for their non-completion. It is possible that respondents preferred only to answer questions about themselves and their behaviour and considered questions about other members of the household to be unreasonably intrusive.

I did not consider it safe to assume that missing responses to the items asking about the number of children should be recoded to zero, because a similar item asking about the number of cars using an identical instruction ('Write in number. If none, write "0"') had very few missing responses. I therefore concluded that I had no choice but to disregard these variables in analysis.

Travel behaviour

Although some respondents did appear to have misunderstood the instructions for completing the travel diary, for example by entering ticks or bus service numbers instead of times, these unusable responses formed only a small proportion of the overall sample and are therefore unlikely to have introduced important bias into the overall estimates of travel time. With hindsight, more detailed piloting of the travel diary in a larger sample may have enabled me to identify these misunderstandings and amend the instructions before proceeding with the main survey, but it is probably inevitable that some respondents would have had difficulty completing the travel diary, however clear the instructions, without help from a researcher.

Considering the complexity of the travel diary, the general quality of the travel data obtained was acceptable. In particular, the observations that the average numbers of journeys, and the average total daily time spent travelling, were similar to those obtained in my analysis of the SHS and to those reported from the National Travel Survey (NTS) (see Section 6.5.2 in Chapter 6) suggest acceptable criterion validity compared with those surveys, which represent the closest approximation to a ‘gold standard’ in this context. (The contrast in the distribution of travel time by mode between the local area study and the national surveys is discussed below.)

Respondents varied in how they had entered multi-stage journeys, or multi-journey days, in the travel diary. In a survey such as the SHS, where a trained interviewer enters travel data on behalf of the respondent, considerable effort is made to standardise this aspect of recording travel, which includes giving 13 pages of instructions to the interviewers; [446] it would not have been feasible to include such detailed instructions in a postal survey. I therefore took a pragmatic view of how to collect these data: I was more interested in the time spent travelling by different modes than in the precise origins, destinations and purposes of each stage of each journey, and therefore designed my travel diary to concentrate on the temporal aspect of travel behaviour and regarded each completed row of the travel diary as one journey, even though I could see when coding the diaries that some respondents had disaggregated multi-stage journeys into one row per stage. My analysis of the SHS travel diaries shows that multi-stage journeys account for a comparatively small proportion of all journeys; this explains why the average number of journeys per person per day in the local area study was similar to that expected from the national surveys.

The questionnaire included two items about dates: one asking for the numerical date of completion, the other asking for the day of the week to which the travel diary referred, which should have been ‘yesterday’, the day before the questionnaire was completed. I included both items in order to be able to validate the two responses against each other. One-fifth of respondents gave responses which were inconsistent in this respect. Some may have given the wrong date or day of the week; others may not have recorded the previous day's travel, either because they misunderstood the instructions or because they considered the previous day's travel to be atypical and preferred to record the travel they made on the same day or another recent day. When I found active travel to be strongly associated with whether travel had been recorded on a weekday or at the weekend, I decided to exclude all cases with inconsistent dates from further modelling, despite the consequent reduction in sample size, in order to ensure that the day of the travel diary was correctly adjusted for in multivariate analysis.

Physical activity

Although most respondents entered some data about their physical activity, a substantial proportion of responses had to be disregarded in analysis because their physical activity data were incomplete or internally inconsistent and therefore unacceptable in the terms specified in the IPAQ scoring protocol. [430]

Although excluding these cases substantially reduced the size of the sample available for modelling, there is no particular reason why the subset of respondents who returned complete and usable physical activity data should have been unrepresentative of the entire sample. A larger number of cases could have been included in analysis if I had made assumptions about how to interpret missing or inconsistent responses and decided, for example, to impute missing values, but the results of such an analysis would not have been comparable with other analyses using IPAQ owing to the substantial deviations from the scoring protocol which would have been required. The frequency of unusable responses was not reported in the international multi-centre study which originally established the validity and reliability of IPAQ. [412]

While the grounds for excluding unsuitable cases from analysis specified in the protocol appear reasonable, it was noticeable that many of the respondents whose data I had to exclude from analysis had ticked the 'Don't know' box for the daily duration of one, or more, of the categories of physical activity. I did not offer a 'Don't know' option for the duration of travel in the travel diary. It is possible that offering this option in the IPAQ questionnaire encourages respondents to tick 'Don't know' rather than to enter what may be a reasonably precise estimate of the actual time; the respondent has no way of knowing that a single 'Don't know' response will result in all of their physical activity data being disregarded in analysis.

9.2.4 Comparability of study areas

Within the local area study

I was able to show that the aggregate characteristics of the samples achieved in each of the three study areas were not significantly different on any measure except for one borderline case, housing tenure (P=0.056). Given the number of simultaneous comparisons I made between the study areas, this single difference of borderline significance could be a false positive result. In any case, since both active travel and physical activity appeared to be strongly associated with housing tenure, this variable was retained in all multivariate models; any real difference in housing tenure between study areas can therefore be considered to have been adequately adjusted for in the final analysis.

Between the local and regional area studies

I did not use the same spatial definition for the M74 corridor in the regional area study as I used in the local area study because I could only attribute SHS respondents to postcode sectors of residence, whereas the local study areas were defined in terms of the smaller units of census output areas. However, although the M74 corridor as defined in the regional area study was larger than that in the local area study, it still represented the smallest meaningful intervention study area which could have been defined from the available SHS data, contributing only 502 residents over a four-year survey period.

9.2.5 Neighbourhood scale

Statistical perspective

From a statistical perspective, the neighbourhood scale which I devised for the local area study appeared to perform adequately.

First, the distribution of responses varied between items: for some, the peak of the distribution was at the midpoint of the scale (e.g. safety walking after dark and likelihood of attack) whereas for others, the distribution exhibited a clear skew towards positive responses (e.g. proximity to a park, public transport, proximity to shops and safety crossing the road) or negative responses (e.g. traffic volume, traffic noise and road safety for cyclists). Second, the correlation matrix showed little evidence of collinearity between the items, even within pairs of items. Both of these observations suggest that the different items were indeed measuring different aspects of respondents' perceptions of their surroundings.

Third, the test–retest reliability of the items, although suboptimal, was broadly comparable with that achieved in other studies of similar instruments which used four- or five-point rating scales — especially taking into account the long test–retest interval in this study (six months). I chose to analyse test–retest reliability using a variety of measures in order to maximise comparability with other studies, which have tended to use the intraclass correlation coefficient (ICC) as a measure of reliability. For example, in their assessment of a new 17-item module to assess perceptions of the local environment as an adjunct to IPAQ in a Swedish population, Alexander and colleagues reported test–retest ICCs for individual items ranging from 0.36 to 0.98; however, their test–retest interval was only one week, and the only two items with an ICC of greater than 0.9 involved asking questions which appeared considerably more concrete and objective than those addressed in my scale ('What is the main type of housing in your neighborhood?' and 'How many motor vehicles in working order are there in your household?'). [447] Similarly, in an study of three questionnaires developed in the US (the South Carolina and St. Louis instruments and the San Diego instrument, now known as the Neighbourhood Environment Walkability Scale or

NEWS) using a test–retest interval of one to three weeks, Brownson and colleagues reported ICCs for individual items comparable with those used in my scale ranging from 0.18 to 0.78 in San Diego, from 0.39 to 0.87 in South Carolina and from 0.36 to 0.80 in St. Louis. [52]

Although the precise ranks of the individual items varied according to which of these metrics was used (e.g. using the intraclass correlation coefficient compared with Cohen's κ), across all metrics the item which stood out as being the most reliable was that on access to public transport. This may reflect a greater degree of certainty (and therefore relative lack of variability) in respondents' assessment of their access to public transport, which might be interpreted in a more concrete way than their assessment of more subjective characteristics such as the attractiveness of their surroundings.

Fourth, the summary score obtained by summing the responses to the individual items in the scale was approximately symmetrically distributed about a mean of zero, had acceptable test–retest reliability, and exhibited a highly significant association with the alternative single-item rating scale 'How do you feel about living in your local area', suggesting acceptable criterion validity in the terms within which it would be possible to establish such validity in this context.

Fifth, although the maximum-likelihood exploratory factor analysis did not produce useful results and the cluster analysis produced clusters whose meaning was difficult to interpret, the principal components analysis suggested three latent factors which could be meaningfully interpreted, and summary scores calculated by summing the scores for the items most significantly associated with each factor had acceptable internal consistency and test–retest reliability and did not exhibit significant collinearity.

Substantive perspective

The contribution of the neighbourhood scale to understanding the correlates of active travel and physical activity is discussed in more detail below, but the main finding of the regression analyses was that differences in perceptions of the local environment accounted for little additional variance in either active travel or physical activity after personal characteristics were taken into account. At this stage in the discussion, I therefore conclude that I achieved the methodological aim of developing, piloting and demonstrating the reliability of a new neighbourhood scale suitable for an intervention study of this kind in this setting, but that the significance of this scale, and the constructs it seeks to measure, for understanding patterns of active travel and physical activity in the local population are unclear.

9.3 Substantive findings

9.3.1 Demographic, socioeconomic and health profile of study populations

Although the simple comparisons with census data from 2001 suggest that the achieved sample in the local area study may have been less economically deprived than the local population as a whole, the aggregate characteristics of the achieved sample nonetheless describe a population with fewer material assets and poorer health than average. The comparisons between the M74 corridor and the rest of Scotland in the regional area study confirm this finding.

In the local area study, substantial minorities of respondents were renting from a 'social' landlord in the public or voluntary sector (41%), had no access to a car or van (48%), or reported a long-term illness, health problem or disability (38%); the average mental health summary score derived from the SF-8 was also significantly below the published norm for the general population. Data on housing tenure were not available in the specialised extract from the SHS, but I was able to confirm using that dataset that residents of the M74 corridor were significantly more likely than respondents in the rest of Scotland to have no access to a car and to have a long-term health problem; their household income was also significantly more likely to be in a lower band.

These findings confirm my expectations from the initial efforts to define the study areas for the local area study, which showed that all the postcode sectors most closely associated with the proposed route of the motorway were in the sixth or seventh (most deprived) deprivation categories based on the Carstairs index. They show that the population most exposed to the environmental changes brought about by the M74 project — not just those within the more precise area used in the local area study, but also those in the wider corridor used in the regional area study — are already disadvantaged, in terms of their socioeconomic status and their health, compared with the rest of Scotland. From the transport perspective, the most striking difference is in car ownership: a weighted comparison in the regional area study showed 38% of respondents with no access to a car in the M74 corridor compared with 22% in the rest of Scotland. Although this difference may be partly accounted for by the greater availability of public transport in the M74 corridor compared with the rural areas of Scotland, it nonetheless reflects a difference in the ‘susceptibility’ of populations to changes to transport infrastructure: people living in households with access to a car are more likely to be able to use a car when they choose to and are less likely to be ‘captive’ users of public transport or active modes of transport.

Despite the comparatively low prevalence of access to cars, respondents in the local area study were still more than twice as likely to have access to a car than to a bicycle. In some ways, this is a surprising finding. It is much cheaper to buy and run a bicycle than a car, and a large proportion of journeys in urban areas are likely to be within cycling distance: this is illustrated by the finding that for those travelling to a place of work or study, the median distance was 3.5 miles, which is not considered an excessive distance to cycle in contemporary thinking in transport policy. [448] The low level of bicycle ownership may therefore reflect non-financial constraints on the ownership or use of bicycles. These may include the perception that cycling is too dangerous or the ease of access to public transport, especially bus services, in the local study areas, both of which were reflected in the balance of responses to the relevant items in the neighbourhood scale reported in Figure 24. A further possible constraint is the difficulty of storing bicycles in flats, which are the dominant form of housing in the local study areas.

9.3.2 Descriptive epidemiology of travel behaviour

After excluding the 10% of respondents in the local area study who recorded no travel, the local and regional area studies found similar average total daily travel times in the M74 corridor, with a mean of about 70 minutes and a median of about 60 minutes in each case (after weighting, in the regional area study). The similarity of these estimates to each other and to those from the NTS provides a degree of reassurance about the ascertainment of travel in the local area study: my travel diary appears unlikely either to have ascertained a significant quantity of spurious journeys (which could have happened if, for example, recreational walking had been recorded as journeys) or to have under-ascertained genuine journeys (which could have happened if, for example, the travel of non-respondents, or of respondents whose travel diaries were unusable, had been systematically different from that of respondents whose travel diaries were included in analysis). In the context of a public health message which emphasises the importance of undertaking 30 minutes of moderate-intensity physical activity on most days, the time which people spend travelling therefore offers a clear opportunity for incorporating more physical activity into everyday life.

Beneath the surface of these comparable overall estimates of total travel time lie important differences in how that total travel time was distributed between modes, both between the M74 corridor and the rest of Scotland in the regional area study and between the local and regional area studies.

In the regional area study, although there was no significant difference in total travel time between the M74 corridor and the rest of Scotland, there were substantial and significant differences in average daily travel time at the level of most specific modes of transport. Although non-parametric tests offered a more appropriate statistical test of the differences between such skewed datasets, it is easier to appreciate the proportionate contribution of different modes of transport by comparing mean times, because the median times for several specific modes were zero. The most obvious differences were in the use of cars and buses, rather than the active modes: in the weighted analysis, respondents living in the M74 corridor recorded, on average, 13.7 minutes’ less car travel and 5.9 minutes’ more bus travel than those living in the rest of Scotland. These patterns are consistent with the differences in access to cars and public transport discussed above.

A more interesting comparison is between the mode-specific average daily travel times from the local area study and the unweighted regional area study data for residents living in the M74 corridor. After excluding the 10% of respondents in the local area study who recorded no travel, respondents in the local area study were almost twice as likely to have recorded 30 minutes of active travel than those in the M74 corridor in the regional area study. This reflects large differences in the mean travel times reported for car travel and walking: local area respondents recorded, on average, 7.7 minutes' less car travel and 8.7 minutes' more walking than regional area respondents living in the M74 corridor. These may be conservative estimates: using weighted, rather than unweighted, regional area study data for these comparisons increased the size of the differences.

It is unlikely that these discrepancies could be entirely accounted for by real differences. Although the local study areas are not identical to the M74 corridor as defined in the regional area study, they are similar in socio-spatial terms; it appears unlikely that real differences between the areas could account for differences of this magnitude in travel behaviour. On the other hand, apparent differences in travel behaviour may partly reflect differences in either sampling or ascertainment between the studies. The first potential explanation is that the low response rate in the local area study produced an unrepresentative sample whose travel behaviour was atypical compared with that obtained in the more representative SHS. However, as I have shown above, the achieved sample in the local area study reported a higher prevalence of car access than expected from census data; it therefore appears unlikely that respondent bias could have accounted for a lower reported quantity of car travel in the local area study. The second, and perhaps more plausible, explanation is that the travel diary used in the local area study differentially encouraged more complete recording of walking because active travel was the aspect of travel behaviour of particular interest, in the same way that it is already recognised that the SHS under-ascertains walking trips compared with the NTS. [404] It is not possible to resolve this problem without further investigation, but the clear implication which can be drawn is that it may be unwise to compare absolute quantities of travel by specific modes of transport which have been estimated using different instruments.

9.3.3 Descriptive epidemiology of physical activity

As I discussed in Chapter 6, the problem of non-comparability of absolute quantities estimated using different instruments is widely acknowledged in the field of physical activity measurement, which is why I chose to use the International Physical Activity Questionnaire (IPAQ) in the local area study and to summarise physical activity using categorical rather than continuous variables. Most published studies using the same, short form of IPAQ have either not reported the distribution of the continuous summary measures or not reported data for the UK separately from those for other countries where higher levels of physical activity are reported. However, the aggregate continuous data I obtained were broadly comparable to those reported in the single comparable published study based on a random sample of UK adults by Rütten and colleagues (Table 116). [418]

Study	Summary measure	Average overall physical activity recorded	
		Mean (sd)	Median (IQR)
M74 study	Walking (min/week)	318.4 (366.1)	180.0 (375.0)
Rütten [413]	Walking (min/week)	322.71 (531.68)	NR
M74 study	Total activity (MET-min/week)	3000.1 (3323.1)	1935.0 (3645.0)
Rütten [413]	Total activity (MET-min/week)	3238.31 (4524.17)	1653.0 (NR)

IQR: interquartile range. NR: not reported. sd: standard deviation.

Table 116. Average physical activity in population-based studies using IPAQ

9.3.4 Correlates of travel behaviour and physical activity

General approach

I chose to approach the problem of understanding the correlates of active travel and physical activity in the local area study by using multivariate logistic regression, first to model how active travel and physical activity are related to 'personal' (demographic, socioeconomic and health) characteristics, and secondly to model the influence of 'environmental' characteristics after these personal characteristics had been taken into account. I then took a similar, but more limited, approach in the regional area study in which I had fewer potential explanatory variables at my disposal.

I could have used more complex modelling techniques, such as multilevel modelling to examine the influence of hierarchical clustering of respondents, or latent path analysis to examine the relationships between personal and environmental characteristics, travel behaviour, physical activity and health in a single model. However, the aim of this study was not to produce a general model to 'explain' active travel or physical activity in the population as a whole, but to do so in the context of a specific intervention study in a specific setting. Therefore, although respondents in the local area study could be said to have been sampled from three 'clusters' (study areas) which could have been represented as such in a multilevel model, such an approach would have been unnecessarily complex for a study in which no claim was made that those clusters were representative of any wider population. It was simpler to treat the study area as one of the explanatory variables in a single-level model, an approach for which a precedent has been set in the case of the Twenty-07 study. [423] Similarly, although it would be desirable to develop a comprehensive model of all the relationships between personal and environmental characteristics, travel behaviour, physical activity and health, such a complex exercise in modelling would be of much greater value if conducted using longitudinal data so that the influence of changes in certain parameters (such as car ownership) on others (such as active travel) could be modelled. This should therefore be regarded as a potential ultimate aspiration for the study after the completion of the follow-up phase or, more appropriately, for analysis of other more general population datasets.

I discuss the findings about the correlates of active travel and physical activity in three sections: first, focusing on the similarities, both between the local and regional area studies and between the correlates of active travel and those of physical activity; second, focusing on the differences; and third, considering the interpretation of the 'non-significant' findings.

Similarities

There were more similarities between the local and regional area studies with respect to the correlates of active travel than between the correlates of active travel and physical activity in the local area study.

The associations identified with housing tenure, distance to work or study, access to a bicycle, day of travel diary (in the local area study) and survey year (in the regional area study) are not open to comparison between studies because each of these explanatory variables was unique to one dataset or the other. In most other respects, the findings of the local and regional area studies were consistent. In both studies, the likelihood of active travel decreased with access to a car, with difficulty walking or the presence of a health problem (the nearest equivalent measure to 'difficulty walking' in the regional area study), and with increasing age (or age group); in both studies, the association with age was similar among those with, and without, access to a car. These associations are all in the expected direction.

In the local area study, the only explanatory variable identified as being significantly associated with both active travel and physical activity was difficulty walking (chosen as the most salient of several variables representing health and wellbeing). Owing to the interactions between this variable and other explanatory variables, it is not possible to make a direct comparison of the magnitude of the odds ratios for the two outcome measures, but it is possible to say that the association with active travel was stronger (that is, the estimated odds ratio was more than twice as large) among those with access to a car than among those without. This may be the first illustration from these results of the concept of 'captivity' in mode choice: in those who have access to a car, difficulty walking may be a more effective deterrent to active travel (or in other words, associated with a higher odds ratio) than among those without access to a car, who may be more likely to make active journeys because they have to, irrespective of their difficulty in doing so.

Differences

Correlates of active travel in local and regional area studies

Sex and working situation both emerged as significant correlates of active travel in the regional area study but not in the local area study.

Describing the association with sex in the regional area study is not straightforward because of an interaction with access to a car whereby the influence of car ownership on active travel was greater among men than among women. Among those with access to a car, women were slightly more likely than men to report active travel (this difference was not significant), whereas among those without access to a car, men were significantly more likely to report active travel than women.

In their review of the literature on the environmental correlates of walking, Owen and colleagues identified three studies which had found 'strong gender differences' and suggested that such correlates should be be examined separately for men and women. [20] It is therefore of interest that sex did not emerge as being significantly associated with active travel in the local area study. One possible explanation is that the three studies identified by Owen and colleagues were all concerned with walking for exercise or recreation rather than with walking as a mode of transport. Another possible explanation is that there may indeed be a significant association with gender which only applies, or can only be detected, in the general population rather than in the more specific population sampled in the local area study — in which, for example, the proportion of respondents with no access to a car and who are therefore more 'captive' walkers is much higher than in the regional area study.

The observed associations with working situation provide an interesting contrast between the studies. In the regional area study, respondents categorised as 'retired' or 'other' were significantly more likely to report active travel than those categorised as 'employed'. In the local area study, in contrast, working situation as such did not emerge as significantly associated with active travel, but there was a significant association with distance to work or study: respondents who did not travel to work or study, or travelled less than four miles, were more likely to be active travellers than those who travelled four miles or more.

The most obvious explanation for these findings is that across Scotland as a whole, the journey to work is more likely to be too far to walk or cycle, or not possible by public transport, than in the Glasgow conurbation. In the 2001 census, the average distance for the journey to work in Scotland was 5.3 miles; the average distance was lowest for residents of the four city council areas (Aberdeen, Edinburgh, Glasgow and Dundee: 2.9, 3.3, 3.3 and 3.5 miles respectively) and greatest for residents of Eilean Siar (the Western Isles) and the Shetland Islands (10.8 and 9.7 miles respectively). [449] At a national level, respondents in employment may therefore be more likely to need a car because they have to get to work, and may also meet other objectives such as shopping, leisure or taking children to school on the same journey; the need to go to work therefore poses a serious obstacle to the possibility of active travel, while those who do not need to travel to work are more likely to be active travellers in their own localities. In contrast, in the local area study most people who travel to work or study travel less than four miles to get there in a conurbation which is comparatively well served by public transport. In this context, having to go to work need not be a barrier to active travel and it is distance to work or study, rather than working situation, which emerges as the significant explanatory variable.

In the regional area study, respondents in 2001 or 2002 were significantly more likely to report active travel than those responding in 2004. Further work would be required to establish whether this is likely to reflect a real downward trend (in other words, a continuation of the long-standing downward trend in active travel discussed in Chapter 1) or an artefact of sampling variability; this is outside the scope of the thesis. However, for the purposes of designing an intervention study, this finding provides strong support for the argument in favour of a controlled design: without a control group, it may be impossible to detect a beneficial effect of an intervention against a larger background downward trend in the general population from which participants in an uncontrolled study are sampled.

Correlates of active travel and physical activity in the local area study

A comparison of the correlates of active travel and physical activity identified in the local area study raises several important differences, which can be considered in two groups.

The first group consists of variables found to be significantly associated with one outcome but not with the other. Distance to work or study, access to a bicycle, access to a car, perceived proximity to shops, and perceived road safety for cyclists were associated only with active travel, whereas body mass index and neighbourhood cluster membership were associated only with overall physical activity.

The explanatory variables exclusively associated with active travel all have an obvious intuitive relationship with the use of walking or cycling as modes of transport. It is therefore not surprising that they should be associated with active travel. The finding that they were not significantly associated with overall physical activity suggests either that active travel contributes only a minority of respondents' overall physical activity or that other factors not measured in this study are more important correlates of overall physical activity than those which determine active travel. My comparison of the estimated weekly energy expenditure associated with active travel recorded in the travel diaries with that associated with all activity recorded using IPAQ suggested that on average, active travel may indeed make only a small (15%) contribution to overall physical activity in this study population. However, the real contribution may be substantially greater than this if, as has been shown previously, respondents tend to over-report their physical activity when completing the short form of IPAQ. [411] There can be little doubt that active travel makes a substantial contribution to the total quantity of *walking* reported in this study population -- particularly among younger adults, women and those without access to a car, among whom walking as a means of getting from place to place may account for half or more of all walking. Irrespective of the true contribution of active travel to overall physical activity, however, it remains likely that other unmeasured personal and social factors which were outside the scope of this study may be more important correlates of overall physical activity and would have helped to explain more of the variance in that outcome measure had they been included.

The association of body mass index with overall physical activity but not with active travel may reflect the fact that the great majority of active travel recorded in this study population was walking, not cycling. Walking (at an intensity not otherwise defined) is both more feasible for people who are overweight, and less likely on its own to lead to a reduction in body mass index, than some of the other, more vigorous forms of physical activity captured by IPAQ. Therefore, irrespective of whether body mass index is seen as an 'explanation for' or a 'result of' active travel, it is not surprising that a significant association was not found; if the intensity of the walking recorded in the travel diaries had been taken into consideration, it is possible that a significant association would have been found.

I discuss the more general interpretation of the findings about the 'environmental' characteristics below, but it may be useful at this point to consider possible explanations for why different 'environmental' variables were found to be associated with active travel and physical activity.

The two variables which emerged as significantly associated with active travel were perceived proximity to shops and perceived road safety for cyclists. The positive association with perceived proximity to shops suggests that for active travel to be undertaken in this population, it may be more important that people live close to the amenities they need than that they live in an environment with more favourable subjective or discretionary considerations such as attractiveness or noise. This would be consistent with an understanding that walking as a mode of transport is primarily a way of undertaking journeys which have to be made anyway, as opposed to more discretionary (recreational) forms of walking which may be more susceptible to the influence of more subjective or discretionary characteristics of the local environment. The negative association with perceived road safety for cyclists appears counter-intuitive, but is amenable to at least two potential explanations. The first is that this 'significant' result is simply a false positive result which was not unlikely to emerge by chance from testing the statistical significance of fourteen separate items on the neighbourhood scale. The second is that it is a real finding which reflects an association in the reverse direction to that anticipated. Titze and colleagues found the same 'paradoxical inverse relationship' in a study of the correlates of cycling among students, [450] and Humpel and colleagues reported a similar finding whereby men who perceived their neighbourhood as 'highly safe' were less likely to walk for pleasure. [433] Titze and colleagues suggest that respondents who cycle regularly are more likely to be aware of the danger posed by traffic than non-cyclists or infrequent cyclists because of their personal experience of that danger; in other words, that people who report more cycling are thereby more likely to report adverse conditions for cyclists.

The variable which emerged as significantly associated with physical activity was neighbourhood cluster membership, in that members of the third cluster were significantly more likely to record sufficient physical activity than those in the first cluster. However, even after examining the distributions of the two items which contributed most strongly to the definitions of the clusters (perceived safety walking after dark and perceived attractiveness of surroundings), there is no easily-interpretable difference between the first and third clusters. It may be most helpful to regard the results of the cluster analysis, and the significance of the derived clusters in the final physical activity model, as a result which is technically correct rather than one which makes a significant contribution to understanding how to improve public health. [56]

The second group consists of variables found to be significantly associated with both outcomes but in opposite directions. Respondents living in owner-occupied households were more likely to report active travel than those living in social-rented accommodation but less likely to report sufficient overall physical activity, and respondents who recorded their travel on a weekday were more likely to report active travel than those who recorded their travel at the weekend but less likely to report sufficient overall physical activity.

Since working situation and perceived financial situation did not emerge as significantly associated with active travel or physical activity, housing tenure and car ownership are the remaining explanatory variables in this dataset which can be interpreted as markers of socioeconomic status. Although car ownership clearly reflects the possession of a material asset, it has been argued that this is a less direct marker of socioeconomic status than some other markers because, in Scotland at least, access to a car is a more-or-less essential requirement for living in many rural areas whereas, conversely, it is possible to live in a dense urban settlement such as Glasgow without using a car. In the final models in this study, therefore, housing tenure may be regarded as the primary marker of socioeconomic status, and the findings may be interpreted as showing conflicting socioeconomic gradients in prevalence whereby active travel was more prevalent among the more advantaged respondents but sufficient overall physical activity was more prevalent among the more disadvantaged.

These findings reflect a more general pattern described in the literature and referred to in Chapter 1. Unlike some other health-related behaviour, such as smoking, there is no clear overall social gradient in physical activity, but conflicting social gradients have been identified for different domains of physical activity. Therefore, the higher prevalence of sufficient overall physical activity among those living in social-rented accommodation, despite their lower propensity for active travel, is likely to reflect higher quantities of physical activity in other domains. It was not the purpose of this study to discriminate between these other domains, but on the basis of other published work referred to in Chapter 1 it appears likely that occupational and domestic activities would account for the difference, since leisure-time physical activity tends to be higher among more advantaged groups.

A full analysis of the relationships between active travel and the purposes of individual journeys has not been possible, but the observed association between active travel and day of travel diary suggests some preliminary conclusions in this respect. Respondents who recorded travel on a weekday were more likely to be categorised as active travellers than those who recorded travel at the weekend. This is likely to reflect the fact that many of the journeys which offer a realistic opportunity for active travel, such as journeys to and from work or taking children to and from school, are more likely to take place on a weekday. It also suggests that journeys more typically associated with the weekend, such as those made to supermarkets or leisure activities, are less likely to contribute to active travel. These postulates could be tested in future analysis at the level of the individual journey.

On the other hand, it is not clear why the day of travel diary should be associated (in the opposite direction) with the likelihood of recording sufficient overall physical activity, since this outcome is based on recall of the previous seven days' activity. One possible explanation is that the completion of the travel diary influenced the completion of the physical activity instrument which immediately followed it in the questionnaire. For example, it is possible that respondents who recorded comparatively large quantities of active travel on a busy weekday then unwittingly 'compensated' for this by under-recording their overall walking in the last seven days, either because they misunderstood the instructions and thought that walking as a mode of transport should be excluded from their IPAQ response or because they wanted to reach the end of the questionnaire. I am not aware of any precedents for a self-completed questionnaire which includes both a travel diary and a physical activity instrument with which to compare data on this point.

Non-significant putative explanatory environmental variables

With the exception of the two specific items (perceived proximity to shops and perceived road safety for cyclists) and the results of the two-step cluster analysis, discussed above, I did not find convincing evidence that either objective or subjective characteristics of the local environment made a significant contribution as correlates of active travel or physical activity in the local area study. Including those 'environmental' items which did emerge as significant in the multivariate models contributed a modest increase in the proportion of the variance in active travel or physical activity accounted for by those models, but their influence was small compared with that of the 'personal' characteristics found to be significant.

There are two classes of potential explanation for this overall finding of 'little significant assocation'. The first regards the finding as an artefact of the research methods, or in other words a type II (false negative) error. The second regards the finding as a real absence of an association, which therefore needs to be considered in light of the considerable evidence in the literature which suggests that characteristics of the physical environment are associated with active travel and physical activity, even if their role in 'causing' behaviour is regarded as necessary rather than sufficient.

Type II error

The first potential cause of a type II error is a form of differential misclassification — as suggested above with respect to the interpretation of the negative association between active travel and perceived road safety for cyclists — whereby respondents who are more active are more likely to be aware of, and report, adverse characteristics of their local environment than those who are not active. If this were the case, any real influence of these environmental characteristics would be diluted by the differential misclassification which would tend to bias the results of analysis towards supporting the null hypothesis of no association.

A second potential cause, which is by no means limited to this study, is that the environmental characteristics ascertained are those of the immediate surroundings of respondents' homes, whereas much of the travel which people undertake need not occur in that environment; one might express this in epidemiological terms by suggesting that the 'wrong' exposure may have been measured. For example, if a respondent travels four miles to work, by definition only about one-eighth of that journey will take place within the radius specified in the questionnaire ('Think of your local area as everywhere within a ten-minute walk (about half a mile) from your home.') The propensity to choose active modes for part or all of this journey may be strongly influenced by the characteristics of the environment elsewhere on the route, for example the perceived danger of cycling in the city centre — an association which may be absent, or at least diluted, when the 'exposure' under consideration is limited to the residential environment. An alternative approach, which may have been more appropriate had the study been focused on the journey to work, would have been to ask respondents about environmental conditions along the route to their place of work or study. [450]

A third potential cause is that of insufficient validity or reliability of the items measuring perceptions of the local environment. The only single item which was significantly and positively associated with active travel was perceived proximity to shops, which was also one of the items with the highest test–retest reliability (measured using Cohen's κ) and could be regarded as assessing a more concrete characteristic than, for example, the attractiveness of surroundings. Although within-subject reliability of most items on the neighbourhood scale was acceptable in general terms, if between-subject agreement on the more subjective items were poor this would dilute any observed association between those characteristics and active travel. It was not among the objectives of this study to 'validate' the measurement of perceived environmental characteristics, but in a future study it may be possible to undertake a form of validation by compare responses made to these items with 'norms' established by questioning people living in the same micro-environment (the same street or the same building) and therefore objectively exposed to the same environmental characteristics.

Real absence of association

As I showed in Chapter 1, a growing body of evidence — mainly from cross-sectional studies conducted in North America and Australia — suggests that both objective and subjective characteristics of the local environment may be associated with physical activity, even after adjustment for personal characteristics; this appears to be true for overall physical activity, for walking in general and for walking as a mode of transport, although different specific environmental characteristics appear to be associated with different domains of physical activity or forms of walking. At first sight, therefore, my results appear to conflict with the published literature. However, my finding of 'little significant association' is not necessarily inconsistent with other work published in the field. In their review of environmental correlates of physical activity, Wendel-Vos and colleagues noted that of all the environmental factors examined in all the studies included included in their review, analysis showed a 'null association' in 76% of cases. [45] With respect to the particular context of the M74 study, it is also possible that residents — who had lived in their local area for a median of 14 years — may simply have become adapted to adverse conditions in their local environment. For example, in a qualitative study conducted among residents living close to new roads built in the UK in the 1970s, [451] Hedges showed that over the course of three years, residents adapted in various ways to objectively-ascertained increases in noise, for example by making environmental adaptations (such as installing double glazing) and behavioural adaptations (such as ceasing to sit out in the garden). One of Hedges' findings which may particularly apply in the context of the M74 study is the phenomenon of attitudinal adaptation, which Hedges characterises as developing an attitude that it is futile to resist. This may particularly apply in a situation in which many respondents may become resigned to the quality of their surroundings, seeing them as inevitable and not amenable to change, either through environmental improvement or through their moving to another area. The plausibility of this explanation is strengthened by an acknowledgement that the social and environmental contexts of most published studies on the environmental correlates of walking differ in important ways from the conditions that pertain in the west of Scotland: there is no particular reason to believe that the environmental correlates of walking in, for example, a sprawling Australian metropolitan area with a high level of car ownership and poor public transport provision would be the same as those in the more deprived areas of Glasgow, which are characterised by comparatively good public transport services and, for many households, limited economic means and no access to a car. It may therefore be that respondents in the local area study are both objectively constrained by their socioeconomic circumstances and psychologically adapted to living in conditions which others would consider to pose a barrier to active travel. Under these circumstances, environmental characteristics shown to influence discretionary active travel in other studies may simply be irrelevant in a population which is more captive in its travel choices.

Implications for the longitudinal study

The finding of ‘little significant association’ between either active travel or physical activity and environmental characteristics in the cross-sectional (baseline) study does not necessarily challenge the basis for the longitudinal study. In Chapter 1, I referred to the widely-acknowleged observation that evidence for environmental correlates at cross-sectional level does not constitute evidence that changing the environment results in changes in behaviour. The converse also applies: absence of evidence for environmental correlates at cross-sectional level, particularly if that absence could plausibly be explained by the context of the study, does not constitute evidence that changes to the environment will not result in changes in behaviour. It remains entirely plausible that the M74 project will result in changes in perceptions of the local environment, that these changes will influence patterns of active travel or physical activity, and that these changes will influence health or wellbeing, whether directly or via changes in patterns of activity. However, the limited evidence for environmental correlates at baseline does make it more difficult to project which environmental perceptions are likely to be most significant in mediating any changes in the outcomes of interest; the only clear pointer in this respect is that proximity to amenities such as shops may be most important. The environmental impact assessment for the M74 project notes that, although no existing pedestrian journeys are likely to be objectively lengthened as a result of the presence of the new motorway, the need to cross new motorway slip roads and feeder roads with increased traffic volumes is likely to result in 'substantial' severance effects for residents in some areas, particularly those with impaired mobility. [389] This may result in their perceiving that some amenities are no longer within what they consider to be walking distance.

9.4 Future work

The ultimate purpose of the M74 study is to examine the effects of a major modification to the urban transport infrastructure on travel behaviour and health-related consequences in the population. Although the methodological and substantive findings from the cross-sectional (baseline) phase of the M74 study discussed so far in this chapter can be regarded as findings in their own right, the analyses undertaken for the thesis constitute no more than an initial foray into the datasets involved. In the final part of this chapter, I therefore discuss how the work done so far could be developed further. Two main strands of further work are possible. In the shorter term, the data could be used for further cross-sectional analysis to address questions of interest in public health or travel behaviour research. I have not been able to pursue these questions — which are somewhat tangential to the theme of the thesis — in the time available, but it would be possible to explore them using the data I have produced or, preferably, using other, more suitable datasets. I then go on to discuss how the baseline findings could contribute to the design of an eventual longitudinal (follow-up) phase of the M74 study. This is more directly relevant to the theme of the thesis: how can evidence be produced about the effects on population health of interventions made in an area of public policy whose primary aim is not to improve health, but which may nonetheless have important effects on health?

9.4.1 Further cross-sectional analyses

In the thesis, I have concentrated on those analyses which I considered most relevant to my stated focus on the problem of population-level intervention research. The primary focus of the thesis is neither physical activity research nor travel behaviour research. However, the data collected could be used to explore additional research questions of interest in these fields.

Physical activity

Environmental correlates of physical activity

One possible line of investigation would be to explore further whether the membership of clusters based on perceptions of the local environment, which was identified as significantly associated with overall physical activity, has any substantive meaning or is simply a technically correct, statistically significant finding. For example, it might be possible to use advanced methods of spatial cluster analysis to test whether the spatial distribution of cluster membership is associated with any objective characteristics of the area of residence, such as proximity to major road infrastructure or aggregate socioeconomic characteristics. However, I suggest that these questions would be more appropriately pursued in another study, for two reasons. First, the primary outcome of interest in the M74 study is active travel in a specific study population, not overall physical activity in the general population; since active travel in this population was not shown to be associated with cluster membership, there are no grounds for investigating cluster membership further as a potential explanatory variable for active travel. Second, the data collected on environmental perceptions in this study were limited to constructs thought to be relevant to active travel in this particular context and did not include all constructs likely to influence overall physical activity. If there is any meaningful spatial clustering of environmental characteristics which influence overall physical activity, such clustering is therefore likely to include characteristics not measured in this study, not relevant in this particular study population, or both; it would therefore be more appropriate to explore such clustering in a separate study designed to examine the correlates of overall physical activity in the general population.

A second possible line of investigation would be to examine the relationship between the subjective environmental characteristics reported by respondents and the objective proximity of their unit postcode of residence to a motorway or to any major road. This would reflect a major current theme in research on environmental correlates of physical activity, which is to attempt to validate self-reported measures of the physical environment against 'objective' measures, which might be derived either from spatially referenced routine data (such as the objectively-measured distance to the nearest green space) or from trained observers using validated and reliable methods (such as scores for the observed prevalence of graffiti in a neighbourhood). In this study, I chose not to pursue this question of the 'validation' of respondents' perceptions, for two reasons. First, although it would be possible to identify sources of objective data with which to validate certain items, such as proximity to shops, it is much less clear how one might validate responses to items whose content is avowedly concerned with the perception of the respondent, such as 'It is pleasant to walk': the assessment of one or more trained observers who are unlikely to live in the local area would not necessarily provide a robust criterion against which to establish the validity of such an opinion. Second, although it would be possible to explore the relationships between each of the subjective environmental characteristics and objectively-measured proximity to motorway or major road infrastructure, it is not clear what such an analysis would add to a study in which I have already shown that there is little significant association between either subjective characteristics or proximity and active travel.

Correlates of sedentariness

There is now increasing public health interest in understanding and influencing the correlates of 'sedentary behaviour' as well as its counterpart, physical activity. [452] The data collected in the local area study include an item in the IPAQ which asks about the time spent sitting. It would therefore be possible to analyse the personal and environmental correlates of time spent sitting in the same way as I have done for active travel and overall physical activity. This might be of interest in helping to understand why some people report large quantities of time during which they are physically inactive. However, as with further investigation of the environmental correlates of physical activity, such analysis could more usefully be performed on data from a representative sample of the general population which included measures of a larger range of potential explanatory variables than those collected in the local area study. An additional reason for caution identified in the IPAQ scoring protocol is that 'there are few data on sedentary (sitting) behaviours and no well-accepted thresholds'. [430]

An alternative marker of 'sedentary behaviour' available in both local and regional area studies is the frequency of short car trips. These are discussed below under the heading of travel behaviour.

Health benefits of physical activity

Using the data from the local area study, it would be possible to examine the cross-sectional relationships between active travel or physical activity and health (measured by SF-8 physical and mental health summary scores). However, this is likely to be of limited utility. It is worthwhile to explore the cross-sectional relationships between active travel or physical activity and characteristics of the environment because — as I showed in Chapter 1 — the nature of these relationships remains an active field of research in which findings are not yet seen to be consistent between studies or settings, and few studies have yet examined these relationships in longitudinal studies. In contrast, the relationships between active travel or physical activity and health outcomes have been extensively researched in rigorous longitudinal epidemiological (cohort) studies, as summarised in authoritative reports such as the 2004 report of the Chief Medical Officer. [11] As I indicated in Chapter 1, for the purposes of the thesis I have therefore taken as read that physical activity confers health benefits; in light of the established evidence from cohort studies which are widely accepted as demonstrating a causal relationship between physical activity and health outcomes, further cross-sectional analyses would appear to have little to contribute in this area.

Travel behaviour

I chose to concentrate on the time people spend travelling by different modes of transport because this is the aspect of travel behaviour which can most easily be related to the public health goals of increasing the quantity of physical activity which people undertake. I therefore designed a travel diary with the primary objective of establishing the duration of travel by different modes of transport, which I had to simplify as much as possible in order to produce an instrument which could realistically be completed as part of a postal survey. One cost of this decision was that the data I obtained were less suitable for analysing other aspects of travel behaviour, particularly the frequency, characteristics and correlates of short car trips and the spatial distribution of travel in general.

Short car trips

It would have been interesting to explore the frequency and, particularly, the characteristics and correlates of short car trips — partly because these can be regarded in some senses as markers of 'sedentary behaviour', as discussed above, and partly because 'discretionary' short car trips may be one of the most promising aspects of travel behaviour for intervention to promote active travel. In this context, I define a short car trip as one which could *in theory* have been walked or cycled (in other words, one whose distance could reasonably have been covered on foot or by bike) and a discretionary short car trip as one which could *in practice* have been walked or cycled (in other words, one made by a respondent who was physically able to walk or cycle and, if appropriate, had access to a bicycle). Behind these definitions lie an assumption that short car trips represent an aspect of travel behaviour that is, in principle, both undesirable and open to change — in other words, that short car trips might be regarded as a 'modifiable risk factor' in epidemiological terminology. The limitations of the data available in the travel diaries for the local and regional area studies pose substantial difficulties for this type of analysis.

The first limitation is that in the local area study — unlike in well-resourced population surveys such as the SHS which are administered by trained interviewers — different respondents recorded their travel in the travel diary in different ways. As discussed above, a single row in the travel diary could represent anything from a single stage of a single journey to an entire 'tour'. This variation in recording should not have influenced the accuracy of the total time recorded spent travelling by each mode over an entire day, but it does mean that there is no simple way of distinguishing 'short car trips' in the sense defined above from components of longer journeys which were made by car.

The second limitation is that in both local and regional area studies, the duration rather than the distance of each stage of each journey was recorded. It may be reasonable to assume that car journeys of very short duration (for example, five minutes or less) made by urban residents would be of a distance which could reasonably be cycled, on the basis that the average speed is unlikely to have exceeded 30 miles per hour and the distance is therefore unlikely to have exceeded 2.5 miles, but only 8% of respondents in the local area study recorded such a short car trip. It would be very difficult reliably to identify car trips which covered a distance which could realistically have been walked; a realistic walking distance of, say, 1.5 miles could be covered in a car in three minutes at 30 miles per hour or in 1.5 minutes at 60 miles per hour.

The third limitation concerns the difficulty of distinguishing 'discretionary' car trips — those realistically amenable to a modal shift — from other short car trips. Making this distinction depends on being able to identify the characteristics of each traveller and of the purpose of each trip, but neither the local nor the regional area study datasets are really sufficient to allow this. For example, a trip coded as for 'shopping' in either study could have involved buying a family's entire weekly groceries at a supermarket, buying bulky furniture, or buying a pint of milk and a newspaper from a local newsagent; only the latter example could realistically be undertaken on foot or by bike. The specialised extract from the SHS contained comparatively little data on the characteristics of respondents, and in the local area study I encountered problems with the quality of certain data. For example, the presence of pre-school children in the household has clear implications for the feasibility of making certain types of journey on foot or by bike, but I was unable to include this household characteristic in analysis owing to a large number of missing responses.

I therefore suggest that further analysis of short car trips and their contribution to the potential for modal shift would be better conducted using a different, general-population dataset such as the main SHS which would provide the optimal combination of detail about the characteristics of respondents and of their trips (not only duration, but also distance).

Spatial distribution of travel into and out of the M74 corridor

By obtaining a specialised extract of the SHS travel diary dataset, I traded the fuller details of respondents and their trips available in the main dataset for greater spatial resolution in the form of a postcode sector for the origin and destination of each stage of each journey. I had hoped that this would enable me to examine the spatial distribution of travel into and out of the M74 corridor, and attempted to do so for journeys to and from work, but I found that incomplete coding limited what could be achieved. Given time, it would be possible to impute postcode sectors for a place of work (or study) for a higher proportion of respondents by examining more closely all respondents who recorded any journey whose purpose was coded as 'place of work', 'in course of work' or 'educational establishment'. For example, some travel diaries recorded a journey from home to a location coded as 'definite (not home or work)', with a purpose coded as '[to or from] place of work', and a corresponding return journey later in the day; it was not clear why the location of the non-home end of these journeys had not been coded as 'work' in the dataset. However, a preliminary inspection showed that not all cases were as simple as this, so to correctly impute all the 'missing' locations of places of work would require either some further, comparatively complex analysis to integrate the origins and destinations of each stage of each trip, or a case-by-case analysis. The latter approach would be feasible, if time-consuming, for identifying the places of work of people living in the M74 corridor, but it would not be feasible for identifying 'missing' cases of people who work in the M74 corridor from among the many thousands who live outside the M74 corridor. Since the main aim of doing this would be to investigate whether commuting patterns change after the intervention (specifically, to investigate whether any new local employment opportunities are taken up by local residents or are taken up by residents of other areas who end up travelling further afield for work), it is unlikely that this would be worthwhile without a larger number of available cases.

9.4.2 Contribution to design of longitudinal study

Recapitulation of outline design for longitudinal study

As outlined in Chapter 6, I envisaged that the local area study would consist, eventually, of parallel repeated cross-sectional surveys in the intervention and control areas augmented by a more exploratory cohort (panel) study of those individuals who could still be traced at follow-up; the cohort study would enable me to sample participants who typified different responses to the intervention for a further qualitative study to explore the reasons and mechanisms for the changes observed at individual level. I also planned to continue the regional area study by comparing changes in travel behaviour in areas affected by the motorway with general trends for Scotland as a whole.

The findings of the cross-sectional phase of the M74 study have several implications to be taken into account in the design of the eventual follow-up phase of the study in several years' time. These consist of general implications for the design of the study and specific implications for the assessment of particular outcomes of interest.

Implications of findings for study design

First, I have shown that although the cross-sectional analysis has been useful in establishing the descriptive epidemiology of travel behaviour and physical activity in the study population, by itself it has shed little light on the influence of the physical environment on active travel. As I have argued earlier in this chapter, the finding of 'little significant association' between active travel and either perceptions of the local environment or objective proximity to motorway or major road infrastructure does not constitute evidence that a major change to the local environment will not result in detectable changes in active travel or other outcome measures. Since my cross-sectional findings are at odds with some of the published literature on the environmental correlates of walking or of physical activity, there is a clear case for undertaking longitudinal studies to test what can currently only be considered an assumption, namely that changing characteristics of the physical environment identified as correlates of physical activity in cross-sectional studies will result in changes in physical activity. As the recent systematic review by Heath and colleagues has shown, we currently rely particularly heavily on evidence from cross-sectional studies for our understanding of how community-scale urban design and land use influences physical activity. [64]

Second, I have shown both the feasibility of establishing a controlled study and the importance of including control groups. Although the response rate to the local area study was disappointing, I was able to show that the achieved samples in the intervention area and the two control areas were comparable and therefore provide a satisfactory baseline for a controlled longitudinal study. In the regional area study, I was also able to show significant decreases in the proportions of active travellers and of respondents without access to a car, even in the comparatively short interval from 2001 to 2004. Against this background, it would be difficult to interpret the results of an uncontrolled longitudinal study. If respondents were found to be less likely to be active travellers after the opening of the new motorway, it would not be possible to attribute this change to the M74 project. Conversely, any positive effect of the intervention on active travel might appear to be reduced or undetectable against a background downward trend. As I showed in the systematic review, the completion of a controlled longitudinal study of the effects of a major environmental intervention would make a significant contribution to the literature in which most intervention studies to date have been uncontrolled, concerned with individual-level rather than environmental interventions, or both.

Third, I have shown some of the complementary strengths and limitations of the data sources available. The local area study dataset is superior to that available from the SHS in terms of the focus on a precisely-defined bespoke study population, the inclusion of respondents from matched control areas, the inclusion of data on perceptions of the local environment and on physical activity, and the potential to follow up the same respondents in a future cohort (panel) study. On the other hand, the SHS travel diary dataset is superior in terms of the representativeness of sampling, the potential to make comparisons with the rest of Scotland, and the fact that the costs of data collection are met by central government. These observations support the case for using both sources of data in the follow-up phase in ways which draw on their respective strengths, in particular by attempting to follow up as many of the original cohort of respondents to the local area study as possible while also using the repeated cross-sectional waves of the SHS to monitor local and national trends in travel behaviour. Given the acknowledged limitations of both datasets, as well as the conceptual difficulties with applying a classical epidemiological understanding of causal attribution discussed in Chapter 6, the most realistic route to an ultimate assessment that environmental perceptions, active travel, wellbeing or any other outcome of interest have changed as a result of the M74 project may lie through the integration of data from multiple perspectives: a controlled repeated cross-sectional local area study, a nested cohort (panel) study of respondents in the local study areas, a qualitative study of purposively-selected individual members of that cohort, and the analysis of trends in SHS travel diaries.

Implications of findings for assessing outcomes

Active travel and physical activity

In the cross-sectional study, I chose to define active travel and physical activity as binary categorical outcomes, for several reasons: first, because their distributions were highly skewed by a large number of zero values which were therefore not amenable to log-transformation as a precursor to fulfilling the assumptions required for linear regression; second, because in the local area study travel diaries it was not possible clearly to distinguish trips from stages and tours and therefore to report active travel in terms of mode share of trips, which was the common outcome metric I used in the systematic review; third, because of doubts about the validity of the absolute quantities of physical activity reported using IPAQ.

These caveats are also relevant to the question of how to define the ultimate outcome measures for the longitudinal study. The most obvious primary outcome to be detected in the longitudinal study would be a change in the proportion of respondents in the intervention area (in the local area study) or in the M74 corridor (in the regional area study) who met the criterion for active travel; in the local area study, the change in this proportion could be compared with the changes observed in the two control areas. For the secondary question of whether changes in active travel were associated with changes in overall physical activity, which could only be addressed in the local area study, evidence of an effect would be defined as a change in the proportion of respondents in the intervention area who met the criterion for 'sufficient' physical activity, compared with the changes observed in the two control areas.

These outcome measures are easily understood and clearly related to public health goals. Given the baseline sample sizes achieved, however, it may be unrealistic to expect to detect statistically significant changes in these proportions at population level. Also, while a change in the prevalence of active travel would clearly be the aspect of travel behaviour of most relevance to public health, it would offer only a partial account of the effect of the intervention from the transport perspective.

It may therefore be helpful to specify an additional primary outcome measure which would illustrate more clearly the changes in travel behaviour. Rather than calculating changes in mode share (modal shift) in terms of the share of trips, it would be possible to calculate changes in mode share (modal shift) in terms of the share of travel time. This choice of outcome metric would reflect the nature and limitations of the travel diary used in the local area study, which was designed to capture the time spent travelling by different modes rather than trips, and would be useful from both the transport perspective (use of different modes of transport) and the physical activity perspective (time spent being active). It is also much more likely that an effect could be detected using this outcome metric: the sample size required to detect an absolute increase of 1% in the proportion of respondents who reported thirty minutes of active travel is the same as that required to detect an absolute increase of 1% in the proportion of daily travel time undertaken by active modes of transport, but the latter is more likely to be achieved than the former.

The baseline comparison of travel times by mode reported in the local and regional area studies shows that it is not appropriate to compare data of this kind collected using different instruments. In the longitudinal study, it would therefore be necessary to analyse changes in travel behaviour separately in the local and regional area studies (and then to explore differences in the findings between the studies, if any) and to ensure that the data collection instruments (travel diaries) were changed as little as possible between survey waves. In the case of the SHS, there is a risk that the travel diary might be changed between baseline and follow-up study periods. In the case of the local area study, there is no likelihood of externally-imposed changes to the design of the travel diary, but there may be a case for clarifying the instructions to respondents in order to reduce the number of unusable responses. Similar considerations apply to the follow-up assessment of physical activity using IPAQ: it may be appropriate to augment or modify the instructions in order to discourage 'Don't know' responses, but it would not be appropriate to modify the instrument itself.

It may be particularly important to examine how the effects of the intervention are distributed between groups in the study populations — particularly between those with and without access to a car, who may be subject to different influences on their mode choice, and between those living in owner-occupied and in social-rented accommodation, in order to examine the implications of the effects of the intervention for equity and social justice.

Perceptions of the local environment

The results of the cross-sectional study do not provide a clear basis for assuming either that perceptions of the local environment will change as a result of the intervention or that these will be a significant factor in influencing travel behaviour. Nonetheless, the longitudinal objective of detecting changes in perceptions of the local environment remains — whether these changes are seen as an end in themselves, as a factor in influencing travel behaviour or physical activity, or as a factor in influencing general health and wellbeing — and the cross-sectional findings provides a useful basis for such longitudinal analysis. First, I have shown that the items in the neighbourhood scale have acceptable test–retest reliability, are not collinear, and can be grouped on the basis of latent factors identified using principal components analysis. In other words, although I was not able to identify clear relationships between most of these items — or summary measures derived from them — and active travel or physical activity at baseline, I was able to show that the instrument has the potential to be used to detect changes in these perceptions over time which may turn out to be related to the outcomes of ultimate interest. Second, I have identified one possible explanation for the 'little significant association' found at baseline, namely that residents had become adapted to adverse environmental characteristics. This suggests that a follow-up local area survey should be conducted soon after the opening of the new motorway and that if this follow-up survey identifies substantial changes in perceptions of the local environment, these should be re-assessed in a subsequent survey several years later to investigate whether adaptation has occurred. Third, the cross-sectional analysis suggests that the characteristic of the local environment most likely to be associated with active travel is perceived proximity to shops. It may therefore be helpful to explore this particular characteristic in more detail in the follow-up study, for example by attempting to validate subjective reports against the objectively-measured distance to the nearest shops or by exploring the importance of access to shops in the qualitative study.

10 Conclusions

10.1 Overview of this chapter

In this chapter, I draw a set of conclusions from the thesis as a whole. These are organised under headings which broadly reflect the sequence of work undertaken. Where possible, however, I have tried to integrate conclusions across multiple chapters. Each paragraph is cross-referenced to the relevant chapter or chapters.

The chapter concludes with a summary of the claim that the thesis constitutes an original contribution to knowledge.

10.2 Modal shift and public health

Interventions in the transport sector which may promote a modal shift from using cars towards walking and cycling have the potential to change the population distribution of a putative determinant of health and therefore constitute at least putative public health interventions. The potential health benefits of such a modal shift include those associated with a reduction in the adverse health effects associated with motor traffic, but a particular causal association can be hypothesised which links a modal shift to an increase in the population level of physical activity and thereby an improvement in health on account of the subsequent reduction in the risk of many chronic diseases. (Chapter 1)

10.3 Evidence synthesis

Intervention studies in this field form a diverse body of evidence, with considerable heterogeneity of interventions, study designs and outcome measures. Most of the interventions have not been primarily intended to improve health; studies conducted to evaluate their effects have therefore tended not to consider effects on health. The rationale and methods for systematic reviews of the effects of interventions are comparatively well accepted in biomedical research, but it is increasingly acknowledged that such methods may not be entirely suitable for addressing questions about the effects of interventions from the perspective of public health. This reflects two main underlying tensions. First, conventional methods of cumulating evidence, designed to minimise bias, have tended to favour study designs which may be unfeasible in the public health field. Second, conventional methods of synthesising the cumulated data, designed to reduce imprecision in the estimation of an overall effect size, may be neither statistically appropriate nor meaningful as a means of understanding the effects of the complex types of intervention which characterise the public health field. Applying certain methods of evidence synthesis, for example excluding study designs other than randomised controlled trials or attempting to combine estimates of effect sizes using meta-analysis, would not have produced a useful or meaningful synthesis of the available evidence. There is therefore a clear need for an approach which is more inclusive and thoughtful, but which also incorporates the rigour and transparency of the scientific method. Methods for achieving this are still evolving, and there is currently no consensus on how best to go about this. The most promising approach, which I adopted, may be that described as best evidence synthesis — in other words, not allowing a desire for the best evidence to stand in the way of using the best available evidence. (Chapters 2 to 5)

Some of my methodological findings contradict those of others who have published methodological analyses of their systematic reviews. This is not surprising, given the heterogeneity of review questions and the nature of the evidence available in different topic areas. Researchers planning to synthesise evidence about the health effects of 'social' interventions should consider three important findings from the systematic review reported in this thesis. First, the temptation to rely on the electronic databases of health literature with which public health researchers are most familiar may seriously compromise the scope and value of the exercise. Second, evidence from systematic reviews on clinical topics about the relative contributions of literature databases, the internet, and contacting experts cannot necessarily be generalised to wider public health topics. Third, undertaking a comprehensive search may appear inefficient, but may also provide unique evidence — and insights into that evidence — that would not be obtained using a more focused search. (Chapters 4 and 5)

Taking an inclusive approach to the search strategy and the inclusion criteria for the systematic review contributed greater insight into the available evidence than would have been obtained through a more narrowly specified systematic review, but did not contribute significant additional robust evidence of effectiveness. In order to advance the body of evidence in this area, it is therefore likely that at present, greater value will be obtained from designing and conducting new primary intervention studies which are capable of providing more robust evidence than from repeating or further expanding efforts to synthesise existing primary studies. (Chapters 4 and 5)

10.4 Evidence of effectiveness

It is not yet possible to prove a complete causal chain linking transport interventions, changes in travel behaviour, changes in physical activity, and changes in health outcomes according to established principles of causal inference in epidemiology. However, real-world intervention research is not the same thing as classical risk-factor epidemiology, and there is no *a priori* reason why this chain should need to be proved within a single study. It may therefore be more realistic to seek to integrate evidence between the different links in that chain in order to elucidate how health really can be influenced by changes in wider public policy. (Chapter 6)

It is widely asserted that changing transport infrastructure is likely to be important in changing travel behaviour. However, the belief that changing the environment will bring about changes in population patterns of active travel, or of physical activity in general, is currently based almost exclusively on evidence from cross-sectional correlational studies rather than from studies of the actual effects of interventions in practice. The claims made in the physical activity research literature about the causal nature of this relationship are more circumspect than those made in the transport policy literature. In the systematic review, I found little evidence that the packages of policy and infrastructure measures which pertain in cities with high mode shares for walking and cycling had caused a modal shift in population travel behaviour. (Chapters 1, 4 and 5)

On the other hand, the systematic review did find that it is possible to change travel behaviour and to bring about a modal shift from using cars towards walking and cycling. The best available evidence of effectiveness in promoting a modal shift was for targeted behaviour change programmes. This finding is consistent with — although certainly not proof for — a view that interventions which engage people in a participative process and address factors of personal salience may be more effective than those which simply aim to raise awareness or impose changes in the physical and economic environments. It may also provide a degree of support for the current emphasis in both health and transport policy on encouraging individuals by means of 'soft measures' to take responsibility for their own behavioural choices rather than attempting to exercise control through 'hard measures'. (Chapters 1, 4 and 5)

However, targeted interventions of this kind may be differentially taken up by, or differentially effective among, certain groups in the population, not necessarily those with the greatest capacity to benefit from them in terms of health improvement. It may therefore also be necessary to pursue other, population-level approaches to promoting modal shift, both to address extrapersonal factors which may constrain people's travel choices and to reach a wider population. Although I found a relative lack of evidence in the systematic review for the effectiveness of other approaches, this is likely to reflect absence of robust evidence as much as it reflects robust evidence for the absence of effectiveness. (Chapters 4 and 5)

10.5 Natural experiments

In order to address the evaluative bias manifested in the relative lack of evidence about the effects of population-level interventions, it may be particularly important to take opportunities to study the effects of 'natural experiments' involving changes to transport policy and infrastructure, since these sometimes offer the only realistic opportunity to investigate changes in population health and health-related behaviour associated with interventions in the environment. Such an opportunity presented itself in the form of the M74 project. Researching natural experiments of this kind is difficult and involves taking some risks. Some may feel that the conceptual or practical problems are overwhelming and that researchers and funders should therefore stick to safer areas of investigation, but such a response appears incompatible with political and professional rhetoric about the importance of social determinants of health and about evidence-based policymaking. (Chapter 6)

Interventions undertaken in natural experiments of this kind are typically complex and specific to their context. It therefore appeared appropriate to frame the causal question for the M74 study not in terms of testing a binary hypothesis, such as that the new motorway 'caused' or did not 'cause' a modal shift, but in more indirect terms: under the conditions of the new motorway, is there any detectable change in travel behaviour, and if so, in which people, groups or areas does it occur, is it associated with a change in levels of physical activity or any other measures of health, and how plausible is it that the effects are attributable to the intervention? (Chapter 6)

Studies of natural experiments of this kind are unlikely, on their own, to produce evidence of effectiveness which could be considered 'generalisable'. Those who call for, or succeed in conducting, opportunistic intervention studies of natural experiments should be aware that they may be unlikely to produce the type of clear answer that is implicitly demanded by policy questions framed in terms of 'what works?' Such studies may have more to contribute in terms of highlighting uncertainties, contradictions, and inequities in the effects of public policy than in terms of producing generalisable estimates of effect sizes. The latter may come only, if ever, from the subsequent synthesis of multiple heterogeneous studies using innovative methods of systematic review. (Chapter 6)

10.6 The M74 study

The M74 project involves a major modification to the transport infrastructure and built environment of the Glasgow conurbation. The population living closest to the route of the new motorway, and therefore most directly exposed to the effects of the intervention, includes some of the most deprived communities in Scotland. The systematic review found limited evidence about the potential for interventions to have differential effects between groups in the population; such evidence as I did find was concerned with cycling. However, cycling currently makes a minimal contribution to the travel of residents in the M74 study area. It is therefore more appropriate to focus on walking, both as the mode of transport most likely to contribute towards overall physical activity and as the outcome in which differential effects might be sought. (Chapters 6 and 7)

Understanding the effects of interventions of this kind is likely to depend on using a combination of specially-collected and routinely-collected quantitative data and specially-collected qualitative data in order to provide complementary perspectives on the changes which may take place after the intervention. The baseline quantitative data collected in the local area study will enable longitudinal analyses to be done which would not have been possible using routinely-collected data such as those from the Scottish Household Survey and which have not been achieved in most previous intervention studies in this field. These analyses include comparing changes in active travel observed in the intervention area with those observed in matched control areas; measuring changes in perceptions of the local environment and examining their association with proximity to motorway or major road infrastructure; and examining associations between changes in active travel and changes in overall physical activity and wellbeing. (Chapters 5 to 9)

10.7 Designing intervention studies

There is no scientific consensus on how to design intervention studies of this kind. The TREND statement represents one recent attempt to codify some principles for the reporting of non-randomised evaluation studies which recognises the need for a variety of research designs and types of evidence, but it may be too restricted in scope for some public health intervention research, particularly studies of the indirect health effects of natural experiments, which were specifically cited in the second Wanless report as a potentially important source of evidence. Wanless enumerated four issues to be addressed in a framework for designing studies of this kind: the use of controls, the use of appropriate time frames, the choice of outcome measures, and the magnitude of change that should constitute 'success' for an intervention. (Chapter 6)

10.7.1 Controls and time frames

After personal factors were taken into account, neither perceptions of the local environment nor objective proximity to motorway or major road infrastructure appeared to explain much of the variance in active travel or overall physical activity in the study population. Possible explanations for this finding of 'little evidence of association' with environmental correlates are, first, that exposure to the environment around to people's homes has little explanatory power for their travel behaviour which covers a wider area; or, second, that environmental characteristics are less significant as explanatory factors in this population, which has a low level of car ownership and therefore less capacity for making discretionary travel choices than the populations studied in most published research on the environmental correlates of physical activity. (Chapters 8 and 9)

The absence of clear evidence of a strong association with environmental correlates at baseline does not necessarily mean that perceptions of the local environment will not change as a result of the intervention or that these will not be associated with changes in travel behaviour. In order to detect changes in perceptions of the local environment, however, it may be important to measure these as soon as possible after the opening of the new motorway in order to detect such changes before residents adapt to their altered surroundings. (Chapters 8 and 9)

I showed that the identification of control areas matched on aggregate demographic and socioeconomic characteristics and broad topographical characteristics was both necessary, in light of the evidence of a recent, significant downward trend in time spent in active travel in the Scottish Household Survey, and feasible, using a combination of census data, geographical data and field visits to identify one intervention area and two matched control areas from which I was able to achieve comparable baseline samples. Active travel was much more strongly associated with access to a car than with any putative environmental correlate at baseline. If the current rising trend in car ownership in the local population should continue, it may therefore be associated with a continuing decrease in active travel which is likely to outweigh or conceal a more modest effect attributable to the environmental changes brought about by the M74 project. Incorporating a comparison with control areas which are also subject to the same trends in car ownership is therefore likely to be particularly important in order to be able to detect any change in travel behaviour associated with the intervention. (Chapters 7 to 9)

10.7.2 Outcome measures and magnitude of change

The most promising common outcome metric with which to synthesise the effects of interventions in the systematic review was modal shift expressed in terms of the proportion of trips, but from a population physical activity perspective it may be more useful to examine changes in the time spent in active travel. An effect is more likely to be detected if measured in terms of the proportion of travel time spent using active modes than in the proportions of respondents meeting pre-determined thresholds of activity, such as 30 minutes of active travel per day. Such an effect is unlikely to exceed about two to four minutes per day and could be either positive or negative. (Chapters 4, 5 and 9)

The optimal trade-off between the richness of data and the burden placed on respondents appeared to be achieved using a one-day travel diary designed primarily to collect data on the time spent travelling by different modes of transport rather than on the characteristics of individual trips. Some respondents may find such diaries difficult to complete, particularly as part of a postal survey without the assistance of a researcher. The mode-specific data obtained using travel diaries are likely to be instrument-dependent, and results obtained using different instruments should not be treated as directly comparable. (Chapters 5 to 9)

Instruments for measuring the perceived characteristics of the local environment are still in a comparatively early stage of development. Many of those shown to be valid and reliable in the published literature were too long or lacked local face validity for use in the M74 study. I therefore developed a set of items appropriate for this particular study. These items were found to measure perceptions of the local environment with acceptable test–retest reliability and to be capable of being combined into a summary scale, or into subscales based on apparently-meaningful latent factors identified using principal components analysis. (Chapters 1 and 6 to 9)

10.8 Claim to originality

The first study reported in this thesis was a systematic review of previous studies of the effects of interventions on choice of mode of transport, about how these effects are distributed in the population, and about associated effects on direct measures of individual and population health. To the best of my knowledge, no other systematic review has examined these research questions. This study therefore makes an original substantive contribution to the available evidence in its own right. It also makes a methodological contribution to the field of evidence synthesis by exploring some of the boundaries of accepted methods and examining the implications of decisions made at certain critical points in the process.

The findings of the systematic review have been published as three separate papers. The paper on the substantive findings [453] has been cited by others, for example in an evidence briefing by Killoran and colleagues for the National Institute for Health and Clinical Excellence (NICE), [73] and has been used as the starting point for a subsequent integrative systematic review of quantitative and qualitative data by Brunton and colleagues at the EPPI-Centre. [454] The methods have also been favourably reviewed in a critique of recent reviews in the field by Gebel and colleagues. [455] The papers on the methodological findings [456 457] are now cited in the NICE manual on process and methods for developing public health guidance. [458]

The systematic review showed that more studies, using more rigorous methods, of the health effects of natural experiments in transport policy and practice are required. Leading directly from the first study and drawing on other relevant literature, I developed the second study to address some of the identified gaps in knowledge. The rationale and design for this study have been published in a fourth paper arising from the thesis. [459] Further papers reporting the results of the cross-sectional analyses reported in Chapter 8 are now in preparation. These analyses contribute original evidence about the environmental correlates of active travel and physical activity in a comparatively deprived urban population.

The design and baseline data for the M74 study reported in the thesis now provide the basis for a controlled longitudinal study of changes in perceptions of the local environment, active travel and physical activity associated with a major intervention in the transport infrastructure and built environment which could not otherwise have been carried out. This study, which I intend to complete after the opening of the new motorway in 2011, will contribute to addressing the call for better evidence of health effects associated with natural experiments in public policy.

References

1. National Statistics. Transport. In: *Social Trends 31*. London: Stationery Office, 2001.

2. Illich I. The industrialization of traffic. In: *Energy and equity*. London: Calder and Boyars, 1974.

3. Adams J. The social implications of hypermobility. In: *Project on environmentally sustainable transport (EST): the economic and social implications of sustainable transportation. Proceedings from the Ottawa Workshop*. Paris: Organisation for Economic Co-operation and Development, 1999.

4. McCarthy M. Transport and health. In: Marmot M, Wilkinson R, editors. *Social determinants of health*. Oxford: Oxford University Press, 1999.

5. Egan M, Petticrew M, Ogilvie D, Hamilton V. New roads and human health: a systematic review. *Am J Public Health* 2003; 93: 1463-1471.

6. Brunekreef B, Holgate S. Air pollution and health. *Lancet* 2002; 360: 1233-1242.

7. Department for Trade and Industry. *Our energy future: creating a low carbon economy*. London: Stationery Office, 2003.

8. Department for Transport. *Road casualties in Great Britain: main results 2005*. London: National Statistics, 2006.

9. Roberts I, DiGuiseppi C, Ward H. Childhood injuries: extent of the problem, epidemiological trends, and costs. *Inj Prev* 1998; 4: S10-S16.

10. Morris J. Exercise in the prevention of coronary heart disease: today's best buy in public health. *Med Sci Sports Exercise* 1994; 26: 807-814.

11. Chief Medical Officer. *At least five a week: evidence on the impact of physical activity and its relationship to health*. London: Department of Health, 2004.

12. Lean M, Gruer L, Alberti G, Sattar N. Obesity — can we turn the tide? *BMJ* 2006; 333: 1261-1264.

13. Pate R, Pratt M, Blair S, Haskell W, Macera C, Bouchard C, et al. Physical activity and public health: a recommendation from the Centers for Disease

Control and Prevention and the American College of Sports Medicine. *JAMA* 1995; 273: 402-407.

14. Bromley C, Sproston K, Shelton N. Adult physical activity. In: *The Scottish Health Survey 2003. Volume 2: adults*. Edinburgh: Scottish Executive Health Department, 2005.

15. Stamatakis E. Physical activity. In: Sproston K, Primatesta P, editors. *Health survey for England 2003. Volume 2: risk factors for cardiovascular disease*. London: National Statistics, 2004.

16. Physical Activity Task Force. *Let's make Scotland more active: a strategy for physical activity*. Edinburgh: Scottish Executive, 2003.

17. Ainsworth B, Haskell W, Whitt M, Irwin M, Swartz A, Strath S, et al. Compendium of physical activities: An update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000; 32: S498-S516.

18. Morris J, Hardman A. Walking to health. *Sports Med* 1997; 23: 306-332.

19. Mutrie N, Hannah M-K. Some work hard while others play hard. The achievement of current recommendations for physical activity levels at work, at home, and in leisure time in the west of Scotland. *Int J Health Promot Educ* 2004; 42: 109-117.

20. Owen N, Humpel N, Leslie E, Bauman A, Sallis J. Understanding environmental influences on walking: review and research agenda. *Am J Prev Med* 2004; 27: 67-76.

21. Handy S. *Critical assessment of the literature on the relationships among transportation, land use, and physical activity*. Washington, DC: Transportation Research Board and Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use, 2004.

22. Besser L, Dannenberg A. Walking to public transit: steps to help meet physical activity recommendations. *Am J Prev Med* 2005; 29: 273–280.

23. Ellaway A, Macintyre S, Hiscock R, Kearns A. In the driving seat: psychosocial benefits from private motor vehicle transport compared to public transport. *Transport Res F* 2003; 6: 217-231.

24. Davis A, Cavill N, Rutter H, Crombie H. *Making the case: improving health through transport*. London: Health Development Agency, 2005.

25. Oram J, Conisbee M, Simms A. *Ghost town Britain II: death on the high street*. London: New Economics Foundation, 2003.

26. Black A. Reconfiguring health systems. *BMJ* 2002; 325: 1290-1293.

27. Sonkin B, Edwards P, Roberts I, Green J. Walking, cycling and transport safety: an analysis of child road deaths. *J R Soc Med* 2006; 99: 402–405.

28. Jacobsen P. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Inj Prev* 2003; 9: 205-209.

29. Rose G. *The strategy of preventive medicine*. Oxford: Oxford University Press, 1992.

30. Kölbl R, Helbing D. Energy laws and human travel behaviour. *New J Phys* 2003; 5: 48.

31. Department for Transport. *Transport Statistics Bulletin: National Travel Survey 2005*. London: National Statistics, 2006.

32. Handy S, Boarnet M, Ewing R, Killingsworth R. How the built environment affects physical activity: views from urban planning. *Am J Prev Med* 2002; 23 (2S): 64-73.

33. Jones P. Setting the research agenda: response to new transport alternatives and policies. In: Mahmassani H, editor. *In perpetual motion: travel behaviour research opportunities and application challenges*. Oxford: Elsevier, 2002.

34. Tolley R. Ubiquitous, everyday walking and cycling: the acid test of a sustainable transport policy. In: Docherty I, Shaw J, editors. *A new deal for transport? The UK's struggle with the sustainable transport agenda*. Oxford: Blackwell, 2003.

35. *Study of European best practice in the delivery of integrated transport: report on stage 1 — benchmarking*. London: Commission for Integrated Transport, 2001.

36. Pucher J, Dijkstra L. Promoting safe walking and cycling to improve public health: lessons from the Netherlands and Germany. *Am J Public Health* 2003; 93: 1509-1516.

37. Annex 1: Comparison of cities with different shares of walking and cycling. In: *ADONIS project: best practice to promote cycling and walking*. Copenhagen: Road Directorate, Danish Ministry of Transport, 1998.

38. *Study of European best practice in the delivery of integrated transport: summary report*. London: Commission for Integrated Transport, 2001.

39. Trost S, Owen N, Bauman A, Sallis J, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc* 2002; 34: 1996-2001.

40. Dora C. A different route to health: implications of transport policies. *BMJ* 1999; 318: 1686-1689.

41. Hillsdon M, Foster C, Thorogood M. Interventions for promoting physical activity. *The Cochrane Database of Systematic Reviews* 2007; Issue 2.

42. Owen N, Leslie E, Salmon J, Fotheringham M. Environmental determinants of physical activity and sedentary behavior. *Exerc Sports Sci Rev* 2000; 28: 153-158.

43. Bauman A, Sallis J, Dzewaltowski D, Owen N. Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal

variables, mediators, moderators, and confounders. *Am J Prev Med* 2002; 23 (1S): 5-14.

44. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med* 2002; 22: 188-199.

45. Wendel-Vos W, Droomers M, Kremers S, Brug J, van Lenthe F. Potential environmental determinants of physical activity in adults. In: Brug J, van Lenthe F, editors. *Environmental determinants and interventions for physical activity, nutrition and smoking: a review*. Rotterdam: Erasmus University Medical Centre, 2005.

46. Duncan M, Spence J, Mummery K. Perceived environment and physical activity: a meta-analysis of selected environmental characteristics. *Int J Behav Nutr Phys Act* 2006; 2: 11.

47. Saelens B, Sallis J, Frank L. Environmental correlates of walking and cycling: findings from the transportation, urban design and planning literatures. *Ann Behav Med* 2003; 25: 80-91.

48. Badland H, Schofield G. Transport, urban design and physical activity: an evidence-based update. *Transport Res D* 2005; 10: 177-196.

49. Davison K, Lawson C. Do attributes of the physical environment influence children's physical activity? A review of the literature. *Int J Behav Nutr Phys Act* 2006; 3: 19.

50. Ferreira I, van der Horst K, Wendel-Vos W, Kremers S, van Lenthe F, Brug J. Potential environmental determinants of physical activity in youth. In: Brug J, van Lenthe F, editors. *Environmental determinants and interventions for physical activity, nutrition and smoking: a review*. Rotterdam: Erasmus University Medical Centre, 2005.

51. Giles-Corti B, Donovan R. The relative influence of individual, social and physical environment determinants of physical activity. *Soc Sci Med* 2002; 54: 1793–1812.

52. Brownson R, Chang J, Eyter A, Ainsworth B, Kirtland K, Saelens B, et al. Measuring the environment for friendliness toward physical activity: a comparison of the reliability of three questionnaires. *Am J Public Health* 2004; 94: 473-483.

53. Humpel N, Marshall A, Leslie E, Bauman A, Owen N. Changes in neighbourhood walking are related to changes in perceptions of environmental attributes. *Ann Behav Med* 2004; 27: 60-67.

54. Handy S, Cao X, Mokhtarian P. Self-selection in the relationship between the built environment and walking. *J Am Plan Assoc* 2006; 72: 55-74.

55. Handy S. Methodologies for exploring the link between urban form and travel behavior. *Transport Res D* 1996; 1: 151-165.

56. Bauman A. The physical environment and physical activity: moving from ecological associations to intervention evidence. *J Epidemiol Community Health* 2005; 59: 535-536.

57. Centre for Transport Studies, University College London. Reducing children's car use: the health and potential car dependency impacts. http://www.ucl.ac.uk/transport-studies/chcaruse.htm (accessed 13 January 2003).

58. Granville S, Laird A, Barber M, Rait F. *Why do parents drive their children to school?* Edinburgh: Scottish Executive Central Research Unit, 2002.

59. Department for Transport. *Making travel plans work: lessons from UK case studies*. London: Stationery Office, 2002.

60. Department for Transport. *A review of the effectiveness of personalised journey planning techniques*. London: Stationery Office, 2002.

61. Cairns S, Sloman L, Newson C, Anable J, Kirkbride A, Goodwin P. *Smarter choices — changing the way we travel*. London: Department for Transport, 2004.

62. Morrison D, Petticrew M, Thomson H. What are the most effective ways of improving population health through transport interventions? Evidence from systematic reviews. *J Epidemiol Community Health* 2003; 57: 327-333.

63. Kahn E, Ramsey L, Brownson R, Heath G, Howze E, Powell K, et al. The effectiveness of interventions to increase physical activity: a systematic review. *Am J Prev Med* 2002; 22 (4S): 73-107.

64. Heath G, Brownson R, Kruger J, Miles R, Powell K, Ramsey L, et al. The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. *J Phys Act Health* 2006; 3 (Suppl 1): S55-S76.

65. Foster C, Hillsdon M. Changing the environment to promote health-enhancing physical activity. *J Sports Sci* 2004; 22: 755-769.

66. Vuori I, Oja P, Paronen O. Physically active commuting to work — testing its potential for exercise promotion. *Med Sci Sports Exerc* 1994; 26: 844-850.

67. Kremers S, De Bruijn G-J, Wendel-Vos W, van Lenthe F, Brug J. Environmental interventions on physical activity in adults. In: Brug J, van Lenthe F, editors. *Environmental determinants and interventions for physical activity, nutrition and smoking: a review*. Rotterdam: Erasmus University Medical Centre, 2005.

68. Hillsdon M, Foster C, Cavill N, Crombie H, Naidoo B. *The effectiveness of public health interventions for increasing physical activity among adults: a review of reviews*. London: Health Development Agency, 2005.

69. *Four commonly used methods to increase physical activity: brief interventions in primary care, exercise referral schemes, pedometers and*

community-based exercise programmes for walking and cycling. London: National Institute for Health and Clinical Excellence, 2006.

70. Dora C, Phillips M. *Transport, environment and health. World Health Organization Regional Publications, European Series, No. 89*. Copenhagen: WHO Regional Office for Europe, 2000.

71. World Health Organization. *Charter on transport, environment and health*. Copenhagen: WHO Regional Office for Europe, 1999.

72. Department for Transport. *A new deal for transport: summary*. London: Stationery Office, 1998.

73. Killoran A, Doyle N, Waller S, Wohlgemuth C, Crombie H. *Transport interventions promoting safe cycling and walking: evidence briefing*. London: National Institute for Health and Clinical Excellence, 2006.

74. Wanless D. Public health evidence. In: *Securing good health for the whole population: final report*. London: HM Treasury, 2004.

75. Hillman M, Henderson I, Whalley A. *Transport realities and planning policy: studies of friction and freedom in daily travel*. London: Political and Economic Planning, 1976.

76. *Scotland's national transport strategy*. Edinburgh: Scottish Executive, 2006.

77. Department of Health. *Choosing activity: a physical activity action plan*. London: Stationery Office, 2005.

78. Steer Davies Gleave, Rye T, Gorman D. *Joined up policy and practice in health and transport: executive summary and final report*. Edinburgh: Scottish Executive Social Research, 2006.

79. Hunter D. Choosing or losing health? *J Epidemiol Community Health* 2005; 59: 1010-1013.

80. Macintyre S, Petticrew M. Good intentions and received wisdom are not enough. *J Epidemiol Community Health* 2000; 54: 802-803.

81. Badger D, Nursten J, Williams P, Woodward M. Should all literature reviews be systematic? *Eval Res Educ* 2000; 14: 220-230.

82. Chalmers I, Hedges L, Cooper H. A brief history of research synthesis. *Eval Health Prof* 2002; 25: 12-37.

83. Lavis J, Posada F, Haines A, Osei E. Use of research to inform public policymaking. *Lancet* 2004; 364: 1615-1621.

84. Slavin R. Best evidence synthesis: an intelligent alternative to meta-analysis. *J Clin Epidemiol* 1995; 48: 9-18.

85. The Lancet. CONSORT E-Checklist. http://www.consort-statement.org (accessed 12 January 2006).

86. Macintyre S, Chalmers I, Horton R, Smith R. Using evidence to inform health policy: case study. *BMJ* 2001; 322: 222-225.

87. Health Development Agency. HDA evidence base: topics where systematic reviews are suggested or where updates of existing reviews would be helpful. http://www.hda-online.org.uk/evidence/sr_list.html (accessed 5 March 2004).

88. Millward L, Kelly M, Nutbeam D. *Public health intervention research: the evidence*. London: Health Development Agency, 2001.

89. Pawson R, Greenhalgh T, Harvey G, Walshe K. *Realist synthesis: an introduction. ESRC Research Methods Programme working paper no. 2*. Manchester: University of Manchester, 2004.

90. Oliver S, Harden A, Rees R, Shepherd J, Brunton G, Garcia J, et al. An emerging framework for including different types of evidence in systematic reviews for public policy. *Evaluation* 2005; 11: 428-446.

91. Petticrew M. Systematic reviews from astronomy to zoology: myths and misconceptions. *BMJ* 2001; 322: 98-101.

92. Petticrew M. Presumed innocent: why we need systematic reviews of social policies. *Am J Prev Med* 2003; 24 (3S): 2-3.

93. Dickersin K. Systematic reviews in epidemiology: why are we so far behind? *Int J Epidemiol* 2002; 31: 6-12.

94. Campbell Collaboration. Campbell Collaboration guidelines. http://www.campbellcollaboration.org/guidelines.asp (accessed 14 December 2006).

95. Petticrew M. Why certain systematic reviews reach uncertain conclusions. *BMJ* 2003; 326: 756-758.

96. Antman E, Lau J, Kupelnick B, Mosteller F, Chalmers T. A comparison of results of meta-analyses of randomized control trials and recommendations of clinical experts. Treatments for myocardial infarction. *JAMA* 1992; 268: 240-248.

97. Kleinen J. Does doing systematic reviews make you want to give up research? *J Health Serv Res Policy* 2003; 8: 64.

98. Chalmers I. Trying to do more good than harm in policy and practice: the role of rigorous, transparent, up-to-date evaluations. *Ann Am Acad Polit SS* 2003; 589: 22-39.

99. Glass G. Meta-analysis at 25. http://glass.ed.asu.edu/gene/papers/meta25.html (accessed 4 January 2007).

100. Last J, editor. *A dictionary of epidemiology*. Oxford: Oxford University Press, 2001.

101. Truman B, Smith-Akin C, Hinman A, Gebbie K, Brownson R, Novick L, et al. Developing the Guide to Community Preventive Services — overview and rationale. *Am J Prev Med* 2000; 18 (1S): 18-26.

102. Cochrane A. 1931-1971: a critical review, with particular reference to the medical profession. In: *Medicines for the year 2000*. London: Office of Health Economics, 1979: 1-11.

103. The Cochrane Collaboration. Impact of Cochrane evidence. http://www.cochrane.org/reviews/impact/index.htm (accessed 14 December 2006).

104. Khan K, ter Riet G, Glanville J, Sowden A, Kleijnen J, editors. *Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews*. York: Centre for Reviews and Dissemination, University of York, 2001.

105. Higgins J, Green S. Cochrane handbook for systematic reviews of interventions 4.2.6 [updated September 2006]. In: *The Cochrane Library, Issue 4, 2006*. Chichester: Wiley, 2006.

106. Jackson N. *Systematic reviews of health promotion and public health interventions*. Melbourne: Deakin University, 2005.

107. Jackson N, Waters E, for the Guidelines for Systematic Reviews of Health Promotion and Public Health Interventions Taskforce, editors. *Guidelines for systematic reviews of health promotion and public health interventions. Version 1.2*. Melbourne: Deakin University, 2005.

108. Jackson N, Waters E, Guidelines for Systematic Reviews of Health Promotion and Public Health Interventions Taskforce. The challenges of systematically reviewing public health interventions. *J Public Health* 2004; 26: 303-307.

109. Green J, Tones K. Towards a secure evidence base for health promotion. *J Public Health Med* 1999; 21: 133-139.

110. Hammersley M. *Systematic or unsystematic, is that the question? Some reflections on the science, art and politics of reviewing research evidence*. London: Health Development Agency Public Health Steering Group, 2002.

111. Rychetnik L, Frommer M, Hawe P, Shiell A. Criteria for evaluating evidence on public health interventions. *J Epidemiol Community Health* 2002; 56: 119-127.

112. Higgins J, Green S. Formulating the problem. Cochrane handbook for systematic reviews of interventions 4.2.6 [updated September 2006]; section 4. In: *The Cochrane Library, Issue 4, 2006*. Chichester: Wiley, 2006.

113. Khan K, Popay J, Kleijnen J. Stage I: Planning the review. Phase 2: Development of a review protocol. In: Khan K, ter Riet G, Glanville J, Sowden A, Kleijnen J, editors. *Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews*. York: Centre for Reviews and Dissemination, University of York, 2001.

114. Petticrew M, Roberts H. *Systematic reviews in the social sciences: a practical guide*. Oxford: Blackwell, 2006.

115. Khan K, ter Riet G, Popay J, Nixon J, Kleijnen J. Stage II: Conducting the review. Phase 5: Study quality assessment. In: Khan K, ter Riet G, Glanville J, Sowden A, Kleijnen J, editors. *Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews*. York: Centre for Reviews and Dissemination, University of York, 2001.

116. Petticrew M, Roberts H. What sorts of studies do I include in the review? Deciding on the review's inclusion/exclusion criteria. In: *Systematic reviews in the social sciences: a practical guide*. Oxford: Blackwell, 2006.

117. Higgins J, Green S. Assessment of study quality. Cochrane handbook for systematic reviews of interventions 4.2.6 [updated September 2006]; section 6. In: *The Cochrane Library, Issue 4, 2006*. Chichester: Wiley, 2006.

118. Kunz R, Oxman A. The unpredictability paradox: review of empirical comparisons of randomised and non-randomised clinical trials. *BMJ* 1998; 317: 1185-1190.

119. Higgins J, Green S. Reviews including non-randomised studies. Cochrane handbook for systematic reviews of interventions 4.2.6 [updated September 2006]; appendix 6a. In: *The Cochrane Library, Issue 4, 2006*. Chichester: Wiley, 2006.

120. Benson K, Hartz A. A comparison of observational studies and randomized, controlled trials. *N Engl J Med* 2000; 342: 1878-1886.

121. Concato J, Shah N, Horwitz R. Randomized, controlled trials, observational studies, and the hierarchy of research designs. *N Engl J Med* 2000; 342: 1887-1892.

122. Ioannidis J, Haidich A, Lau J. Any casualties in the clash of randomised and observational evidence? *BMJ* 2001; 322: 879–880.

123. Higgins J, Green S. Locating and selecting studies. Cochrane handbook for systematic reviews of interventions 4.2.6 [updated September 2006]; section 5. In: *The Cochrane Library, Issue 4, 2006*. Chichester: Wiley, 2006.

124. Petticrew M, Roberts H. Evidence, hierarchies, and typologies: horses for courses. *J Epidemiol Community Health* 2003; 57: 527-529.

125. Glasziou P, Vandenbroucke J, Chalmers I. Assessing the quality of research. *BMJ* 2004; 328: 39-41.

126. Nutbeam D. How does evidence influence public health policy? Tackling health inequalities in England. *Health Promot J Aust* 2003; 14: 154-158.

127. Petticrew M, Whitehead M, Macintyre S, Graham H, Egan M. Evidence for public health policy on inequalities: 1: The reality according to policymakers. *J Epidemiol Community Health* 2004; 58: 811-816.

128. Des Jarlais D, Lyles C, Crepaz N, and the TREND group. Improving the reporting quality of nonrandomized evaluations of behavioral and public health interventions: the TREND statement. *Am J Public Health* 2004; 94: 361-366.

129. Peersman G, Harden A, Oliver S, Oakley A. Discrepancies in findings from effectiveness reviews: the case of health promotion interventions to change cholesterol levels. *Health Educ J* 1999; 58: 192-202.

130. Thomson H, Hoskins R, Petticrew M, Ogilvie D, Craig N, Quinn T, et al. Evaluating the health effects of social interventions. *BMJ* 2004; 328: 282-285.

131. Barreto M. Efficacy, effectiveness, and the evaluation of public health interventions. *J Epidemiol Community Health* 2005; 59: 345-346.

132. Serra C, Cabezas C, Bonfill X, Pladevall-Vila M. Interventions for preventing tobacco smoking in public places (Cochrane Review). In: *The Cochrane Library, Issue 1, 2004.* Chichester: Wiley, 2004.

133. Stead L, Lancaster T. Interventions for preventing tobacco sales to minors (Cochrane Review). In: *The Cochrane Library, Issue 1, 2004.* Chichester: Wiley, 2004.

134. Pawson R. *Assessing the quality of evidence in evidence-based policy: why, how and when? ESRC Research Methods Programme working paper no. 1*. Manchester: University of Manchester, 2003.

135. Higgins J, Green S. Guide to the contents of a protocol and review. Cochrane handbook for systematic reviews of interventions 4.2.6 [updated September 2006]; section 3. In: *The Cochrane Library, Issue 4, 2006*. Chichester: Wiley, 2006.

136. McNally R, Alborz A. Developing methods for systematic reviewing in health services delivery and organization: an example from a review of access to health care for people with learning disabilities. Part 1. Identifying the literature. *Health Info Libr J* 2004; 21: 182-192.

137. Hammersley M. On 'systematic' reviews of research literatures: a 'narrative' response to Evans and Benefield. *Br Educ Res J* 2001; 27: 543-554.

138. Matthews E, Edwards A, Barker J, Bloor M, Covey J, Hood K, et al. Efficient literature searching in diffuse topics: lessons from a systematic review of research on communicating risk to patients in primary care. *Health Libr Rev* 1999; 16: 112-120.

139. Stevinson C, Lawlor D. Searching multiple databases for systematic reviews: added value for diminishing returns? *Complement Ther Med* 2004; 12: 228-232.

140. Howes F, Doyle J, Jackson N, Waters E. Evidence-based public health: the importance of finding 'difficult to locate' public health and health promotion intervention studies for systematic reviews. *J Public Health* 2004; 26: 101-104.

141. Royle P, Milne R. Literature searching for randomized controlled trials used in Cochrane reviews: rapid versus exhaustive searches. *Int J Technol Assess Health Care* 2003; 19: 591-603.

142. Helmer D, Savoie I, Green C, Kazanjian A. Evidence-based practice: extending the search to find material for the systematic review. *Bull Med Libr Assoc* 2001; 89: 346-352.

143. Avenell A, Handoll H, Grant M. Lessons for search strategies from a systematic review, in the Cochrane Library, of nutritional supplementation trials in patients after hip fracture. *Am J Clin Nutr* 2001; 73: 505-510.

144. Glanville J. Stage II: Conducting the review. Phase 3: Identification of research. In: Khan K, ter Riet G, Glanville J, Sowden A, Kleijnen J, editors. *Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews*. York: Centre for Reviews and Dissemination, University of York, 2001.

145. Roberts I, Bunn F, Wentz R. How can we discover what works in the prevention of road traffic crashes? *BMC News Views* 2001; 2: 1.

146. Grayson L, Gomersall A. *A difficult business: finding the evidence for social science reviews*. London: ESRC UK Centre for Evidence Based Policy and Practice, Queen Mary University of London, 2003.

147. Powell G, Glanville J, Mather L, Weightman A. *Indexing in databases of relevance to public health: report of the HDA/CRD/Cardiff University (HEBW) collaborative group*. London: Health Development Agency, 2004.

148. Wentz R, Roberts I, Bunn F, Edwards P, Kwan I, Lefebvre C. Identifying controlled evaluation studies of road safety interventions: searching for needles in a haystack. *J Safety Res* 2001; 32: 267-276.

149. McManus R, Wilson S, Delaney B, Fitzmaurice D, Hyde C, Tobias R, et al. Review of the usefulness of contacting other experts when conducting a literature search for systematic reviews. *BMJ* 1998; 317: 1562-1563.

150. McAuley L, Pham B, Tugwell P, Moher D. Does the inclusion of grey literature influence estimates of intervention effectiveness reported in meta-analyses? *Lancet* 2000; 356: 1228-1231.

151. Egger M, Jüni P, Bartlett C, Holenstein F, Sterne J. How important are comprehensive literature searches and the assessment of trial quality in systematic reviews? Empirical study. *Health Technol Assess* 2003; 7: 1.

152. Sutton A, Duval S, Tweedie R, Abrams K, Jones D. Empirical assessment of effect of publication bias on meta-analyses. *BMJ* 2000; 320: 1574-1577.

153. Greenhalgh T, Peacock R. Effectiveness and efficiency of search methods in systematic reviews of complex evidence: audit of primary sources. *BMJ* 2005; 331: 1064-1065.

154. Hawker S, Payne S, Kerr C, Hardey M, Powell J. Appraising the evidence: reviewing disparate data systematically. *Qual Health Res* 2002; 12: 1284-1299.

155. Bowling A. Unstructured interviewing and focus groups. In: *Research methods in health*. Buckingham: Open University Press, 2002: 377-401.

156. Petticrew M, Roberts H. How to find the studies: the literature search. In: *Systematic reviews in the social sciences: a practical guide*. Oxford: Blackwell, 2006.

157. Armstrong R, Jackson N, Doyle J, Waters E, Howes F. It's in your hands: the value of handsearching in conducting systematic reviews of public health interventions. *J Public Health* 2005; 27: 388-391.

158. Khan K, Kleijnen J. Stage II: Conducting the review. Phase 6: Data extraction and monitoring progress. In: Khan K, ter Riet G, Glanville J, Sowden A, Kleijnen J, editors. *Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews*. York: Centre for Reviews and Dissemination, University of York, 2001.

159. Petticrew M, Roberts H. How to appraise the studies: an introduction to assessing study quality. In: *Systematic reviews in the social sciences: a practical guide*. Oxford: Blackwell, 2006.

160. Deeks J, Dinnes J, D'Amico R, Sowden A, Sakarovitch C, Song F, et al. Evaluating non-randomised intervention studies. *Health Technol Assess* 2003; 7: 27.

161. Weightman A, Ellis S, Cullum A, Sander L, Turley R. *Grading evidence and recommendations for public health interventions: developing and piloting a framework*. London: Health Development Agency, 2005.

162. Zaza S, Wright-De Agüero L, Briss P, Truman B, Hopkins D, Hennessy M, et al. Data collection instrument and procedure for systematic reviews in the Guide to Community Preventive Services. *Am J Prev Med* 2000; 18 (1S): 44-74.

163. Deeks J, Khan K, Song F, Popay J, Nixon J, Kleijnen J. Stage II: Conducting the review. Phase 7: Data synthesis. In: Khan K, Kleijnen J, Glanville J, Sowden A, Kleijnen J, editors. *Undertaking systematic reviews of research on effectiveness: CRD's guidance for those carrying out or commissioning reviews*. York: Centre for Reviews and Dissemination, University of York, 2001.

164. Higgins J, Green S. Analysing and presenting results. Cochrane handbook for systematic reviews of interventions 4.2.6 [updated September 2006]; section 8. In: *The Cochrane Library, Issue 4, 2006*. Chichester: Wiley, 2006.

165. Petticrew M, Roberts H. Synthesizing the evidence. In: *Systematic reviews in the social sciences: a practical guide*. Oxford: Blackwell, 2006.

166. Popay J, Roberts H, Sowden A, Petticrew M, Arai L, Rodgers M, et al. *Guidance on the conduct of narrative synthesis in systematic reviews: a product from the ESRC Methods Programme*. Lancaster: Institute for Health Research, Lancaster University, 2006.

167. Pawson R, Tilley N. *Realistic evaluation*. London: Sage, 1997.

168. Alderson P, Roberts I. Should journals publish systematic reviews that find no evidence to guide practice? Examples from injury research. *BMJ* 2000; 320: 376-377.

169. Campbell M, Machin D. Cohen's kappa. In: *Medical statistics: a commonsense approach*. Chichester: Wiley, 1999: 175.

170. Bland M. Comparison of two proportions. In: *An introduction to medical statistics*. Oxford: Oxford University Press, 1995: 127-129.

171. Altman D. Inter-rater agreement. In: *Practical statistics for medical research*. London: Chapman and Hall, 1991: 403-409.

172. Lohmann-Hansen A, Lahrmann H. The BikeBus'ter project in Aarhus. Velo Australis International Bicycle Conference, Fremantle, Western Australia, 1996.

173. Hülsmann W. The "bicycle-friendly towns" project in the Federal Republic of Germany. In: Tolley J, editor. *The greening of urban transport: planning for walking and cycling in western cities*. London: Belhaven Press, 1990.

174. Zvonkovic P. *Lane Transit District "Curb your car" project: final report*. Eugene, OR: Lane Transit District, 2001.

175. *TravelSmart Frome pilot project*. Bristol: Sustrans, 2002.

176. *TravelSmart Gloucester pilot project*. Bristol: Sustrans, 2002.

177. Cervero R, Creedman N, Pohan M, Pai M, Tsai Y-H. *City CarShare: assessment of intermediate-term travel-behavior impacts*. Berkeley: Institute of Urban and Regional Development, University of California at Berkeley, 2002.

178. Dean D. *The Stockton cycle route after study (1986)*. Crowthorne, Berkshire: Transport Research Laboratory, 1993.

179. Babtie Group. *Urban street activity in 20 mph zones: final report*. London: Department for Transport, Local Government and the Regions, 2001.

180. Perkins A, Giannakodakis G. *The greenhouse abatement potential of travel behaviour change initiatives. Report by Transport SA in conjunction with Transport WA for the NGS Measure 5.3 Taskforce*. Walkerville: Transport South Australia, 2001.

181. Ampt E. Reducing car travel through travel blending. 25th European Transport Forum Annual Meeting, London, 1997.

182. Ampt L. Grass routes: from travel blending to living neighbourhoods. *Traffic Eng Control* 1999; 40: 475-478.

183. Rose G, Ampt E. Travel blending: an Australian travel awareness initiative. *Transport Res D* 2001; 6: 95-110.

184. Department for Transport. *A review of the effectiveness of personalised journey planning techniques*. London: Stationery Office, 2002: 25-48.

185. *Initial results from travel behaviour change projects in Australia. Research summary TP-02/6*. Walkerville: Transport South Australia, 2002.

186. *Travel behaviour change programs in Australia. Research summary TP-02/5*. Walkerville: Transport South Australia, 2002.

187. Australian Greenhouse Office. Living neighbourhoods: partnerships for change. http://www.greenhouse.gov.au/coolcommunities/publications/living.html (accessed 20 August 2003).

188. Weisbrod G, Loudon W, Pitschke S, Reid P, Rittenhouse B, Hazard H, et al. *Downtown Crossing: auto restricted zone in Boston (final report 1977-1980)*. Cambridge, MA: Cambridge Systematics, 1982.

189. Algmin J. Boston's Downtown Crossing: its effects on downtown retailing. *Transit J* 1980; 6: 15-26.

190. Weisbrod G. Business and travel impacts of Boston's Downtown Crossing automobile-restricted zone. *Transport Res Rec* 1982; 882: 25-32.

191. Boston. In: *Ombygning af det eksisterende trafiknet: muligheder og følgevirkninger. Et litteraturstudium vedrørende gennemførte trafiksaneringsprojekter [Reorganisation of the existing traffic network: possibilities and consequences. A literature review of completed traffic management projects]*. Oslo: Nordisk Vejteknisk Forbund, 1992: 11-12.

192. Shoup D. Evaluating the effects of cashing out employer-paid parking: eight case studies. *Transport Policy* 1997; 4: 201-216.

193. Shoup D. *Evaluating the effects of parking cash out: eight case studies*. Sacramento: Air Resources Board Research Division, California Environmental Protection Agency, 1997.

194. Mokhtarian P, Varma K. The trade-off between trips and distance traveled in analyzing the emissions impacts of center-based telecommuting. *Transport Res D* 1998; 3: 419-428.

195. Wilmink A, Hartman J. *Evaluation of the Delft bicycle network plan: final summary report*. The Hague: Ministry of Transport and Public Works, 1987.

196. Katteler H, Förg O, Brög W. *Evaluatie fietsroutenetwerk Delft: het verplaatsingsgedrag: vooronderzoek [Evaluation of the Delft bicycle network: travel behaviour: before study]*. Nijmegen: Instituut voor Toegepaste Sociologie, 1984.

197. Katteler H, Förg O, Brög W. *Evaluatie fietsroutenetwerk Delft: marges voor het fietsgebruik: vooronderzoek [Evaluation of the Delft bicycle network: effects on bicycle use: before study]*. Nijmegen: Instituut voor Toegepaste Sociologie, 1985.

198. *Evaluation of the Delft bicycle network: summary report of the before study*. The Hague: Ministry of Transport and Public Works, 1986.

199. Bovy P, Veeke P. Intensiteitspatronen voor en na realisering van het Delftse fietsrouteplan [Changes in bicycle and car traffic volume after implementation of the Delft bicycle network plan]. *Bijdragen Verkeerskundige Werkdagen* 1987; 29.

200. Bovy P, den Adel D. *Evaluatie fietsroutenetwerk Delft: mobiliteit in de middelgrote steden [Evaluation of the Delft bicycle network: mobility in medium-sized cities]*. Delft: Onderzoeksinstituut voor Stedebouw, Planologie en Architectuur, Technische Universiteit Delft, 1987.

201. Bovy P. Wijzigingen verkeersintensiteiten door Delfts fietsrouteplan [Changes in traffic intensity as a result of the Delft bicycle network plan]. *Verkeerskunde* 1988; 39: 54-58.

202. Hartman J. The Delft bicycle network. In: Tolley J, editor. *The greening of urban transport: planning for walking and cycling in western cities*. London: Belhaven Press, 1990.

203. Tolley R. The Delft cycle network. In: *Calming traffic in residential areas*. Tregaron, Dyfed: Brefi Press, 1990: 89-91.

204. Louisse C, ten Grotenhuis D, van Vliet J. Evaluatie fietsroutenetwerk Delft: lessen en leergeld voor integraal stedelijk verkeersbeleid [Evaluation of the Delft bicycle network: lessons for integrated urban traffic policy]. *Colloquium Vervoersplanologisch Speurwerk* 1994; 56.

205. Delft. In: *More bikes — policy into best practice*. Godalming: Cyclists' Touring Club, 1995: 51.

206. Hartman J. The Delft bicycle network revisited. In: Tolley R, editor. *The greening of urban transport: planning for walking and cycling in European cities*. Chichester: Wiley, 1997.

207. Vallar J-P, Kerveillan A. Delft (NL). In: *Politiques en faveur du développement du vélo: bonnes pratiques de villes européennes [Policies to promote the bicycle: good practice in European towns]*. Brussels: ADEME/Energie-Cités, 2001: 31-34.

208. Dammann F, Hänel K, Richard J. *Abschließender Bericht zum Modellvorhaben "Fahrradfreundliche Stadt". Teil B: Fahrradverkehrsplanung in der Modellstadt Detmold [Final report of the "bicycle-friendly town" demonstration project. Part B: Planning for bicycle traffic in the demonstration town of Detmold]*. Berlin: Umweltbundesamt, 1987.

209. Eichenauer M, Von Winning H, Streichert E. *Abschließender Bericht zum Modellvorhaben "Fahrradfreundliche Stadt". Teil C: Fahrradverkehrsplanung in der Modellstadt Rosenheim [Final report of the "bicycle-friendly town" demonstration project. Part C: Planning for bicycle traffic in the demonstration town of Rosenheim]*. Berlin: Umweltbundesamt, 1987.

210. Tolley R. Urban cycling in West Germany. In: *Calming traffic in residential areas*. Tregaron, Dyfed: Brefi Press, 1990: 92-93.

211. Bracher T. Germany. In: McClintock H, editor. *The bicycle and city traffic: principles and practice*. London: Belhaven Press, 1992.

212. Hülsmann W. Towards the bicycle-friendly town in Germany. In: Tolley R, editor. *The greening of urban transport: planning for walking and cycling in European cities*. Chichester: Wiley, 1997.

213. *Bypass demonstration project: further research and analysis in relation to attitudes to walking*. Leicester: Social Research Associates, 1999.

214. Barrell J, Robson C. The bypass demonstration project: an overview. *Traffic Eng Control* 1995; 36: 398-403.

215. Hodgkinson M, Whitehouse J. Urban street activity in 20mph zones — emerging findings. European Transport Conference, Cambridge, 1999.

216. Slow speeds benefits found elusive. *Air Qual Manag* 2002; January: 5.

217. Unpublished technical report on TravelSmart Frome pilot project. Bristol: Sustrans, 2002.

218. Mutrie N, Carney C, Blamey A, Crawford F, Aitchison T, Whitelaw A. "Walk in to Work Out": a randomised controlled trial of a self help intervention to promote active commuting. *J Epidemiol Community Health* 2002; 56: 407-412.

219. Mutrie N, Carney C, Blamey A, Whitelaw A, Crawford F, Aitchison T. Can active commuting increase quality of life? Three-month results from a randomized control trial. *J Sports Sci* 2000; 18: 18-19.

220. Unpublished technical report on TravelSmart Gloucester pilot project. Bristol: Sustrans, 2002.

221. Rowland D, DiGuiseppi C, Gross M, Afolabi E, Roberts I. Randomised controlled trial of site specific advice on school travel patterns. *Arch Dis Child* 2003; 88: 8-11.

222. Hodgson F, May T, Tight M, Conner M. Evaluation of the MIST travel awareness campaign: 2. The before-and-after study. *Traffic Eng Control* 1998; 39: 103-112.

223. *South Perth large scale evaluation report*. Perth: Department for Planning and Infrastructure, Government of Western Australia, 2001.

224. Brög W, Cohrs R, Schädler M. Innovative approaches for mobility management: results from an international demonstration project. European Conference on Mobility Management, Nottingham, 1998.

225. *Results of individualised marketing pilot*. Perth: Department for Planning and Infrastructure, Government of Western Australia, 1998.

226. James B. Changing travel behaviour through individualised marketing: application and lessons from South Perth. 22nd Australasian Transport Research Forum, Sydney, 1998.

227. James B. Changing travel behaviour through individualised marketing: application and lessons from South Perth, Australia. European Conference on Mobility Management, Nottingham, 1998.

228. Ker I, James B. *Evaluating behaviour change in transport: benefit cost analysis of individualised marketing for the city of South Perth*. Perth: Department of Transport, Government of Western Australia, 1999.

229. Socialdata Australia. *Community survey and marketing campaign for the South Perth TravelSmart project: report of the second evaluation*. Perth: Department for Planning and Infrastructure, Government of Western Australia, 1999.

230. *TravelSmart: a cost effective contribution to transport infrastructure*. Perth: Department of Transport, Government of Western Australia, 2000.

231. Socialdata Australia. *Community survey and marketing campaign for the South Perth TravelSmart project: third evaluation report*. Perth: Department for Planning and Infrastructure, Government of Western Australia, 2000.

232. James B, Brög W. Increasing walking trips through TravelSmart® Individualised Marketing. *World Transport Policy Pract* 2001; 7: 61-66.

233. Ashton-Graham C, John G, James B, Brög W, Grey-Smith H. Increasing cycling through 'soft' measures (TravelSmart) — Perth, Western Australia. In: McClintock H, editor. *Planning for cycling: principles, practice and solutions for urban planners*. Cambridge: Woodhead, 2002.

234. Brög W, Grey-Smith H. The Perth experience: reducing the use of cars — the homeopathic way. In: *Alternatives to congestion charging: proceedings of a seminar held by the Transport Policy Committee*. London: London Assembly, 2002: 33-47.

235. James B. TravelSmart — large-scale cost-effective mobility management. Experiences from Perth, Western Australia. *Proc Inst Civil Eng — Munic Eng* 2002; 151: 39-47.

236. Ker I. *Preliminary evaluation of the financial impacts and outcomes of the TravelSmart individualised marketing programme — update*. Perth: ARRB Transport Research, 2002.

237. Walsh B. Australians put brakes on car use with major programme of personalised travel planning. *Local Transport Today* 2002; February 14: 110-111.

238. *Travel behaviour change program for the city of South Perth under the TravelSmart program: technical appendix*. Perth: Department for Planning and Infrastructure, Government of Western Australia, 2003.

239. Alcott R, DeCindis M. Clean Air Force Campaign 1989-1990: programs, attitudes, and commute behavior changes. *Transport Res Rec* 1991; 1321: 34-44.

240. Cervero R, Creedman N, Pohan M, Pai M. *City CarShare: assessment of short-term travel-behavior impacts*. Berkeley: Institute of Urban and Regional Development, University of California at Berkeley, 2002.

241. Cervero R. *City CarShare: first-year travel demand impacts*. Berkeley: Institute of Urban and Regional Development, University of California at Berkeley, 2002.

242. Oja P, Paronen O, Mänttäri A, Kukkonen-Harjula K, Laukkanen R, Vuori I, et al. Occurrence, effects and promotion of walking and cycling as forms of transportation during work commuting — a Finnish experience. In: Oja P, Telama R, editors. *Proceedings of World Congress on Sport for All, Tampere, Finland, 1990*. Amsterdam: Elsevier, 1991: 233-238.

243. Oja P, Vuori I, Paronen O. Daily walking and cycling to work: their utility as health-enhancing physical activity. *Patient Educ Couns* 1998; 33 (Suppl 1): S87-S94.

244. Meland S. *Road pricing in urban areas. The Trondheim toll ring — results from panel travel surveys*. Trondheim: SINTEF Transport Engineering, 1994.

245. Meland S, Polak J. Impact of the Trondheim toll ring on travel behaviour: some preliminary findings. 21st PTRC Summer Annual Meeting, University of Manchester Institute of Science and Technology, 1993.

246. Meland S. Generalised and advanced urban debiting innovations: the GAUDI project. 3: The Trondheim toll ring. *Traffic Eng Control* 1995; 36: 150-155.

247. Polak J, Meland S. An assessment of the effects of the Trondheim toll ring on travel behaviour and the environment. In: *Towards an intelligent transport system: proceedings of the first World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems*. Brussels: ERTICO, 1995: 994-1001.

248. PROGRESS Project. Trondheim (Norway). http://www.progress-project.org/progress/tron.html (accessed 21 August 2003).

249. Arentze T, Borgers A. Assessing urban context-induced change in individual activity travel patterns: case study of new railway station. *Transport Res Rec* 2001; 1752: 47-52.

250. Bunde J. The BikeBus'ters from Århus, Denmark: 'We'll park our cars for 200 years...' In: Tolley R, editor. *The greening of urban transport: planning for walking and cycling in European cities*. Chichester: Wiley, 1997.

251. Lahrmann H, Lohmann-Hansen A, Bunde J. The BikeBuster project in Aarhus. Velo-City Conference, Barcelona, 1997.

252. C-56: BikeBus'ters in Aarhus. In: *ADONIS project: best practice to promote cycling and walking*. Copenhagen: Road Directorate, Danish Ministry of Transport, 1998: 255-257.

253. The "bike busters". In: *Walcyng: how to enhance walking and cycling instead of shorter car trips and to make these modes safer*. Luxembourg: Office for Official Publications of the European Community, 1998: 66.

254. Lahrmann H, Lohmann-Hansen A. A sustainable transport system — from cars to bicycles via incentive motivation. 3rd International Conference on Civil Engineering and the Environment, Vilnius Technical University, 1998.

255. Prochaska J, Marcus B. The transtheoretical model: applications to exercise. In: Dishman R, editor. *Advances in exercise adherence*. Champaign, IL: Human Kinetics, 1994.

256. Cairns S, Sloman L, Newson C, Anable J, Kirkbride A, Goodwin P. Introduction. In: *Smarter choices — changing the way we travel*. London: Department for Transport, 2004.

257. Ajzen I. The theory of planned behavior. *Organ Behav Hum Decis Process* 1991; 50: 179-211.

258. Malmö. In: *Ombygning af det eksisterende trafiknet: muligheder og følgevirkninger. Et litteraturstudium vedrørende gennemførte trafiksaneringsprojekter [Reorganisation of the existing traffic network: possibilities and consequences. A literature review of completed traffic management projects]*. Oslo: Nordisk Vejteknisk Forbund, 1992: 35-36.

259. Katteler H, Pas B. *Beinvloeding automobiliteit via informatie: een experimenteel onderzoek naar het effect van informatieverschaffing [Influencing automobility via information: an experimental study of the effect of information provision]*. Nijmegen: Instituut voor Toegepaste Sociale Wetenschappen, 1990.

260. *Södra Katarina: uppföljning av trafikomläggningen [Södra Katarina: follow-up of traffic re-routeing]*. Stockholm: Stockholms Kommune, 1976.

261. Apel D. Erfahrungen mit stadtischen Konzepten zur Verkehrsentlastung und Emissionsreduzierung im In- und Ausland [Experiences with urban concepts for restraining traffic and reducing emissions in Germany and abroad]. *Informationen zur Raumentwicklung* 1991; 1: 101-109.

262. *Trafikreglering av Uppsala stadskärna 1972: efterstudier 1978 [Traffic reorganisation of Uppsala city centre 1972: after study 1978]*. Stockholm: Transportforskningsdelegationen, 1979.

263. Topp H, Pharoah T. Car-free city centres. *Transportation* 1994; 21: 231-247.

264. Pharoah T, Apel D. Amsterdam. In: *Transport concepts in European cities*. Aldershot: Avebury, 1995.

265. Cairns S, Hass-Klau C, Goodwin P. Cambridge Core Scheme 1997 — phase 1. In: *Traffic impact of highway capacity reductions: assessment of the evidence*. London: Landor, 1998: 81-86.

266. Gantvoort J. Effects upon modal choice of a parking restraint measure. *Traffic Eng Control* 1984; 25: 198-200.

267. O'Mahony M, Geraghty D. Potential response to road user charging in Dublin, Ireland. *Transport Res Rec* 2000; 1732: 50-54.

268. O'Mahony M. Pricing for sustainable transport. SAVE Conference for an Energy Efficient Millennium, Graz, 1999.

269. Bureau Goudappel Coffeng BV. *Demonstratieproject herindeling stedelijke gebieden Eindhoven en Rijswijk: na-onderzoek verkeerscirculatie [Demonstration project on reclassification of residential areas in Eindhoven and Rijswijk: after study of traffic circulation]*. Deventer, Netherlands: BGC, 1985.

270. Janssen S, Kraay J. *Demonstratieproject herindeling en herinrichting van stedelijke gebieden (in de gemeenten Eindhoven en Rijswijk): eindrapport [Demonstration project on reclassification and reconstruction of residential areas (in the municipalities of Eindhoven and Rijswijk): final report]*. Leidschendam, Netherlands: Stichting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV), 1984.

271. Matthijsen M. *Reclassification and reconstruction of urban roads in the Netherlands: effects on safety, the environment and commerce*. Leidschendam, Netherlands: Institute for Road Safety Research (SWOV), 1985.

272. Taylor D, Tight M. *Feet first: public attitudes and consultation in traffic calming schemes*. Leeds: Institute of Transport Studies, University of Leeds, 1996.

273. Marshall S, Banister D. Travel reduction strategies: intentions and outcomes. *Transport Res A* 2000; 34: 321-338.

274. Marshall S, Banister D. Travel reduction strategies: intentions and outcomes. European Transport Forum, Brunel University, 1997.

275. Banister D. *Final report for publication: DANTE (Designs to Avoid the Need to Travel in Europe)*. London: Bartlett School of Planning, University College London, 1999.

276. Louw E, Maat K. Enschede: measures in a package. *Built Environ* 1999; 25: 118-128.

277. Monheim R. Policy issues in promoting the green modes. In: Tolley J, editor. *The greening of urban transport: planning for walking and cycling in western cities*. London: Belhaven Press, 1990.

278. Vallar J-P, Kerveillan A. Erlangen (DE). In: *Politiques en faveur du développement du vélo: bonnes pratiques de villes européennes [Policies to promote the bicycle: good practice in European towns]*. Brussels: ADEME/Energie-Cités, 2001: 35-38.

279. Pharoah T, Apel D. Freiburg. In: *Transport concepts in European cities*. Aldershot: Avebury, 1995.

280. Pucher J. Bicycling boom in Germany: a revival engineered by public policy. *Transport Q* 1997; 51: 31-46.

281. Cairns S, Hass-Klau C, Goodwin P. Freiburg 1960-1997. In: *Traffic impact of highway capacity reductions: assessment of the evidence*. London: Landor, 1998: 101-102.

282. Havlick S, Newman P. Can demand management tame the automobile in a metropolitan region? *World Transport Policy Pract* 1998; 4: 30-35.

283. Pucher J. Urban transport in Germany: providing feasible alternatives to the car. *Transport Rev* 1998; 18: 285-310.

284. Nordisk Vejteknisk Forbund. *Ombygning af det eksisterende trafiknet: muligheder og følgevirkninger. Et litteraturstudium vedrørende gennemførte trafiksaneringsprojekter [Reorganisation of the existing traffic network: possibilities and consequences. A literature review of completed traffic management projects]*. Oslo: Nordisk Vejteknisk Forbund, 1992: 12-14.

285. Hass Klau C. Effects of environmental traffic management: examples from West Germany. In: Hass Klau C, editor. *New life for city centres: planning, transport and conservation in British and German cities*. London: Anglo-German Foundation for the Study of Industrialised Society, 1988.

286. Pressl R, Reiter K. GOAL — Graz: noise and emission reduction through the promotion of alternative means of transport for the citizens' personal well-being. European Conference on Mobility Management, Gent, 2002.

287. Pressl R. Graz, A: GOAL (Gesund ohne Auto und Lärm) [Health without cars and noise]. http://www.epommweb.org (accessed 25 March 2003).

288. WS Atkins Transport Planning. Graz, Austria. In: *European best practice in the delivery of integrated transport. Report on stage 2: case studies*. London: Commission for Integrated Transport, 2001: 66-81.

289. Sammer G. Experience of the city of Graz in cycling promotion. In: Boivin R, Pronovost J, editors. *Proceedings of Conference on the Bicycle: Global Perspectives*. Montreal: Vélo Québec, 1992: 501-504.

290. Case study: Graz. In: *More bikes — policy into best practice*. Godalming: Cyclists' Touring Club, 1995: 43-44.

291. Honig M. Longtime survey on bicycle use. Velo-City Conference, Edinburgh and Glasgow, 2001.

292. Bourdrez J. An evaluation of the traffic management plan for Groningen. In: Hakkert A, editor. *Traffic, transportation and urban planning. Volume 2*. London: George Godwin, 1981: 49-61.

293. De Groot H, Zunderzorp R, Beukers B, van der Sterren K, Hofstra P, Hurenkamp H, et al. *Voor- en nastudies rond het verkeerscirculatieplan Groningen [Before and after studies concerning the Groningen traffic management plan]*. Den Haag: Studiecentrum Verkeerstechniek, 1981.

294. Van Werven G. The city of Groningen experience. Velo-City Conference, Milan, 1991.

295. Groningen. In: *Ombygning af det eksisterende trafiknet: muligheder og følgevirkninger. Et litteraturstudium vedrørende gennemførte trafiksaneringsprojekter [Reorganisation of the existing traffic network: possibilities and consequences. A literature review of completed traffic management projects]*. Oslo: Nordisk Vejteknisk Forbund, 1992: 23-24.

296. Van Werven G. Groningen, Netherlands. In: McClintock H, editor. *The bicycle and city traffic: principles and practice*. London: Belhaven Press, 1992: 154-164.

297. Case study: Groningen. In: *More bikes — policy into best practice*. Godalming: Cyclists' Touring Club, 1995: 49-50.

298. Huyink W. Integrated town planning and traffic policy in Groningen. *Curr Issues Plann* 1995; 2: 36-42.

299. Pharoah T, Apel D. Groningen. In: *Transport concepts in European cities*. Aldershot: Avebury, 1995.

300. Cairns S, Hass-Klau C, Goodwin P. London — Hammersmith Bridge closure 1997. In: *Traffic impact of highway capacity reductions: assessment of the evidence*. London: Landor, 1998: 127-137.

301. Kruse J. Remove it and they will disappear: new evidence why building new roads isn't always the answer. 6th National Conference on Transportation Planning for Small and Medium Sized Communities, Spokane, WA, 1999.

302. Vuchic V. Urban transportation policies: United States and peer countries. In: *Transportation for livable cities*. New Brunswick: Center for Urban Policy Research, 1999.

303. Safe cycling in Herning. In: *Collection of cycle concepts*. Copenhagen: Road Directorate, Danish Ministry of Transport, 2000: 146-149.

304. Herning — sikker på cykel [Herning — safe on the bike]. In: *Trafikpuljereview III: helhødsninger til fremme af sikker cykeltrafik i byområder [Traffic review III: overall approaches to the promotion of safe cycle traffic in urban areas]*. Copenhagen: Vejdirektoratet, Trafikministeriet, 2002: 9-12.

305. Rethati A, Pej K. Impacts of constructed regional bicycle roads in Hungary on the economy, transport and other systems. Velo-City Conference, Edinburgh and Glasgow, 2001.

306. Bohle W. German cycling policy experience. In: McClintock H, editor. *Planning for cycling: principles, practice and solutions for urban planners*. Cambridge: Woodhead, 2002.

307. Verkehrspargemeinde Langenlois. Erfolgsmessung [Evaluation]. www.vspar.at/llevaluation.html (accessed 21 August 2003).

308. European Platform on Mobility Management. Langenlois, A: The traffic saving community. http://www.epommweb.org (accessed 25 March 2003).

309. Blessington H, McClintock H. Radical solutions: ‘car-free’ cities. Conference of the Institution of Civil Engineers, Birmingham, 1995.

310. Dowland C. Lüneburg — a study of a car free city. European Transport Forum, University of Warwick, 1994.

311. Cairns S, Hass-Klau C, Goodwin P. Lüneburg 1991-1994. In: *Traffic impact of highway capacity reductions: assessment of the evidence*. London: Landor, 1998: 168-170.

312. Symons N, Bennie J, McAuley J. The Melbourne Travel Management Association (TMA) demonstration project — an interim assessment. 17th ARRB Conference, Gold Coast, Queensland, 1994.

313. Germany. In: *More bikes — policy into best practice*. Godalming: Cyclists’ Touring Club, 1995: 46-47.

314. WS Atkins Transport Planning. Munich, Germany. In. European best practice in the delivery of integrated transport. Report on stage 2: case studies. London: Commission for Integrated Transport, 2001: 25-45.

315. Case study: Munster. In: *More bikes — policy into best practice*. Godalming: Cyclists’ Touring Club, 1995: 47-48.

316. Stanton B, Andersen T. The cutting edge of strategies for cycling promotion. In: *Proceedings of Velo-City '99, Graz and Maribor*. Salzburg: Semaco Ges, 1999: 415-419.

317. C-2: Bicycle route — an example from Odense. In: *ADONIS project: best practice to promote cycling and walking*. Copenhagen: Road Directorate, Danish Ministry of Transport, 1998: 119-121.

318. Odense — Danmarks nationale cykelby [Odense — Denmark's national cycling city]. In: *Trafikpuljereview III: helhødsninger til fremme af sikker cykeltrafik i byområder [Traffic review III: overall approaches to the promotion of safe cycle traffic in urban areas]*. Copenhagen: Vejdirektoratet, Trafikministeriet, 2002: 31-34.

319. OPIUM Project. *Final report for publication: OPIUM (Operational Project for Integrated Urban Management)*. Liverpool: Merseytravel, 1999.

320. James N, Fereday D, Stokes G. Changing travel behaviour. European Transport Conference, Cambridge, 1999.

321. Mamoli M. Padua: a decade to become a cycle city. In: McClintock H, editor. *Planning for cycling: principles, practice and solutions for urban planners*. Cambridge: Woodhead, 2002.

322. Nicholson F. *Cycle routes in Portsmouth. II — Traffic studies*. Crowthorne, Berkshire: Transport and Road Research Laboratory, 1979.

323. Præstø Indkøbscyklen [The Præstø shopping bike]. In: *Trafikpuljereview III: helhødsninger til fremme af sikker cykeltrafik i byområder [Traffic review*

III: overall approaches to the promotion of safe cycle traffic in urban areas]. Copenhagen: Vejdirektoratet, Trafikministeriet, 2002: 23-26.

324. Shopping bikes in Præstø. In: *Collection of cycle concepts*. Copenhagen: Road Directorate, Danish Ministry of Transport, 2000: 144-145.

325. Vernon M, Brewin M, Vernon D. Sustainability and evidence of success: an 18-month follow-up study of the Doorstep Walks initiative. *Health Educ J* 2002; 61: 44-51.

326. Vernon D, Brewin M. Doorstep Walks: an evaluation of the impact of a low cost intervention to assist primary health care teams in promoting physical activity. *Health Educ J* 1998; 57: 224-231.

327. Gabel M, Nihan N. Passenger-only ferry service between Vashon Island and Seattle, Washington. *Transport Res Rec* 1993; 1383: 1-7.

328. WS Atkins Transport Planning. Stuttgart, Germany. In: *European best practice in the delivery of integrated transport. Report on stage 2: case studies*. London: Commission for Integrated Transport, 2001: 46-65.

329. Södra Katarina, Stockholm. In: *Ombygning af det eksisterende trafiknet: muligheder og følgevirkninger. Et litteraturstudium vedrørende gennemførte trafiksaneringsprojekter [Reorganisation of the existing traffic network: possibilities and consequences. A literature review of completed traffic management projects]*. Oslo: Nordisk Vejteknisk Forbund, 1992: 26.

330. Ashley A, Bartlett H. An evaluation of a walking scheme based in primary care: the participants' perspective. *Prim Health Care Res Dev* 2001; 2: 98-106.

331. Ashley A, Bartlett H, Lamb S, Steel M. *Evaluation of the Thames Valley health walks scheme: participants' feedback survey*. Oxford: Oxford Centre for Health Care Research and Development, Oxford Brookes University, 1999.

332. Widmer P. Parking policy in the canton of Thurgau. In: *Parking policy measures and their effects on mobility and the economy: Swiss case studies (COST 342/18/CH)*. Luxembourg: Community Research and Development Information Service (CORDIS), 2001: 78-100.

333. Herry M, Schuster M. *Parking policy measures and their effects on mobility and the economy: overview of national/regional parking policies: Austria (COST 342/19-A Rev.1)*. Luxembourg: Community Research and Development Information Service (CORDIS), 2000: 45-57.

334. Dawson J. Comprehensive traffic management in York — the monitoring and modelling. *Traffic Eng Control* 1979; 20: 510-515.

335. White J. A walk on the (not so) wild side — promoting the pedestrian in York. Traffic Management and Road Safety Conference, Coventry, 1994.

336. Jovic J. Changes in users' behaviour under conditions of restricted passenger car use — experiences in Yugoslavia. PTRC Summer Annual Meeting, University of Sussex, 1986.

337. The ABC project in Aalborg (Aalborg-Bicycle-Commute). In: *Collection of cycle concepts*. Copenhagen: Road Directorate, Danish Ministry of Transport, 2000: 140-143.

338. Nyrup H. Work-home cycling project, 1995-1998. In: *Proceedings of Velo-City '99, Graz and Maribor*. Salzburg: Semaco Ges, 1999: 432-435.

339. Aalborg: Arbejde-Bolig-Cykel-projektet [Aalborg: the Work-Home-Cycle project]. In: *Trafikpuljereview III: helhødsninger til fremme af sikker cykeltrafik i byområder [Traffic review III: overall approaches to the promotion of safe cycle traffic in urban areas]*. Copenhagen: Vejdirektoratet, Trafikministeriet, 2002: 27-31.

340. Nordisk Vejteknisk Forbund. *Ombygning af det eksisterende trafiknet: muligheder og følgevirkninger. Et litteraturstudium vedrørende gennemførte trafiksaneringsprojekter [Reorganisation of the existing traffic network: possibilities and consequences. A literature review of completed traffic management projects]*. Oslo: Nordisk Vejteknisk Forbund, 1992: 35-6.

341. Rossi P. The iron law of evaluation and other metallic rules. *Res Soc Probl Public Policy* 1987; 4: 3-20.

342. Wimbush E, MacGregor A, Fraser E. Impacts of a national mass media campaign on walking in Scotland. *Health Promot Int* 1998; 13: 45-53.

343. Hillsdon M, Cavill N, Nanchahal K, Diamond A, White I. National level promotion of physical activity: results from England's ACTIVE for LIFE campaign. *J Epidemiol Community Health* 2001; 55: 755-761.

344. DiGuiseppi C, Roberts I, Li L, Allen D. Determinants of car travel on daily journeys to school: cross sectional survey of primary school children. *BMJ* 1998; 316: 1426-1428.

345. Adams J, White M. Why don’t stage-based activity promotion interventions work? *Health Educ Res* 2004; 20: 237–243.

346. Brug J, Conner M, Harré N, Kremers S, McKellar S, Whitelaw S. The transtheoretical model and stages of change: a critique. Observations by five commentators on the paper by Adams, J. and White, M. (2004) Why don't stage-based activity promotion interventions work? *Health Educ Res* 2005; 20: 244-258.

347. Troelsen J, Jensen S, Andersen T. *Evaluering af Odense — Danmarks nationale cykelby [Evaluation of Odense — Denmark's national cycle city]*. Odense: Odense Kommune, 2004.

348. Chesterton G. *Chesterton day by day: the wit and wisdom of G. K. Chesterton*. Seattle, WA: Inkling, 2002.

349. Ferguson J, Bauld L, Chesterman J, Judge K. The English smoking treatment services: one-year outcomes. *Addiction* 2005; 100 (s2): 59-69.

350. Baker D, Middleton E. Cervical screening and health inequality in England in the 1990s. *J Epidemiol Community Health* 2003; 57: 417-423.

351. Van Evert H, Brög W, Erl E. *Survey design: the past, the present and the future*. Rotterdam and Munich: AVV Transport Research Centre and Socialdata Institut für Verkehrs- und Infrastrukturforschung, 2004.

352. Cooper M, Ungar W, Zlotkin S. An assessment of inter-rater agreement of the literature filtering process in the development of evidence-based dietary guidelines. *Public Health Nutr* 2006; 9: 494-500.

353. Taylor B, Dempster M, Donnelly M. Hidden gems: systematically searching electronic databases for research publications for social work and social care. *Br J Soc Work* 2003; 33: 423-439.

354. Gibson C, Bailey B, Carper M, Le Cheminant J, Kirk E, Huang G, et al. Author contacts for retrieval of data for a meta-analysis on exercise and diet restriction. *Int J Technol Assess Health Care* 2006; 22: 267–270.

355. Moller J. Reconsidering community based interventions. *Inj Prev* 2004; 10: 2-3.

356. Rees R, Harden A, Shepherd J, Brunton G, Oliver S, Oakley A. *Young people and physical activity: a systematic review of research on barriers and facilitators*. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London, 2001.

357. Medawar P. Is the scientific paper a fraud? In: Edge D, editor. *Experiment: a series of scientific case histories*. London: British Broadcasting Corporation, 1964.

358. Kaptchuk T. Effect of interpretive bias on research evidence. *BMJ* 2003; 326: 1453-1455.

359. Marinelli P, Roth M. Travelsmart suburbs Brisbane: a successful pilot of a voluntary travel behaviour change technique. *Australasian Transport Research Forum* 2002; 13.

360. *Travel behaviour change program for parts of the Perth Metropolitan Area under the TravelSmart program 2001 to 2005. Final report: TravelSmart® households program, city of Melville*. Fremantle: Socialdata Australia, 2004.

361. *TravelSmart Sheffield (Hillsborough/Middlewood) 2003-04: a report on the individualised marketing project funded through the Department for Transport's personalised travel planning demonstration programme*. Bristol: Sustrans, 2004.

362. *Greater Nottingham TravelSmart (Lady Bay and the Meadows): a report on the individualised marketing project funded through the Department for Transport's personalised travel planning demonstration programme*. Bristol: Sustrans, 2004.

363. *TravelSmart Gloucester (Quedgeley) 2003-04: a report on the individualised marketing project funded through the Department for Transport's personalised travel planning demonstration programme*. Bristol: Sustrans, 2004.

364. *Cramlington TravelSmart: a report on the individualised marketing project funded through the Department for Transport's personalised travel planning demonstration programme*. Bristol: Sustrans, 2004.

365. *Bishopston TravelSmart: a report on the individualised marketing project funded through the Department for Transport's personalised travel planning demonstration programme*. Bristol: Sustrans, 2004.

366. Ogilvie D, Foster C, Rothnie H, Cavill N, Hamilton V, Fitzsimons C, et al. Interventions to promote walking: systematic review. *BMJ* 2007; 334: 1204-1207; originally published online 31 May 2007; doi:10.1136/bmj.39198.722720.BE.

367. *Central London congestion charging impacts monitoring: fourth annual report, June 2006*. London: Transport for London, 2006.

368. *Central London congestion charging impacts monitoring: second annual report, April 2004*. London: Transport for London, 2004.

369. Medical Research Council Social and Public Health Sciences Unit. Evaluating the health effects of social interventions. http://www.msoc-mrc.gla.ac.uk/CurrentResearch/Evaluating/Evaluating_MAIN.html (accessed 8 March 2006).

370. Acheson D. *Independent inquiry into inequalities in health*. London: Stationery Office, 1998.

371. Nutbeam D. Evidence-based public policy for health: matching research to policy need. *Promot Educ* 2001; 2: 15-19.

372. Hawe P, Shiell A, Riley T. Complex interventions: how "out of control" can a randomised controlled trial be? *BMJ* 2004; 328: 1561-1563.

373. Oakley A, Strange V, Toroyan T, Wiggins M, Roberts A, Stephenson J. Using random allocation to evaluate social interventions: three recent U.K. examples. *Ann Am Acad Polit SS* 2003; 589: 170-189.

374. Kirkwood B. Making public health interventions more evidence based. *BMJ* 2004; 328: 966-967.

375. Brown C, Lilford R. The stepped wedge trial design: a systematic review. *BMC Med Res Methodol* 2006; 6: 54.

376. Petticrew M, Cummins S, Ferrell C, Findlay A, Higgins C, Hoy C, et al. Natural experiments: an underused tool for public health? *Public Health* 2005; 119: 751-757.

377. General Register Office for Scotland. Scotland's census results online. http://www.scrol.gov.uk (accessed 11 July 2005).

378. Scottish Public Health Observatory. Constituency profiles 2004: central Scotland region. http://www.scotpho.org.uk (accessed 8 March 2006).

379. *Glasgow and the Clyde Valley joint structure plan 2000*. Glasgow: Glasgow and the Clyde Valley Structure Plan Joint Committee, 2000.

380. Scottish Executive. Central Scotland transport corridor studies. http://www.cstcs.co.uk (accessed 8 March 2006).

381. Hickman R. *Roads (Scotland) Act 1984; Acquisition of Land (Authorisation Procedure) (Scotland) Act 1947. M74 Special Road (Fullarton Road to west of Kingston Bridge) Orders. Report of public local inquiry into objections*. Edinburgh: Inquiry Reporters Unit, Scottish Executive, 2004.

382. Scottish Executive. *Working together for Scotland: a programme for government*. Edinburgh: Stationery Office, 2001.

383. Scottish Executive. *Scotland's transport: delivering improvements. Transport delivery report*. Edinburgh: Stationery Office, 2002.

384. Scottish Executive. Scottish planning policy: SPP 17 — planning for transport. http://www.scotland.gov.uk/Publications/2005/08/16154406/44078 (accessed 26 April 2006).

385. Scottish Executive. *Scotland's transport: delivering improvements. Transport indicators for Scotland*. Edinburgh: Stationery Office, 2002.

386. Scottish Executive. *A partnership for Scotland: partnership agreement*. Edinburgh: Stationery Office, 2003.

387. Scottish Executive. M74 completion: makes complete sense. http://www.m74completion.com (accessed 11 July 2005).

388. Scottish Executive. The Roads (Scotland) Act 1984; the Acquisition of Land (Authorisation Procedure) (Scotland) Act 1947. M74 special road (Fullarton Road to west of Kingston Bridge) orders. http://www.scotland.gov.uk/Publications/2005/03/3083928/39304 (accessed 26 April 2006).

389. *The M74 completion: environmental statement*. Edinburgh: Scottish Executive, 2003.

390. Mindell J, Ison E, Joffe M. A glossary for health impact assessment. *J Epidemiol Community Health* 2003; 57: 647-651.

391. Mindell J, Boaz A, Joffe M, Curtis S, Birley M. Enhancing the evidence base for health impact assessment. *J Epidemiol Community Health* 2004; 58: 546-551.

392. Bradford Hill A. The environment and disease: association or causation? *Proc Roy Soc Med* 1965; 58: 295-300.

393. Rothman K. What is causation. In: *Epidemiology: an introduction*. Oxford: Oxford University Press, 2002.

394. Matt G. Will it Work in Münster? Meta-analysis and the empirical generalization of causal relationships. In: Holling H, Böhning V, Schulze R, editors. *Meta-analysis*. Berlin: Springer, 2003.

395. Cook T, Campbell D. *Quasi-experimentation: design and analysis issues for field settings*. Chicago: Rand McNally, 1979.

396. Shadish W, Cook T, Campbell D. *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton Mifflin, 2002.

397. Berman A. *Enhancing health among drug users in prison* [PhD thesis]. Stockholm: Stockholm University and Karolinska Institutet, 2004.

398. Judge K. Testing evaluation to the limits: the case of English Health Action Zones. *J Health Serv Res Policy* 2000; 5: 3-5.

399. Baum F. Researching public health: behind the qualitative-quantitative methodological debate. *Soc Sci Med* 1995; 40: 459-468.

400. Scottish Executive. Scottish Household Survey. http://www.scotland.gov.uk/Topics/Statistics/16002/4031 (accessed 26 April 2006).

401. Malam S, Angle H, Wimbush E, Fraser E. *Health Education Population Survey 1996-2003*. Edinburgh: NHS Health Scotland, 2004.

402. ISD Scotland. Practice Team Information. http://www.isdscotland.org (accessed 30 March 2006).

403. ISD Scotland. What data are collected: patient and activity data. http://www.isdscotland.org (accessed 30 March 2006).

404. Scottish Executive. *Scottish Household Survey travel diary results for 2004*. Edinburgh: National Statistics, 2006.

405. Stratford N, Simmonds N, Nicolaas G, Costigan P. *National Travel Survey 2002*. London: Department for Transport, 2003.

406. Saelens B, Sallis J, Black J, Chen D. Neighborhood-based differences in physical activity: an environment scale evaluation. *Am J Public Health* 2003; 9: 1552-1558.

407. Lowther M, Mutrie M, Loughlan C, McFarlane C. Development of a Scottish physical activity questionnaire: a tool for use in physical activity interventions. *Br J Sports Med* 1999; 33: 244-249.

408. Shephard R. Limits to the measurement of habitual physical activity by questionnaires. *Br J Sports Med* 2003; 37: 197-206.

409. Sallis J, Saelens B. Assessment of physical activity by self-report: status, limitations, and future directions. *Res Q Exerc Sport* 2000; 71 (2 Suppl): S1-S14.

410. Karolinska Institute. IPAQ: International Physical Activity Questionnaire. http://www.ipaq.ki.se/ (accessed 26 April 2006).

411. Rzewnicki R, van den Auweele Y, de Bourdeaudhuij I. Addressing overreporting on the International Physical Activity Questionnaire (IPAQ) telephone survey with a population sample. *Public Health Nutr* 2003; 6: 299–305.

412. Craig C, Marshall A, Sjöström M, Bauman A, Booth M, Ainsworth B, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003; 35: 1381-1389.

413. Rütten A, Ziemainz H, Schena F, Stahl T, Stiggelbout M, van den Auweele Y, et al. Using different physical activity measurements in eight European countries. Results of the European Physical Activity Surveillance System (EUPASS) time series survey. *Public Health Nutr* 2003; 6: 371-376.

414. Department for Transport. *Transport Statistics Bulletin: National Travel Survey 2002*. London: Stationery Office, 2004.

415. Duncan M, Mummery K. GIS or GPS? A comparison of two methods for assessing route taken during active transport. *Am J Prev Med* 2007; 33: 51-53.

416. Richardson T. Current issues in travel and activity surveys. In: Mahmassani H, editor. *In perpetual motion: travel behaviour research opportunities and application challenges*. Oxford: Elsevier, 2002.

417. Arentze T, Dijst M, Dugundij E, Joh C, Kapoen L, Krijgsman S, et al. A new activity-diary format: design and limited empirical evidence. *Transport Res Rec* 2001; 1768: 79-88.

418. Cronin de Chavez A, Backett-Milburn K, Parry O, Platt S. Understanding and researching wellbeing: its usage in different disciplines and potential for heatlh research and health promotion. *Health Educ J* 2005; 64: 70-87.

419. Hird S. *Individual wellbeing: a report for the Scottish Executive and Scottish Neighbourhood Statistics*. Glasgow: NHS Health Scotland, 2003.

420. Hird S. *What is wellbeing? A brief review of current literature and concepts*. Glasgow: NHS Health Scotland, 2003.

421. QualityMetric Incorporated. SF-36.org: a community for measuring health outcomes using SF tools. http://www.sf-36.org (accessed 26 April 2006).

422. QualityMetric Incorporated. A manual for users of the SF-8® Health Survey. http://www.sf-36.org (accessed 19 May 2005).

423. Macintyre S, Annandale E, Ecob R, Ford G, Hunt K, Jamieson B, et al. The West of Scotland Twenty-07 Study: health in the community. In: Martin C, McQueen D, editors. *Readings for a new public health*. Edinburgh: Edinburgh University Press, 1989: 56-74.

424. McLoone P. *Carstairs scores for Scottish postcode sectors from the 2001 Census*. Glasgow: MRC Social and Public Health Sciences Unit, 2004.

425. Carstairs V, Morris R. Deprivation: explaining differences in mortality between Scotland and England and Wales. *BMJ* 1989; 299: 886-889.

426. US Geological Survey. Geographical information systems. http://erg.usgs.gov/isb/pubs/gis_poster (accessed 26 July 2007).

427. Edwards P, Roberts I, Clarke M, DiGuiseppi C, Pratap S, Wentz R, et al. Increasing response rates to postal questionnaires: systematic review. *BMJ* 2002; 324: 1183-1191.

428. Ware J, Kosinski M, Dewey J, Gandek B. *How to score and interpret single-item health status measures: a manual for users of the SF-8 (TM) Health Survey*. Lincoln, RI: QualityMetric Incorporated, 2001.

429. Jenkinson C. Comparison of UK and US methods for weighting and scoring the SF-36 summary measures. *J Public Health Med* 1999; 21: 372-376.

430. *Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ) — short and long forms*. Stockholm: Karolinska Institute, 2005.

431. Hinton P, Brownlow C, McMurray I, Cozens R. Introduction to factor analysis. In: *SPSS explained*. London: Routledge, 2004: 341-354.

432. Costello A, Osborne J. Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. *Pract Assess Res Eval* 2005; 10: 7.

433. Humpel N, Owen N, Iverson D, Leslie E, Bauman A. Perceived environment attributes, residential location, and walking for particular purposes. *Am J Prev Med* 2004; 26: 119–125.

434. Twostep Cluster. In: *SPSS 12.0 Command Syntax Reference*. Chicago: SPSS, Inc: 1591-1600.

435. Hosmer D, Lemeshow S. Model-building strategies and methods for logistic regression. In: *Applied logistic regression*. New York: Wiley, 1989: 82-134.

436. *Scottish Household Survey: methodology 2003/2004*. Edinburgh: Scottish Executive, 2005.

437. *Scottish Household Survey: fieldwork outcomes 2003/2004*. Edinburgh: Scottish Executive, 2005.

438. Altman D, Bland M. Presentation of numerical data. *BMJ* 1996; 312: 572.

439. Bland M, Altman D. Cronbach's alpha. *BMJ* 1997; 314: 572.

440. *Research into the delivery experiences of residents of Scottish tenements*. Edinburgh: Postwatch Scotland, 2006.

441. Parry O, Bancroft A, Gnich W, Amos A. Issues of respondent recruitment in areas of deprivation. *Critical Public Health* 2001; 11: 305–317.

442. Cummins S, Petticrew M, Higgins C, Findlay A, Sparks L. Large scale food retailing as an intervention for diet and health: quasi-experimental evaluation of a natural experiment. *J Epidemiol Community Health* 2005; 59: 1035-1040.

443. *Consumers' use of fixed telephony. Q14 August 2003*. London: Office for Communications (Oftel), 2003.

444. Scottish Executive. Digital inclusion strategy 2006. http://www.scotland.gov.uk/Publications/2006/12/22112316/0 (accessed 29 May 2007).

445. Nicolaas G. Putting voters in the frame. *NatCen News* 2006; 13: 12.

446. *Scottish Household Survey. The travel diary: additional information*. Edinburgh: TNS Social Research and MORI Scotland, 2003.

447. Alexander A, Bergman P, Hagströmer M, Sjöström M. IPAQ environmental module: reliability testing. *J Public Health* 2006; 14: 76-80.

448. Department for Transport. *A new deal for transport: better for everyone*. London: Stationery Office, 1998.

449. Fleming A. *Scotland’s census 2001: statistics on travel to work or study. Occasional Paper no. 12*. Edinburgh: General Register Office for Scotland, 2006.

450. Titze S, Stronegger W, Janschitz S, Oja P. Environmental, social, and personal correlates of cycling for transportation in a student population. *J Phys Act Health* 2007; 4: 66-79.

451. Hedges A. *Adaptations to traffic noise*. London: Social and Community Planning Research, 1983.

452. Varo J, Martínez-González M, De Irala-Estévez J, Kearney J, Gibney M, Martínez A. Distribution and determinants of sedentary lifestyles in the European Union. *Int J Epidemiol* 2003; 32: 138-146.

453. Ogilvie D, Egan M, Hamilton V, Petticrew M. Promoting walking and cycling as an alternative to using cars: systematic review. *BMJ* 2004; 329: 763-766.

454. Brunton G, Oliver S, Oliver K, Lorenc T. *A synthesis of research addressing children’s, young people’s and parents’ views of walking and cycling for transport*. London: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London, 2006.

455. Gebel K, Bauman A, Petticrew M. The physical environment and physical activity: a critical appraisal of review articles. *Am J Prev Med* 2007; 32: 361-369.

456. Ogilvie D, Hamilton V, Egan M, Petticrew M. Systematic reviews of health effects of social interventions: 1. Finding the evidence: how far should you go? *J Epidemiol Community Health* 2005; 59: 804-808.

457. Ogilvie D, Egan M, Hamilton V, Petticrew M. Systematic reviews of health effects of social interventions: 2. Best available evidence: how low should you go? *J Epidemiol Community Health* 2005; 59: 886-892.

458. *The public health guidance development process*. London: National Instutute for Health and Clinical Excellence, 2006.

459. Ogilvie D, Mitchell R, Mutrie N, Petticrew M, Platt S. Evaluating health effects of transport interventions: methodologic case study. *American Journal of Preventive Medicine* 2006; 31: 118-126.

Appendix 1: Survey materials

Advance postcard

UNIVERSITY
of
GLASGOW

MRC Social and Public Health Sciences Unit
Medical Research Council

September 2005

Traffic and health in Glasgow

We are carrying out research on traffic and health in your area. We hope you can help us by taking part in a survey of local residents. In the next few days, we will be sending you a questionnaire in the post. Please look out for it. Thank you!

MRC Social and Public Health Sciences Unit, University of Glasgow,
4 Lilybank Gardens, Glasgow, G12 8RZ. Tel: 0141 357 3949

Covering letter

UNIVERSITY
of
GLASGOW

MRC Medical Research Council

September 2005

Dear Sir or Madam

Traffic and health in Glasgow

I am a public health doctor working for the Medical Research Council. I am writing to invite a member of your household to take part in a research study on traffic and health in your local area. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Take time to decide whether or not you wish to take part.

Thank you for reading this letter.

What is the purpose of the study?

The conditions of city life are important for people's health. We want to find out how the local environment affects how people feel, how they travel around, and their general health. We are particularly interested in roads, traffic and transport and how these affect the quality of life in local areas. We will be surveying people who live in three different parts of the city to find out what conditions are like now. We will repeat the survey in a few years' time to find out how things have changed and how these changes have affected the people who live there.

Why have we been chosen?

We chose your address at random from the Royal Mail's list of all the addresses in your area.

Do I have to take part?

It is up to you to decide whether or not to return the questionnaire.

What will happen to me if I take part?

If you return the questionnaire, we will analyse the information you give us and combine it with the information from other people's questionnaires. **You do not have to tell us your name or agree to any further contact from us.**

However, the information you give us will be even more useful if we can come back to you personally again in the future, so we hope you will consider filling in an optional **consent form** with your contact details. If you return this consent form, then:

(a) In the future (probably in four or five years' time), we will send you another questionnaire similar to the one we are sending you today

AND

(b) During the next year, you will have a chance of being invited to talk about the topic in more detail in a one-to-one discussion. If you are chosen for this, I will send you a separate letter nearer the time

AND

(c) You will be entered into a prize draw to win a £50 gift voucher.

We are not asking you to agree to take part in any follow-up study now. We are only asking for permission to contact you again later to invite you to take part. If you do decide to take part in a follow-up study, you will still be free to withdraw at any time and without giving a reason.

What do I have to do now?

We would like you to choose **one adult** member of your household (aged 16 and over) to fill in the questionnaire. The front page of the questionnaire explains how to choose that person. The questionnaire should take about 15 minutes to complete.

Please then send the questionnaire back to us in the envelope provided. No stamp is needed.

If you would like to have the chance to take part in the follow-up studies, then please also fill in and sign the consent form.

What are the possible disadvantages of taking part?

There is no disadvantage to you except for the time you will need to spend on the questionnaire. We will not give your contact details to anyone else.

What are the possible benefits of taking part?

The information that is collected during this study will give us a better understanding of the health effects of traffic and the environment. We hope this will help make sure that future transport policy takes account of people's health needs.

You will receive no direct benefit from taking part in this study, except that if you give us your contact details on the consent form, you will be entered into a prize draw to win a £50 gift voucher.

Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. You will be identified by an ID number and any information about you will have your name and address removed so that you cannot be recognised from it.

What will happen to the results of the research study?

We expect to publish the results of the study in the next few years. No-one will be able to identify you personally in any results that are published. If you give us your contact details on the consent form, we will send you a summary of the results. The results will also form part of my PhD thesis.

Who is organising and funding the research?

The research is organised by the Social and Public Health Sciences Unit at the University of Glasgow and is funded by the Medical Research Council. It is overseen by a steering group of public health experts from the universities of Glasgow, Edinburgh and Strathclyde.

Who has reviewed the study?

The study has been approved by the University of Glasgow Faculty of Medicine Ethics Committee.

Who can I contact for further information?

If you would like further information, please contact me, David Ogilvie, at the Social and Public Health Sciences Unit (telephone 0141 357 3949 or e-mail d.ogilvie@msoc.mrc.gla.ac.uk).

Yours faithfully

Dr David Ogilvie MB BChir MPH MFPHM

Information letter B, version 2, September 2005

Consent form

Traffic and health in Glasgow: postal survey
Consent form for follow-up contact from the research team

I confirm that I have read and understood the information letter for this study (information letter B, version 2, dated September 2005).

I give permission for the research team to contact me in the future, using the information I have supplied below, to invite me to take part in a follow-up postal survey or interview.

I understand that my contact details will be held securely by the research team and will not be passed to anyone else.

I understand that my participation in any future survey or interview is voluntary and that I am free to withdraw my consent at any time, without giving any reason, without my legal rights being affected.

I understand that if I want to withdraw this consent, I can do so at any time by writing to or telephoning the survey department at the MRC Social and Public Health Sciences Unit.

Signed		Date	

Name (please print)	
Address (please print)	Postcode
Telephone number (landline)	
Telephone number (mobile)	
E-mail	

Consent form B, version 2, September 2005

Questionnaire

Traffic and health in Glasgow Questionnaire

CONFIDENTIAL

Who should complete this questionnaire

This questionnaire should be completed by **one adult member of the household** (aged 16 and over) to which the envelope was addressed. Please do **not** pass it on to another household.

If there is more than one adult in the household, please choose the adult who has most recently had their birthday to complete the questionnaire. For example, if one person has a birthday in March and the other has a birthday in May, please choose the person whose birthday is in May.

How to complete the questionnaire

The questionnaire is not long. It should take about 15 minutes to complete.

Please use a blue or black pen.

Some questions ask you to **tick** a box. Please tick the box that applies to you.

Example: Are you male or female? Male ☑ Female ☐

Other questions ask you to **write numbers** in a box.

Example: What is your age? *Write in* [53] years

Don't worry if you make a **mistake** — just cross out the mistake and put in the correct answer.

Example: Do you have access to a bicycle? Yes ☑ No ☑

About you and your household

1 Are you male or female? *Tick one only* Male ☐ Female ☐

2 What is your age? *Write in* ☐ years

3 How far do you have to travel to get to your usual place of work or study?

Tick one only

Do not work or study ☐

Usually work at home or from home ☐

Less than one mile ☐

One mile or more ☐ → *Write in number of miles* ☐

4 Do you have access to a bicycle?

Tick one only Yes ☐ No ☐

5 How many other people live in your household?
We mean people who have your accommodation as their only or main residence, and who either share at least one meal a day with you or share the living accommodation (living room or sitting room) with you.

Write in number
If none, write "0"

Children aged under 5 ☐

Children aged between 5 and 15 ☐

Adults aged 16 and over (do not include yourself) ☐

6 Does your household own or rent its accommodation?

Tick one only

Rents it from the council, Scottish Homes, a housing association, or a charity ☐

Rents it from a private landlord or letting agency ☐

Partly owns it and partly rents it (shared ownership) ☐

Owns it (including buying with a mortgage) ☐

Other ☐

7 **How many cars or vans are owned, or available for use, by members of your household?**
Do not include motorcycles, scooters or mopeds.

Write in number
If none, write "0" ☐

8 **Thinking about the work you do, which of these best describes your situation at present?**
Please answer for yourself, and for your spouse or partner if you have one who lives with you.

	Yourself *Tick one only*	Your spouse/partner *Tick one only*
Doing paid work full time	☐	☐
Doing paid work part time	☐	☐
On a government training scheme	☐	☐
Retired	☐	☐
Full time student	☐	☐
Unemployed	☐	☐
Disabled, invalid or permanently sick	☐	☐
Caring for home and family or dependants	☐	☐
Other	☐	☐
Not living with a spouse or partner		☐

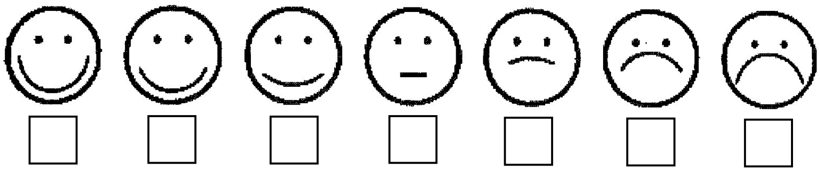
9 **Thinking about the cost of living as it affects you and your household, which of these best describes your situation at present?**

	Tick one only
Find it a strain to get by from week to week	☐
Have to be careful about money	☐
Able to manage without much difficulty	☐
Quite comfortably off	☐

About your health

10 Looking at the faces scale, which face shows best how you feel about your life as it is now?

Tick one only



11 Do you have any long-term illness, health problem or disability which limits your daily activities or the work you can do? Include problems which are due to old age.

Tick one only Yes ☐ No ☐

12 Do you have any difficulty walking for a quarter of a mile on the level?

Tick one only Yes ☐ No ☐

13 How tall are you? (with your shoes off)

Write in ☐ ft ☐ in **OR** ☐ cm

14 How much do you weigh? (in light indoor clothes)

Write in ☐ st ☐ lb **OR** ☐ kg

The next section asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities.

For each of the following questions, please tick the one box that best describes your answer.

15 Overall, how would you rate your health during the PAST FOUR WEEKS?

Excellent	Very good	Good	Fair	Poor	Very poor
☐	☐	☐	☐	☐	☐

16 During the PAST FOUR WEEKS, how much did physical health problems limit your usual physical activities (such as walking or climbing stairs)?

Not at all	Very little	Somewhat	Quite a lot	Could not do physical activities
☐	☐	☐	☐	☐

17 During the PAST FOUR WEEKS, how much difficulty did you have doing your daily work, both at home and away from home, because of your physical health?

None at all	A little bit	Some	Quite a lot	Could not do daily work
☐	☐	☐	☐	☐

18 How much BODILY pain have you had during the PAST FOUR WEEKS?

None	Very mild	Mild	Moderate	Severe	Very severe
☐	☐	☐	☐	☐	☐

19 During the PAST FOUR WEEKS, how much energy did you have?

Very much	Quite a lot	Some	A little	None
☐	☐	☐	☐	☐

20 During the PAST FOUR WEEKS, how much did your physical health or emotional problems limit your usual social activities with family or friends?

Not at all	Very little	Somewhat	Quite a lot	Could not do social activities
☐	☐	☐	☐	☐

21 During the PAST FOUR WEEKS, how much have you been bothered by emotional problems (such as feeling anxious, depressed or irritable)?

Not at all	Slightly	Moderately	Quite a lot	Extremely
☐	☐	☐	☐	☐

22 During the PAST FOUR WEEKS, how much did personal or emotional problems keep you from doing your usual work, school or other daily activities?

Not at all	Very little	Somewhat	Quite a lot	Could not do daily activities
☐	☐	☐	☐	☐

About your local area

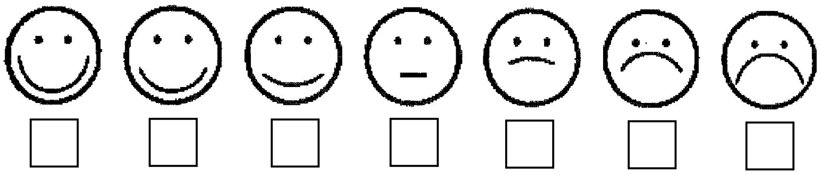
This section asks for your views about your **local area**. Think of your local area as everywhere within a ten-minute walk (about half a mile) from your home.

23 How long have you lived in your local area?
If you have lived this area previously and come back again, please just answer about the current period of time that you have lived in your local area.

Write in ☐ years and ☐ months

24 Looking at the faces scale, which face shows best how you feel about living in your local area?

Tick one only



25 For each of the following statements about your local area, please tick one box to show how strongly you agree or disagree.

Tick one per row

In my local area…	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
It is pleasant to walk	☐	☐	☐	☐	☐
There is a lot of traffic noise	☐	☐	☐	☐	☐
There is a park within walking distance	☐	☐	☐	☐	☐
The roads are dangerous for cyclists	☐	☐	☐	☐	☐
There is convenient public transport	☐	☐	☐	☐	☐
People are likely to be attacked	☐	☐	☐	☐	☐
There are convenient routes for cycling	☐	☐	☐	☐	☐
There is little green space	☐	☐	☐	☐	☐
It is safe to walk after dark	☐	☐	☐	☐	☐
The nearest shops are too far to walk to	☐	☐	☐	☐	☐
There is little traffic	☐	☐	☐	☐	☐
There are no convenient routes for walking	☐	☐	☐	☐	☐
It is safe to cross the road	☐	☐	☐	☐	☐
The surroundings are u nattractive	☐	☐	☐	☐	☐

About your travel

In this section, we are interested in all the journeys you made **yesterday** (between 3 a.m. yesterday morning and 3 a.m. this morning).

26 **Please list each journey you made yesterday to get from place to place.** These might include, for example, going to work, going out to get lunch, coming home from work, going shopping, going to the doctor's, visiting friends, or escorting someone else (e.g. taking a child to school). Please include time spent travelling on foot or by bike, even if this was part of a longer journey (e.g. by bus or train). But please **do not include** journeys you made as part of your job (e.g. as a bus driver), or walking or cycling purely for recreation or exercise (e.g. walking the dog).

We have given you an example of ***one*** *journey. This person walked for ten minutes to the bus stop, rode on the bus for 22 minutes, and then walked for five minutes to get to work (a total of 15 minutes walking). They did not count the time spent waiting for the bus.*

	What was the purpose of the journey? Please give a simple description, e.g. "to work", "to get home from work", "shopping", "take child to school"	**How many MINUTES did you spend TRAVELLING by each mode of transport on this journey?** Do not count time spent waiting for buses, trains etc.						
		Bus or coach	Train or underground	Car, taxi or van	Motorcycle or moped	Bicycle	Walking	Other
Example	To work	22					15	
Journey 1								
Journey 2								
Journey 3								
Journey 4								

Continue over the page if necessary

About your travel (continued)

How many MINUTES did you spend TRAVELLING by each mode of transport on this journey?
Do not count time spent waiting for buses, trains etc.

	What was the purpose of the journey? Please give a simple description, e.g. "to work", "to get home from work", "shopping", "take child to school"	Bus or coach	Train or underground	Car, taxi or van	Motorcycle or moped	Bicycle	Walking	Other
Journey 5								
Journey 6								
Journey 7								
Journey 8								
Journey 9								
Journey 10								
Journey 11								
Journey 12								

27 What day of the week was it yesterday? *Write in* ☐

28 Were you at home at any time yesterday?

Tick one only Yes ☐ No ☐

29 Was yesterday a normal working day for you?

Tick one only Yes ☐ No ☐ Not applicable ☐

About your physical activity

This is the last section of the questionnaire.

In this section, we are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last seven days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, around your home and garden, to get from place to place, and in your spare time for recreation, exercise or sport.

For each question, write the numbers in the boxes to the left OR tick the box to the right, as appropriate.

30 Think about all the **vigorous** activities that you did in the **last seven days**. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least ten minutes at a time.

During the LAST SEVEN DAYS, on how many days did you do vigorous physical activities like heavy lifting, digging, five-a-side football, aerobics, running, or fast cycling?

☐ days per week ***OR** tick* No vigorous activities ☐ → ***Go to Q. 32***

31 How much time did you spend doing VIGOROUS physical activities on average on each of those days?

☐ hours and ☐ minutes per day ***OR** tick* Don't know/not sure ☐

32 Think about all the **moderate** activities that you did in the **last seven days**. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think *only* about those physical activities that you did for at least ten minutes at a time.

During the LAST SEVEN DAYS, on how many days did you do moderate physical activities like carrying light loads, vacuuming, gardening, dancing, leisurely swimming, or cycling at a regular pace? Do not include walking.

☐ days per week ***OR** tick* No moderate activities ☐ → ***Go to Q. 34***

33 **How much time did you spend doing MODERATE physical activities on average on each of those days?**

☐ hours and ☐ minutes per day ***OR** tick* Don't know/not sure ☐

34 **During the LAST SEVEN DAYS, on how many days did you walk for at least ten minutes at a time?**

☐ days per week ***OR** tick* No walking ☐ → ***Go to Q. 36***

35 **How much time did you spend WALKING on average on each of those days?**

☐ hours and ☐ minutes per day ***OR** tick* Don't know/not sure ☐

36 The last question is about the time you spent **sitting** on weekdays during the **last seven days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

During the LAST SEVEN DAYS, how much time did you spend SITTING on average on each weekday?

☐ hours and ☐ minutes per day ***OR** tick* Don't know/not sure ☐

International Physical Activity Questionnaire — Short last seven days self-administered version (August 2002)

Finally

37 **Please enter today's date.** We mean the date on which you filled in the questionnaire.

Write in ☐ / ☐ / 05

date *month*

Thank you very much for taking part. Please now return the questionnaire in the envelope provided. No stamp is required. Don't forget to enclose the **signed consent form** if you agree to being contacted again for a follow-up study.

Appendix 2: Ethical approval

Dr A.M. McNicol
Reader in Pathology
Glasgow Royal Infirmary University NHS Trust
E-mail A.M.McNicol@clinmed.gla.ac.uk
DDI 0141-211-4764 FAX 0141-211-4884

UNIVERSITY
of
GLASGOW

AMMcN/AMJG

Dr David Ogilvie
MRC Social and Public Health Sciences Unit
University of Glasgow
4 Lilybank Gardens
Glasgow
G12 8RZ

23/06/2005

Dear Dr Ogilvie

Medical Faculty Ethics Committee

Project Title: Traffic and Health in Glasgow

Project No.: FM01304

The Faculty Ethics Committee has reviewed your application and has agreed that there is no objection on ethical grounds to the proposed study. They are happy therefore to approve the project, subject to the following conditions:

- The research should be carried out only on the sites, and/or with the groups defined in the application.
- Any proposed changes in the protocol should be submitted for reassessment, except when it is necessary to change the protocol to eliminate hazard to the subjects or where the change involves only the administrative aspects of the project. The Ethics Committee should be informed of any such changes.
- If the study does not start within three years of the date of this letter, the project should be resubmitted.
- You should submit a short end of study report to the Ethics Committee within 3 months of completion.

Yours sincerely,

pp. Alice McGee

Dr. Anne M McNicol
Faculty Ethics Officer

FACULTY OF MEDICINE
Wolfson Medical School Building
University of Glasgow, Glasgow G11 8QQ
Telephone: 0141-330-8637 Fax: 0141-330-5440 Email: a.gee@clinmed.gla.ac.uk

Dr A.M. McNicol
Reader in Pathology
Glasgow Royal Infirmary University NHS Trust
E-mail A.M.McNicol@clinmed.gla.ac.uk
DDI 0141-211-4764 FAX 0141-211-4884

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AMMcN/AMJG

Dr David Ogilvie
MRC Social and Public Health Sciences Unit
University of Glasgow
4 Lilybank Gardens
Glasgow
G12 8RZ

26/01/2006

Dear Dr David Ogilvie

Medical Faculty Ethics Committee

Project Title: Traffic and Health in Glasgow

Project No.: FM01304

Thank you for your recent e-mail to the Ethics Committee regarding a proposed extension to the original protocol. I would like to confirm that there are no ethical objections to the proposed changes and that I am happy to approve the amended project.

Yours sincerely,

pp Dr. Anne M McNicol
Faculty Ethics Officer

FACULTY OF MEDICINE
Wolfson Medical School Building
University of Glasgow, Glasgow G11 8QQ
Telephone: 0141-330-8637 Fax: 0141-330-5440 Email: a.gee@clinmed.gla.ac.uk