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# Impact of interventions encouraging a switch from cars to more sustainable modes of transport

## A rapid evidence assessment (REA)

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# Contents

# 1 Executive Summary

## 1.1 Key Findings

This evidence review assesses the effectiveness of interventions encouraging people to switch from using cars to more sustainable modes of transport. It draws on published and 'grey' literature published between 2010 and 2020 from the UK, Europe, North America, Oceania and the Pacific Rim. While the review was conducted before the Covid-19 pandemic impacted the UK, much of the evidence on people's transport choices and habits is relevant to the current context.

**What is effective in switching away from individual use of cars?** Reducing car use by reducing parking availability or introducing city centre access restrictions, for example, is effective but works best when public or active transport alternatives are put in place first. Financial incentives, such as payments from employers for relinquishing workplace parking bays, can also help incentivise and sustain switching**.** Car-pooling sometimes arises as an unintended consequence of interventions aimed at encouraging a switch to public or active travel, as an adaptation to disincentives for car use. Appealing to environmental or health benefits can have a short-term effect but behaviour change does not appear to be sustained when measured some months after campaigns. It is not clear from the evidence whether this is because of the nature of the messages or the difficulties capturing consistent data on carbon emissions and health benefits to feed back to local residents and attribute to the schemes.

**What is effective in switching from cars to public transport?** Public transport infrastructure is most effective when it is well-integrated with existing transport provision, is highly visible, perceived as safe to use both in terms of personal safety from features such as enhanced lighting as well as the mode of transport itself. It should also compare favourably to the cost and convenience of driving. People are most likely to maintain a switch in the long-term if encouraged to monitor their transport behaviour against social norms, and they respond well to messages highlighting stories of successful switches. This can be supported by making journeys simpler with smart ticketing and travel planning apps together with financial incentives through the apps.

**What is effective in switching to active travel?** The most successful active travel interventions focus on short and simple journeys. Successful interventions to encourage a switch to cycling include separating cycle routes from other vehicles and providing opportunities to try out cycling. Initiatives supporting people with the purchase and maintenance of bicycles are also effective. Allowing people to trial the use of electric assisted bicycles (e-bikes) also results in lower car mileage and an increase in cycling. The impact of bicycle share schemes in cities depends on existing travel choices. In cities like London and Montreal, such schemes have tended to attract users to switch from local public transport or walking, rather than cars, but still result in a reduction in carbon emissions. Schemes to encourage active travel can encounter community concerns about personal and road safety. The evidence shows the importance of community-centred design to tackle concerns, but community involvement must be sustained to have long-term impact.

**Which groups are most likely to switch?** Most evidence reflects the location of interventions in urban or suburban settings. There is very limited evidence for rural areas or how to enable mode switches in these settings.

Looking at different groups of the population, younger people appear less likely to drive, perhaps because they are more likely to live in urban areas and less likely to own a car. Each generation is also driving less than their predecessors as they age. Although younger people are more likely to make a mode switch, older individuals are more likely to sustain any changes that they make. Deprived communities benefit from active transport initiatives, especially where they are involved in decision-making about the design. Making active and public transport more affordable and accessible to unemployed people also supported them to secure jobs. Women and people from ethnic minority backgrounds are less likely to switch to active travel and evidence for other population groups such as older or disabled people is very limited. Further exploration is needed to understand their needs for future schemes.

## 1.2 Background

This review investigates interventions designed to encourage a switch from using cars to more sustainable forms of transport. It explores the effects of interventions, and the factors that facilitate or prevent switching to sustainable modes, whether intended or not. The review also investigates evidence of differential effects of intervention by location, access to transport and socio-demographic groups. The review team selected research studies that addressed the principal research questions and only included studies using quantitative and mixed methods primary research, or meta-analysis that provided an estimate of intervention effect.

The review aimed to answer the following key questions:

1. **What is the effect of interventions encouraging people to switch from using cars to using public transport or active transport?**
    a. How do these effects differ across different lengths of journey?
    b. How do these effects differ across different groups of people, in particular:
        i. across people living in rural/urban/suburban areas?
        ii. across areas with different levels of access to transport?
        iii. across different age and income groups?
        iv. for people with disabilities?
        v. for people with children?
    c. What is the evidence on sustainability of any behaviour-change effects over time (including over the life course)?
2. **Which groups are most likely to switch, and to what forms of transport?**
3. **Is there evidence of unintended consequences of interventions to encourage mode shift?**

The review used a rapid evidence assessment (REA) methodology, which adopts a systematic and transparent approach to the search and selection of data. This review is based on **30** articles selected for their relevance to the research questions and methodological rigour. The reviewed evidence included original research and meta-analyses or systematic reviews of previous research from published and 'grey' literature dating from 2010 to early 2020.[1] It included work from the UK, Europe, North America, Oceania and the Pacific Rim.

[1] Although articles selected are from 2010 onwards they may cite earlier studies.

## 1.3 What types of intervention can achieve travel mode switch?

Interventions designed to encourage a switch to public or active modes of travel broadly fall into two types of activity that operate separately or in combination. The first seek to influence attitudes towards, or incentivise, certain travel behaviours within the existing transport infrastructure. The second develop the available infrastructure, whether through a major scheme or localised improvements.

In terms of influencing behaviour, encouraging people to monitor their transport behaviour against social norms, as well as highlighting stories of successful switches appears most effective in sustaining active and public transport choices. Financial incentives, other rewards, or even penalties delivered through transport planning apps, can also impact behaviour but do not often lead to sustained behaviour change once the incentive is removed. Other strategies, such as smart ticketing and integrated travel planning apps in general, incentivise active and public transport use by making it simpler to plan and potentially pay for a mixed mode journey. Focusing solely or mainly on the environmental or health benefits of using active or public transport does not appear to have a long-term impact on travel mode switch.

Although it might have similar benefits, there was a lack of evidence in articles that have reached publication on the behavioural impact of the Mobility as a Service (MaaS) approach. MaaS enables multi-mode trips across public and private transport to be planned and paid for using a single platform. However, evidence so far tends to focus on the potential and technical viability of such schemes rather than behavioural change.

A small number of infrastructure projects featured heavily in the reviewed literature, potentially reflecting their scale and/or innovative nature. These included the Cambridge Busway which offers a guided Busway along disused railway tracks alongside a wide track for pedestrians, cyclists and horse riders; the Oxonbike scheme, a bike-sharing scheme that formed part of improvements to public and active transport options in Oxford; and the Nottingham Express Transit (NET), a new tram line integrated with existing public transport. All of these infrastructure projects demonstrated success in people switching to modes of active and public transport. However, impact of specific infrastructure schemes can be difficult to isolate from wider developments in transport provision and evaluations sometimes lack evidence of whether changes are sustained in the long-term.

## 1.4 What is effective in encouraging different types of travel mode switch?

**Switching away from individual use of cars.** Restricting access to cars in cities or workplaces to reduce individual car use works best when both public and active transport alternatives are put in place first. While cities such as Bologna in Italy and Lubeck or Aachen in Germany are examples of successful car reduction in city centres, the Trondheim Toll Ring in Norway did not achieve the same impact. This has been partly attributed to the income from the tolls going to road infrastructure rather than being invested in sustainable travel alternatives.

As well as disincentives to bring cars into cities, employers can support a reduction in individual car use by offering financial incentives to relinquish a parking bay usually

allocated or subsidised by the employer. In areas where car preference is strong, or there are limited alternatives, this can also encourage lift sharing for commuter journeys, especially when combined with an information campaign to support this behaviour.

Car sharing and pooling can be an unintended consequence of schemes to drive a switch to public and active transport in cities. Drivers respond to the disincentives for car use by sharing journeys rather than changing their travel mode . There may also be an opportunity to incentivise Ultra-Low Emissions Vehicles (ULEVs) in these scenarios but the review of evidence published to date did not find any examples.

**Switching from cars to public transport.** While increasing use of public transport can be measured at a local, regional or national level, evidence identifying how much of that can be attributed to individual level decisions to switch away from car use for either commuting or leisure journeys is more limited. It is also difficult to identify long-term impact of public transport infrastructure schemes when evaluations do not include comparable areas where the infrastructure did not change.

To succeed, new infrastructure needs to place local community needs at the heart of the development. It needs to be easily accessible to those who live or work nearby, highly visible and understood by local people. It must be integrated with existing public transport and routes and prioritise design features that enhance personal safety, such as lighting at bus stops. At the same time, the new infrastructure needs to be more cost effective and convenient than driving to incentivise use.

**Switching to active travel.** There was more evidence available on switches to active travel than on other mode switches. The most successful interventions encouraging a switch to active travel focus on short and simple journeys. Schemes to encourage cycling and walking are less successful when part of more complex, multi-mode journeys. In the UK, the *Cycle to Work Scheme* has provided tax incentives to support many thousands of people to purchase a bicycle. As well as direct subsidies, cycling can be encouraged as part of a wider infrastructure development by providing safe cycle routes, separated from other vehicles, and support with bike maintenance. In the case of e-bikes, a scheme in Brighton showed that the opportunity to ‘try before you buy’ encourages people both to cycle more and potentially purchase one of the bikes a year after the trial.

City based bicycle share schemes have proven popular for their flexibility, convenience and freedom from the responsibility for maintenance or replacement if stolen. Bicycle share schemes in cities previously highly dependent on car use, such as Minneapolis, USA and Melbourne, Australia, have demonstrated a net reduction in car use since the introduction of such schemes. But schemes in London and Montreal have tended to displace either public or active travel choices, such as a bus or tube journey or walking, reflecting lower initial use of cars in the city.

Increases in active travel were sometimes linked to traffic fatalities, especially among cyclists. Schemes to encourage walking can be effective if they take into account local concerns about personal safety and road safety (especially for children). The *Fitter for Walking Project* across 12 Local Authorities in England successfully worked with communities to identify barriers to walking and make routes more aesthetically pleasing and well looked after. However, if this maintenance of the infrastructure is not sustained the impact can fall away.

## 1.5 Which groups are most likely to switch?

Most evidence reflects the location of interventions in urban or suburban settings. There is very limited evidence on travel mode switches in rural areas. However, there was some evidence to suggest that in rural areas increasing access to public transport could increase the use of both public and active travel.

There are some insights about different groups of the population that can be drawn from the evidence. Younger people spend less time driving than older people, perhaps because they are less likely to own a car and more likely to live in an urban area. But each cohort is driving less than their predecessors as they age. Young people are more likely to make active or public transport switches but when older people do make a shift this is more sustained. Certain groups, such as women and people from minority ethnic backgrounds, are less likely to adopt active travel. Deprived communities appear to benefit from active transport initiatives and interventions, especially where they are involved early on in deciding aims and features of design. There is evidence that lifetime transitions (e.g. losing a job, having children, retiring) may be key moments in which mode shifts can be encouraged. However, the evidence is mixed about the degree to which these can be sustained. Furthermore, some evidence shows that improving access to and affordability of both public and active transport can make a difference in helping those who are unemployed to find work.

Finally, some studies tended to reflect the higher education levels and social advantage of those responding to active and public transport initiatives. There is a gap in considering the needs and responses of disabled and other disadvantaged people.

## 1.6 Conclusions

Behavioural levers which focus on comparing individual travel patterns to social norms, and providing stories of successful switches are most effective in the long term. This may be because such messages resonate more than others but also because of the difficulties faced by local authorities in capturing consistent carbon emission data and health outcomes beyond levels of physical activity in the local community. Although carbon emission reduction and population health improvements can be key objectives of sustainable transport projects, it can be hard to demonstrate these outcomes back to local residents and attribute them to the schemes.

While the evidence in this review was collated and assessed prior to the Covid-19 pandemic impacting the UK, some of the findings are particularly relevant to the shift towards active transport that is being encouraged. For example, initiatives to encourage people to switch away from their cars are more effective where the infrastructure, such as separated cycling and walking routes are already in place. Moreover, shifts to active transport are more successful when focused on shorter, single purpose journeys. While short-term incentives and rewards to encourage mode switch have not been found to lead to a sustained change, larger scale disincentives to car use, such as restricting city-centre access or limiting parking availability, have resulted in changes in behaviour where alternatives were available.

Across all types of initiative there was consistent evidence that community involvement, particularly in deprived areas, contributes to the success of schemes. People want to feel safe and confident using new routes. Safety concerns could be addressed by both improving active travel infrastructure through separated cycling and walking routes, better pathways and crossings, and through improving perceptions of neighbourhood safety, such as through improving lighting. Offering people the opportunity to trial active travel, through the loan of bicycles or e-bikes is effective in improving confidence. However, responses to community needs and the maintenance of infrastructure must be sustained to ensure people do not revert back to using cars.

Whether as a result of the location of some of the major infrastructure projects or their take up, evidence of switching behaviour has tended to come from more socially advantaged groups. We need to know more about the barriers to public and active travel mode switching among more disadvantaged groups to build their needs and concerns into the design of new initiatives.

Some of the evaluations of interventions to encourage public or active travel discovered unintended responses involving increased car-pooling or sharing. Future schemes need to consider the full range of potential responses to any scheme and how to incorporate them into the design.

Evaluations of major transport initiatives can understandably encounter difficulties disentangling the impact of the introduction of new infrastructure on travel choices from behavioural levers, such as transport planning apps, financial rewards and smart ticketing. Evidence that can better isolate how infrastructure developments and different behavioural tools interact, both with each other and with journey requirements, could help identify what sustains public and active transport choices in the long-term. Impact could also be better demonstrated if studies are supported to identify comparable areas against which to benchmark switching behaviour over time. Timescales could be extended to strengthen evidence of whether the behaviours are sustained.

# 2 Introduction

This report presents the findings from a rapid evidence assessment (REA) examining evidence on the effects of interventions encouraging people to switch from using carbon emitting vehicles to more sustainable modes of transport. For the purposes of this review, sustainable modes are primarily defined as non-carbon producing forms of public transport and active forms of transport, such as cycling and walking. However, car sharing and pooling and the use of ultra-low emissions vehicles (ULEVs), such as electric cars, were also included where they were part of wider strategies to address environmental concerns.

## 2.1 Context

The UK government has committed to achieving a target of net zero greenhouse gas emissions by 2050.[2] As part of this target, all aspects of the economy must move to substantially reduce their overall emissions. The transport sector has a significant role to play in this aim. In 2018, the transport sector contributed 28 percent of the UK's domestic greenhouse gas emissions, making it the sector with the largest overall contribution.[3] The Department for Transport has started work on plans targeting specific vehicles, however, in order to develop a more comprehensive approach, the Department recently announced its intention to decarbonise the whole of the transport sector through the Transport Decarbonisation Plan (TDP).[4]

The TDP will work across the sector in order to identify how decarbonisation efforts can be accelerated. Within transport, road transport produces the largest quantity of greenhouse gases, and over half of those come from cars.[5] As a result, one strategic priority of the TDP is accelerating individual switches from carbon emitting vehicles to more sustainable public and active travel modes.[6]

## 2.2 Aims and objectives

This REA aims to inform development of the TDP by exploring what robust evidence already exists of interventions that are most effective in encouraging people to switch to more sustainable modes of travel in the UK. It also provides an assessment of the quality and robustness of the available evidence, and what lessons can be learnt, in order to inform the development of the TDP with key stakeholders. Broadly speaking the REA assessed what encouraged individuals to move:

- from individual, carbon producing forms of transport to more public forms of carbon-reducing or neutral forms of transport;

[2] https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law
[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/876251/decarbonising-transport-setting-the-challenge.pdf pp. 10-11.
[4] Ibid.
[5] Ibid p.12.
[6] Active travel modes include walking and cycling

- from motorised, carbon dependent[7] and/or carbon producing vehicles to more active forms of transport such as cycling or walking.

### 2.2.1 Research questions

In order to address the aims outlined above, the following research questions were developed to guide the research:

1. **What is the effect of interventions encouraging people to switch from using cars to using public transport or active transport?**
    a. How do these effects differ across different lengths of journey?
    b. How do these effects differ across different group of people, in particular:
        i. across people living in rural/urban/peri-urban areas?
        ii. across areas with different levels of access to transport?
        iii. across different age and income groups?
        iv. for people with disabilities?
        v. for people with children?
    c. What is the evidence on sustainability of any the behaviour-change effects over time (including over the life course)?
2. **Which groups are most likely to switch and to what forms of transport?**
3. **Is there evidence of unintended consequences of interventions to encourage mode shift?**

## 2.3 Methodological approach

Time and resources available meant that a Rapid Evidence Assessment (REA) was the best approach for the review. A REA retains the systematic and transparent features of a systematic review but does not seek to include all evidence on a topic. Evidence is carefully selected and scored according to substantive relevance and methodological rigour of studies.

Initial searches were conducted on three academic databases and 15 online transport related/grey literature repositories. Studies from 2010 onwards[8] and from the UK, Europe, North America, Oceania and the Pacific Rim were included. These searches generated 2,707 articles. Details of the methodological approach and studies included can be found in Appendices A and B.

Following title and abstract screening, a long list of 137 articles was produced. Where evidence gaps had emerged, forwards and backwards citation tracking of key texts was adopted to try to fill these gaps. These articles were then subject to full text screening, and in agreement with the Department, 30 articles were selected for full data extraction and synthesis.

## 2.4 Structure of the report

[7] By carbon dependent vehicles we include electric vehicles which, at this time, are still dependent on the burning of carbon-based fuels such as oil, gas and coal to produce the electricity they use.
[8] Some evidence comes from systematic reviews and meta-analysis that drew on studies from before 2010. We have included such studies where they were still pertinent to the aims of the review, and especially where they filled a significant gap in evidence.

This report is divided into the following sections:

- **Chapter 2** presents a typology of different types of interventions and their success in achieving modal shift.
- **Chapter 3** presents evidence on reducing individual use of cars**.**
- **Chapter 4** presents the evidence on shifting to public transport.
- **Chapter 5** presents the evidence on shifts to active travel.
- **Chapter 6** assesses whether there is evidence regarding different impacts of interventions based on location of interventions and socio-demographic groups.
- **Chapter 7** concludes with consideration of lessons learned from this review and evidence gaps.

# 3 Types of interventions

Before discussing the specific factors that facilitated or impeded modal shift, this chapter provides an overview of the effectiveness of different *types* of interventions that were reflected in the evidence to encourage people to switch from using cars to more sustainable modes of transport. Interventions were grouped into those that sought to encourage and influence attitudes and behaviours within existing infrastructure and those where investment had been made in new infrastructure or changes to the built environment. There was some evidence that there could be certain moments of change in people's personal lives in which interventions could have a greater impact, this is explored further in chapter six.

**Key findings**

- Focusing solely, or mainly, on changing preferred mode of transport by appealing to environmental concerns or health benefits rarely worked in the long term. Encouraging people to self-monitor their travel behaviour against perceived norms, and highlighting cases of others who had successfully switched mode, appeared to facilitate greater change in behaviour.
- Making active travel routes safer, more pleasant and well-integrated with local amenities appeared to encourage a switch to active travel for commuting and recreation. Superior design, visibility, promotional activities and involvement of local communities in decision making about priority routes also encouraged modal switch.
- There was limited evidence available on the use of rewards and travel planning applications (apps) as ways to encourage a switch from cars to public and/ or active travel. Rewards for a fixed period tended not sustain a switch to active travel once they ended. However, registered users of travel planning apps used public transport more when they received rewards than unregistered users.
- There was virtually no evidence looking at interventions that adopt a Mobility as a Service approach – highlighting an evidence gap.
- A small number of new integrated transport schemes were consistently highlighted in the literature. However, the amount and robustness of evidence used as measures of the success of the schemes varied considerably.

## 3.1 Changing attitudes and behaviours

**There were several interventions that aimed at achieving a behavioural change by raising concern for the environment or the health benefits of mode switch. There was little evidence that these interventions worked in the long term. However, interventions that invited participants to *compare* their transport behaviour to social norms were more effective. There was some evidence that interventions that encourage shifts using existing infrastructure through the use of rewards, travel planning, and smart ticketing could encourage mode shift. However, the extent to which this was sustained was unclear as most studies did not include longer-term follow up.**

### 3.1.1 Self-monitoring by norms

**There were a few studies that demonstrated that encouraging people to self-monitor their travel behaviour against perceived social norms may be effective in encouraging a switch from using private cars to public or active travel.**

Veitch et al. (2017) found that children were more likely to walk to school by themselves if they and their parents knew other children who did the same. A review by Bird et al. (2013) found that increases in cycling and walking were prompted by interventions that encouraged people to self-monitor their travel behaviour against others.[9] Kormos et al. (2015) conducted a study which investigated the influence of 'descriptive norm formation' on the adoption of sustainable travel. Use of a private car decreased when participants were given information, even if fictitious, on the rates at which others were switching to public or active travel. This suggests that providing information on local levels of transport switching behaviour can motivate people to choose more sustainable modes.

### 3.1.2 Focusing on the environmental benefits

**There was limited evidence on whether emphasising environmental benefits led to behavioural change. Moreover, the evidence reviewed covered a wide time period during which attitudes to the environment have changed. Furthermore, it is hard to attribute environmental gains, such as emission reductions, to mode switch interventions.**

One intervention reviewed by Chillón et al. (2011) was designed to reduce traffic congestion and pollution linked to short car trips to and from schools by changing pupil and parent attitudes using a whole school approach incorporating key learning into the curriculum, adapting the school ethos and environment and strengthening home, school and community links. While the study showed a 3.4 percent reduction in trips to school by car as a result of the intervention, it was difficult to attribute this change to raised awareness of the environmental impacts on wider society. Nor could the study attribute any local environmental changes to the intervention. Longer term impacts were not captured, and the research also lacked a control group to provide a counterfactual.

A second study from the USA (Alcott and DeCindis, 1991) discussed an intervention aimed at improving air quality by encouraging drivers not to drive to work one day per week. The five-month campaign involved radio and television advertisements, newsletters to participants, and included the opportunity to win prizes by taking part. The study found a 3 percent reduction in single person car use following the campaign, although it was unclear whether this change was sustained after the campaign ended.

Other interventions described environmental benefits without adequately measuring them or capturing data. One notable exception to this pattern is the *Local Sustainable Transport Fund* overseen by the Department. This involved 96 local sustainable transport projects; twelve of which were large projects defined as a grant of more than £5 million. These projects consisted of a variety of interventions aimed at increasing active travel and use of public transport. Many of the projects made reducing carbon emissions a key objective but sometimes did not involve communities in their approach to achieving this. Significantly, the projects also used different ways to measure their impact on carbon emissions and some local authorities were unable to capture

[9] Referenced in Arnott et al. (2014).

sufficient time series data.[10] However, Sloman et al. (2017) who provided the interim analysis of the projects, did estimate that the amount of carbon dioxide in the air was reduced by 1,300 tonnes per year across the 13 projects funded. Although attribution of carbon emission reductions to interventions will always be difficult, it seems important to encourage consistent local emission measurements over time when interventions are introduced.

### 3.1.3 Focusing on health benefits

**Evaluations were more likely to focus on and measure prospective health benefits than they were environmental benefits. The evidence on whether promoting health outcomes led to mode shift was mixed. Many interventions were successful in achieving moderate increases in active travel, but rarely achieved the intended health outcomes. There were no studies, among the evidence reviewed, that considered the impact on mental health outcomes.**

One intervention in the UK attempted to change attitudes towards commuting by car in favour of walking to work using workplace-based *Walk to Work Promoters* (Audrey et al. 2014). Employers delivered a ten-week intervention incorporating attitude and behaviour change techniques.[11] Physical activity outcomes were objectively measured using accelerometers and GPS receivers at baseline and twelve-month follow-up. There was no evidence of an intervention effect on walking to work or on overall physical activity at 12-month follow-up. Similarly, a follow up questionnaire for the *Australian Walk to Work Day*, a media campaign aimed at linking environmental concerns with health promotion found that there was very limited effect on travel mode shift and no significant effect on public health.[12] However, this may be due to the short-lived nature of the campaign in the weeks surrounding the day itself.

Other more sustained campaigns show an increase in active travel but limited impact on health. In their systematic review of 14 walk-to-school interventions in the US, the UK and Australia, Chillón et al. (2011) note there was an increase in walking among pupils, but little or no significant impact on their Body Mass Index (BMI). Similarly, Jordan et al. (2008)[13] conducted a quasi-experimental pilot study with baseline and post assessment measures (2005-2006) including 578 parents and 767 children aged 6 -11 years. Although children at the experimental schools walked or biked to school more often than those at control schools both pre and post-test, results about the impact on other physical activity and BMIs were inconclusive.

However, in one small-scale study in Brighton, 47 of 80 (59 percent) of participants self-reported an increase in physical activity when they were loaned an electric bicycle (e-bike) for a month. Those who used the bike also said they felt more energised (Cairns, et al., 2016). However, the study did not include a control group and recruited a relatively small number of participants from those who expressed an interest.

[10] These included: local estimates provided by the then Department for Energy and Climate Change, the Basic Local Authority Carbon Tool, or locally collected data on traffic volumes, speeds and types of vehicles.
[11] Mainly through the setting of goals, identifying barriers and solutions, self-monitoring of travel behaviour and providing social support.
[12] Merom et al. (2005) as found in Scheepers et al. (2014).
[13] Cited in Chillón et al. (2011).

### 3.1.4 Planning apps and rewards

**Interventions that used temporary financial or other rewards as an attempt to encourage people to adopt active travel had little effect in doing so once rewards ended. There was some evidence that registered users of travel planning apps used public transport more when they were given rewards. There was very little evidence looking at interventions that adopt a Mobility as a Service (MaaS) approach, reflecting the novelty of this approach.[14]**

Several studies reported on the use of financial incentives as part of the evaluation design if not already built into the intervention. This did risk a tailing off of the impact in the longer term if the incentive was withdrawn, with interventions varying in length from one month to several years.[15] For example, Scheepers et al. (2014) reported that four studies that used a variety of incentives (e.g. prizes, provision of breakfast, penalties) to encourage intervention participation, but found that modal switch to active travel was not sustained once the incentives were removed.

A study by Tsirimpa et al. (2019) comprehensively looked at the role of rewards and travel planning. They modelled the impact of rewards on behavioural shifts to multi-modal, sustainable journeys and then looked at this in a real-world setting using a travel planning app in two settings (the UK and Austria) for six weeks. They found that among users of the travel-planning app, those receiving rewards (registered users) had much greater increases in public transport, walking and cycling time than those not receiving rewards. Rewards were collected through accruing credits, with higher credits gained for active travel. Rewards included shopping vouchers, public transport tickets and monetary rewards. Their modelling data found that the most effective multi-modal shift considered the user's preferences and tailored rewards accordingly. The results also showed that a shift to public transport was more influenced by rewards.

Other studies have considered the role of travel planning and smart ticketing. However, these interventions are normally part of a wider intervention package, making it difficult to determine the effectiveness of this element. For example, Goodman and Panter (2013) found an increase in cycling rates in towns that invested in cycling infrastructure which included personalising travel planning in several schools and workplaces. Similarly, Schwanen et al. (2011) observed that online journey planners and smart ticketing on buses are just some of the components of innovative interventions in East Oxford's *Oxonbike* scheme (discussed further below) that have aimed to increase active transport. Yet, there was little evidence of the effectiveness of these aspects of the interventions.

## 3.2 Investing in new infrastructure and the built environment

[14] Although not part of this REA see Enoch M (2018) Mobility as a Service (MaaS) in the UK: change and its implications, Foresight, Government Office for Science.
[15] This was the case in the study by Kormos et al. (2015) and a number of studies reviewed by Chillón et al. (2011).

These interventions attempted to make switching to sustainable modes of transport easier and more attractive, while also making travelling by car less attractive. Interventions included:

- Integrated multi-mode infrastructure projects; and
- Changes to the built environment.

They were usually at structural level, targeting whole, regional or local populations.

### 3.2.1 Integrated multi-mode infrastructure projects

**Some new sustainable transport schemes or interventions were consistently highlighted in the literature as ground-breaking developments and examples of an integrated approach. Nonetheless, the amount and robustness of evidence used as measures of the success of the schemes varied considerably.**

- **Oxonbike**: Oxonbike[16] was a bike-sharing scheme aimed at commuters in East Oxford that was linked in with the Thornhill Park and Ride scheme, renovation to bus lanes and innovations encouraging commuters to change from car use to public or active travel (Schwanen et al., 2014). There was also improved design of facilities and signage at Oxford railway station, with smart ticketing for bus travel, and internet-based journey planner provision. There was a 33 percent switch from cars to cycling in Oxford between 2001 and 2011. However, the study emphasised that this increase was dependent on Oxonbike being part of a wider holistic intervention that produced innovations in all areas of a town's transport, be that trains, buses, cycling, and walking. It also employed a multi-stakeholder approach, including politicians, employers, communities and county councils, to encourage a switch away from carbon producing transport.
- **Nottingham Express Transit (NET):** The NET opened in March 2004 as a 14 km tram line with 24 stations with the aim of reducing traffic congestion and stimulating a new regeneration area. The business case for the scheme made better transport integration a key objective. There were several phases of the project but key features of the integration planning included: integration with existing bus networks in terms of routes and ticketing; substantial park-and-ride facilities at each stop; connection with Nottingham's railway stations and other existing/planned hubs; introduction of a parking levy in 2012 for employees, students and regular visitors attending a workplace with more than ten employees. Passengers on the NET increased from 8.5 million to 9.8 million in the first two years (Disney et al., 2018). However, there is no evidence on further outcomes in terms of mode shift or carbon reductions.
- **Cambridge Busway**: The Cambridge guided busway was designed as a solution to traffic congestion. Built on two disused rail tracks, the busway links Huntingdon, Cambridge and Trumpington, consisting of a dual-lane dedicated track for buses and a 'maintenance track' for pedestrians, cyclists and horse riders. The buses are adapted with guided bus technology, ensuring uninterrupted contact between the bus and the kerb of the track (a feature which makes the ride smooth), whilst also allowing the use of normal roads through the city centre and beyond the terminus of the busway to the surrounding towns and villages. The busway therefore offers a traffic-free, off-road route linking workplaces to parts of the commuter belt and to park-and-ride facilities. Several studies found evidence of an increase in active

[16] The scheme was threatened and closed in 2018 by the arrival of a number of dockless share bicycle schemes. However has since re-opened, see: https://travel.admin.ox.ac.uk/article/oxonbike-cycle-hire-service-rises-from-the-dead.

travel, particularly cycling for commuting as a result of the Busway. Living closer to the Busway was associated with a higher increase in commuting by bicycle (Heinen et al. 2015). There was also evidence that the increase was greatest among those least active at baseline (Panter et al. 2016). However, there was less clear evidence of an uptake of public transport following the introduction of the Busway (Kesten et al. 2015, Heinen et al. 2015).

### 3.2.2 Changes to the built environment

**Making routes safer and more pleasant, while making popular destinations easier to reach by bicycle or by foot, influenced mode switch for commuting and recreation. Superior design, visibility, promotional activities and involvement of local communities in decision-making about priority routes and design also encouraged mode switch.**

Several interventions focused on increasing the number, quality and convenience of cycling and walking routse to increase sustainable modes of transport through changes to the built environment. An example was the *Connect2* programme, which tried to increase cycling and walking by making regularly used routes safer, for instance by improving lighting and providing dedicated pathways, more pleasant, and making destinations easier to reach (Salquvist, et al., 2015). Changes to the built environment were examined at three sites with special design features:

- **Cardiff** – a traffic-free People's Bridge among other smaller developments.
- **Kenilworth** – a 10km dedicated cycle and walking path and bridge crossing a dual carriageway.
- **Southampton** – a raised walkway on top of a wall providing better connection between the north and the south of the town.

After two years, in Cardiff 52 percent of respondents to a local residents' survey reported using the infrastructure compared with 37 percent in Kenilworth and 22 percent in Southampton. Nevertheless, both Southampton and Kenilworth reported a greater level of mode switch from car to active transport than Cardiff, with an 8 and 5 percent increase in active travel time respectively. The authors account for this by highlighting that the new infrastructure in Kenilworth and Southampton was better integrated with other routes. Moreover, although the scheme aimed to improve local transport, the study found the infrastructure was mainly used for recreational walking, with 17 percent using them for commuting, compared with 39 percent for recreation across the three locations. This study, together with reviews of the impact of built environment interventions on travel mode switch to sustainable modes (Kärmeniemi et al., 2018; Song et al., 2017), conclude that there are several factors linked to higher levels of effectiveness of these interventions. These include, 'superior design' and increased 'visibility' of the routes, either through greater proximity to them or as a result of local promotional activities. Early involvement of local or deprived communities for changes and design of the built environment also improved awareness and subsequent use (Adams et al., 2015).

# 4 Switching from individual car use

Having reviewed the type of interventions, the following three chapters present findings from the evidence about specific types of mode switches and the factors that may facilitate or prevent them. This chapter examines the degree of effectiveness of interventions which are aimed at encouraging people to reduce individual use of cars, although there was less evidence in this area in comparison to other mode switches.

**Key findings**

- Restricting access for cars to workplaces and city-centres had more success when public and active transport interventions were implemented before or simultaneously with the restrictions.
- Frequent car users and people living in areas with few public transport options were more successfully encouraged to switch to car sharing or pooling than to public or active travel.
- Financial incentives sometimes encouraged an initial switch from individual car use to car sharing or pooling but it was unclear whether this was sustained once they were removed.
- Car sharing and carpooling sometimes occurred as an unintended consequence of attempts to encourage a switch from cars to public or active travel, possibly reflecting preferences for driving or lack of alternative choices (especially in rural areas and for longer or multi-purpose journeys).
- There is very little evidence available on shifts to Ultra Low Emissions Vehicles.

## 4.1 Restricting access for cars

**Restricting access to cars at workplaces or in city centres was the focus of several interventions aiming at reducing car usage. They had most effect in achieving a mode switch when public and active transport initiatives were implemented before or simultaneously with the restrictions.**

Several interventions intentionally tried to reduce the amount of car use alongside initiatives designed to encourage drivers to switch to public or active modes. For example, a study by Brockman and Fox (2011)[17] examined a workplace travel scheme at the University of Bristol to restrict the use of cars alongside measures to encourage the use of more sustainable modes for commuting. Restrictions included severely limiting parking spaces and conditions for permits and increased parking charges. Initiatives to encourage the use of public transport included a university bus service linking local rail and bus stations, and discounted bus season tickets. Improvements were also made to local pathways and cycling facilities. This led to a sustained shift in behaviour (measured over nine years). Self-reported car use for commuting to work decreased significantly from 50 percent to 33 percent. The number of respondents who usually walked to work (defined as four to five times per week) increased from 19 percent to 30 percent. The number of respondents usually cycling to work increased from 7 percent to 12 percent (although this was not statistically significant when compared to the final survey year).

[17] As cited in Scheepers et al. (2014).

Scheepers et al. (2011) described attempts to create car-free cities in their systematic review. For instance, Topp and Pharoah (1994) assessed the impact of restricting cars in the city centres of Bologna, Italy and Lubeck and Aachen, Germany. Restrictions took different forms, but usually included restricting car access to certain parts of the city centre at specific times of the day or week. All three cities saw a positive mode shift. In Bologna cars entering and leaving reduced by 60 percent; in Lubeck they found a reduction of car usage of between 40 to 80 percent (depending on the time of day and what restrictions were in place); and Aachen experienced a reduction of 36 percent in car usage. Switches to public transport and active travel were reported, with twelve percent of respondents in Lubeck switching from their cars to public transport, cycling and walking. It was notable that public transport services were also improved at the same time as the restrictions were put in place. The *Trondheim Toll Ring,* however, was an unsuccessful example of attempting to restrict the use of cars. Drivers were charged to enter the city. However, investment in public transport followed after, rather than alongside the intervention. Results by Meland (1995) showed that the Ring did not reduce the number of car trips. There was no change in the number of bicycle trips, and a decrease in the number of walking trips. The effect on active travel might be related to the focus on public rather than active transport as the alternative to car use.

## 4.2 Encouraging car sharing, pooling and park-and-ride

**The evidence shows that people with a preference to travel by car could be encouraged to car share, carpool or use park-and-ride facilities. Financial incentives and public information campaigns were effective, but there was no evidence of whether this switching was sustained over time. There was also evidence that interventions aimed a different mode shift, for example to active travel, could result in shifts to carpooling.**

Several studies have highlighted the importance of recognising that some car drivers prefer this mode of transport (or have no other option in some rural areas or for multiple purpose journeys) and are more likely to switch to similar carbon reducing modes than they are public or active transport (Tsirimpa et al., 2019). Similarly, a study by Kormos et al. (2015) found that past behaviour was the biggest predictor for future behaviour when looking at the available options for switching mode of travel. However, the study did not report what transport mode people would most like to switch to. There was also no discussion in the reviewed evidence of the level of switch to ultra-low emissions vehicles (ULEVs).

In their systematic review, Scheepers et al. (2014) found evidence that financial incentives to reduce car use, could be combined with existing preferences of car drivers to produce desirable effects. They highlight a study by Shoup (1997) in California of a new law that required employers that subsidised car parking spaces to provide ‘cash-out’ payments for car drivers not to use those spaces, in effect transferring the subsidies. The result was a reduction in individual car usage from 73 percent to 67 percent of trips to and from work after three years. There was also a rise in carpooling from 14 percent to 23 percent of trips to and from work. In a similar vein, Tsirimpa et al. (2019) found that monetary rewards had a greater effect on encouraging individual car drivers to switch car sharing or park-and-ride when compared to other forms of incentives, such as credits towards purchases or reserved seats on public transport.

There was also evidence that public information campaigns on environmental concerns designed to promote public or active travel could work on existing preferences for car

use to promote car sharing. The review by Scheepers et al. (2014) highlights a study in Australia by James and Brög (2001). They found that a five-month targeted media campaign aimed at encouraging a switch from car use to walking resulted in a 14 percent reduction in car use with an increase in a range of different modes, including a 9 percent increase in travel as a car passenger four months after the intervention.

Finally, in some cases, a greater level of switching to car sharing and carpooling was the result of interventions aimed at increasing switches to active or public transport. A systematic review by Chillón et al. (2011), reports on a study by Staunton et al. (2001) that used a quasi-experimental design to investigate switches from individual car use to other modes of travel as part of the *Safe Routes to School* intervention in California. The intervention delivered a programme of community and school promotion of walking and biking routes to school. Despite the principal focus being on switches to active travel, the study reported a 39 percent decrease in cars carrying one student to school, and 91 percent increase in carpooling.[18] Song et al. (2017) also use data from the *iConnect* study, to show that exposure and proximity to new public and active transport infrastructures can also lead to a decrease in the amount of individual car use, and in increase in travel by cars as a passenger. In both cases, the authors do not make any claims about why this effect occurred. However, it points to the importance of measuring a wider range of travel mode switches when investigating the effects of interventions rather than simply the one being targeted.

[18] The base from which this increase occurred is not provided in Chillón et al. (2011).

# 5 Switching to public transport

This section explores the evidence on encouraging a switch from cars to various modes of public transport. Despite the important role public transport may play in reducing carbon emissions, its role was not clearly shown in the evidence reviewed. Similarly, there was limited and inconclusive evidence on what factors encouraged or prevented a switch from cars to various forms of public transport. There was a lack of data on certain large-scale public transport services, likely due to data not being published or being withheld by private companies for commercial reasons.

**Key findings**

- Overall there was very little evidence available on mode switch to public transport.
- The lack of evidence was particularly striking regarding switches to trains, light railways, or underground networks. What was found tended to document the same examples. Rich description of these projects was not always met with similar quality of evaluation of the modal shifts indicated.
- The presence of new, integrated public travel infrastructure was not always enough itself to encourage a switch of mode.
- Factors linked to a switch from cars to busways were: the presence of the new infrastructure itself, proximity to it, and perceptions of its convenience, safety and facilities relative to the stress of driving and difficulties parking in a congested city.

## 5.1 Opening of a new railway station

**One study examining mode switch from cars to trains showed that opening a new railway station led to mode switch from car to rail. However, there was no comparison with a location without a train station, making it difficult to draw firm conclusions about whether changes can be attributed to this alone.**

Scheepers et al. (2014) cite a study by Arentze et al. (2001) that investigated the effectiveness of the opening of a new railway station in the Netherlands on encouraging mode switch from cars to rail. A survey of local residents in the town of Voorhout (n= 360) before the station opened and one year after the opening. The findings showed that the new railway station resulted in a 11 percent decrease in the use of cars in the vicinity, although travelling as a car passenger also increased by 4 percent. Changes in travel for work and school showed a similar pattern, with a decrease in car use of 10 percent and an increase of trips travelling as car passenger by 2 percent suggesting an increase in carpooling. Nevertheless, the study provided no comparison with a similar town or area where a railway station had not been opened. In the review by Kärmeniemi et al. (2018), three US studies found that new railway stations are associated with an increase in physical activity.[19] However, the review does not report on the level of switch to public transport.

[19] Brown and Werner (2009); Brown and Werner (2007); and Curtis and Olaru (2010) as cited in Kärmeniemi et al. (2018).

## 5.2 Provision of new and integrated public transport infrastructures

**Several new, integrated public transport schemes were consistently highlighted in the literature. Despite detailed descriptions of interventions, the articles rarely adequately quantified evidence of the degree of mode switch, or documented factors that might prevent or encourage it.[20] There was less evidence on the effect on mode shift of localised interventions aimed at improving public transport provision – highlighting an evidence gap.**

As discussed in chapter 2, the most frequently cited public transport initiatives were the *Nottingham Express Transit (NET)*, the *Cambridge Busway*, *Oxonbike* and *Connect2* (in the context of the improvements to the built environment of routes, sometimes including public transport options). No further evidence on the success or otherwise of the *NET, Oxonbike, or iConnect* was provided in the articles reviewed other than that covered in chapter 3.

Further evidence on the impact of improvements to public transport came from the interim analysis by Sloman et al. (2017) of 12 large projects (£5 million or more) funded by the *Local Sustainable Transport Fund*. Several of the projects included the opening of new bus routes and/or the enhancement of existing routes as part of the interventions. They found an increase in bus usage in 13 of the 19 new or enhanced public transport infrastructures that could be attributed to the success of the interventions. However, the authors are not able to directly link this to a reduction in individual or total car usage. As the analysis was an interim review, measures that facilitated greater bus usage were not fully evaluated.

## 5.3 The Cambridge Busway as a case study

**Factors linked to a switch from cars to the busway were: the presence of the new infrastructure itself, proximity to it, and perceptions of its convenience, safety and facilities relative to the stress of driving and difficulties parking in a congested city.**

The *Cambridge Busway* was one public transport initiative that received a good deal of attention in the reviewed literature, although even here, data on mode switch from cars to public transport was not comprehensive. As a combined active and public transport infrastructure project, more studies have focused on the uptake of active travel. Nonetheless, Kesten et al. (2015) suggested that the presence of the new infrastructure, as well as use of some work-based interventions in the city, encouraged a switch from single occupancy car use to the use of the Busway, for some people in certain circumstances. For instance, comparisons of the Busway's attributes - such as place and space features including accessibility, convenience, pleasantness and safety – to existing transport modes were key determinants of whether people switched or not. Kesten et al. (2015) noted that crowded buses, and concerns about safety of the route and stops (e.g. poor lighting of pathways leading to bus stops) were regarded as negative factors limiting the use of the busway. Off-road cycling possibilities and on-board internet access were linked with positive perceptions of it. The stress of driving to work and parking difficulties in the city increased car drivers' likelihood of switching to

[20] Prins et al., 2016; Schwanen, 205; Brockman and Fox, 2011 cited in Scheepers et al., 2014

the bus (Kesten et al. 2015). Other studies highlighted that proximity to the Busway, both from home and place of work, also increased the likelihood of using its services (Heinen et al., 2015; Panter et al., 2016). In total, interventions that promote the positive attribute of new public transport and new infrastructure, focusing on safety and access can be important factors in encouraging mode switch.

# 6 Switching to active travel

There were more articles on the effectiveness of encouraging people to move from cars to active transport (cycling and walking) than for any other part of the REA. This perhaps reflected the smaller scale of the interventions and greater ease of collecting data directly from participants. However, as highlighted in previous systematic reviews, this review also found that characteristics of interventions tended to be poorly described and the quality of studies could have been improved (e.g. through use of control groups, better allocation to them, and through longer follow-ups from baseline data). [21]

**Key findings**

- Active travel interventions were more successful in encouraging mode switch from cars when they focused on short distance, straightforward journeys such as walking or cycling to work or school. They were less successful in relation to longer-distance, complex, multi-purpose journeys, and travel for recreation.
- A switch from cars to cycling was encouraged by: proximity to new cycling routes, especially when separate from roadways; workplace-based interventions aimed at promoting cycling for commuting; the opportunity to try out a bicycle or electric assisted bicycle (e-bike) or initiatives supporting people with the purchase and maintenance of bicycles.
- Evidence in support of city-based bicycle share schemes encouraging a switch from cars to bicycles was mixed and depended on the initial level of car usage for commuting. In London and Montreal, the bicycle share scheme was found to replace public transport and walking trips. Bicycle share schemes did, however, appear to contribute to an overall increase in active travel and to keeping carbon emissions down in most cases.
- Safety concerns needed to be addressed before some people would consider switching to active travel. Concerns included: personal safety; sharing busy and congested roads with cars and other vehicles; and the need for road awareness for children and cycling proficiency for children and adults. Early involvement of local communities in decisions about routes and the design features of new infrastructure helped to avoid such concerns.

## 6.1 Cars to cycling

**Interventions aimed at encouraging a switch from cars to cycling focused on cycling to work, or on city- or town-based cycling infrastructure or bicycle share schemes. Offering employees the opportunity to try cycling where new cycling infrastructure was available appeared to have an effect on modal switch. This was partly due to overcoming some of the negative perceptions of the mode, such as difficulties associated with maintenance. Evidence in favour of bicycle share schemes was more variable.**

Cycling as part of new and integrated transport interventions was discussed in chapter 2 in relation to holistic schemes like *Oxonbike*, and changes to the built environment

[21] Chillón et al. (2011) and Scheepers et al. (2014)

like *Connect2.* Here we describe interventions focusing more specifically on encouraging a switch from driving to cycling.

**Trying out cycling to work**

Workplace-based interventions that offered the opportunity for employees to try out cycling and move away from car usage featured among the studies reviewed. They focused on helping employees overcome any negative perceptions or concerns about cycling and theorised that, as they experienced the possible benefits, they may also take up cycling for recreation.

The UK government's *Cycle to Work* scheme, operated through employers, offers employees 40 percent of the cost of a new bicycle for work from reduced income tax or National Insurance. A review by Swift et al. (2016) reports that a survey of 13,000 scheme users associated the scheme with increased cycling to work, although the report notes that it was unclear whether the survey was representative of scheme participants. However, the review authors also comment on the social value of the number of people taking up cycling to work as a result of the scheme. This social value figure is based on DfT guidance and assumes that, even if just 5 percent of scheme participants (9,200 people) cycle for 30 minutes more a working day as a result of their involvement in the scheme, then the social value from reduced absence and increased physical fitness would be £72 million a year. This amounts to more than twice the estimated cost to the Treasury in lost tax and National Insurance (Swift et al. 2016). Nevertheless, this study did not assess the scheme in terms of mode switch from cars.

Similarly, O'Fallon (2010) refers to the *New Zealand Bike Now* initiative, which was aimed at dispelling negative myths about cycling in practical ways (e.g. that bikes are difficult to maintain through bike skills and puncture workshops, feeling self-conscious about cycling by having bike buddying, etc). They found that at follow-up after one year, 32 percent of 675 respondents said they rode their bike to work more often than they did the year before.

Other studies have looked at the impact of allowing people to try out electric assisted bikes (e-bikes). Building on previous studies from across Europe that have estimated that typically around half (40-60%) of e-bike trips replace car trips,[22] Cairns et al. (2017) investigated the impact of loaning 80 employees an e-bike for a six to eight-week period in Brighton. The trial found an overall reduction in car mileage of 20 percent and that the average usage of the e-bike was in the order of 15 to 20 miles per week. Three-quarters of those who were loaned an e-bike used them at least once a week. At the end of the trial, 38 percent of participants expected to cycle more in the future, and 70 percent said that they would like to have an e-bike available for use in the future and would cycle more if this was the case. At a follow-up one year later, 8 percent of respondents now owned an e-bike (although one purchased theirs prior to the trial), and 35 percent said they cycled more in the current year than the previous year.

**Town or city-wide cycling schemes**

Goodman et al. (2013) reported on town-wide cycling initiatives in six *Cycling Demonstration Towns* (funded between 2005 and 2011) and 12 *Cycling Cities and Towns* (funded 2008 and 2011). The initiatives involved a mixture of capital investment (e.g. cycle lanes) and revenue investment (e.g. cycle training), tailored to each town. This controlled before and after natural experimental study used

[22] Studies cited that include an estimate of the number of car trips replaced come from France, Germany, Italy, the Netherlands, Norway, Sweden and the UK. The estimates range from 16 percent reduction in car trips to 70 percent depending on local conditions and transport patterns. Most studies reported around 40-60 percent of e-bike trips replacing car trips.

English Census data to examine impacts on the prevalence of travelling to work by bicycle and other modes. Changes in the intervention towns were compared with similar matched towns with unfunded cycling and a national comparison group. The authors also compared the effects of the interventions between more and less deprived areas and meta-analysis to compare intervention effects between towns.

Among 1.3 million commuters in 18 intervention towns, Goodman et al. found that the prevalence of cycling to work rose from 6 percent in 2001 to 7 percent in 2011. This increase of 1 percentage point was statistically significantly higher than any of the comparison groups. At the same time, driving to work decreased by 3 percentage points and public transport use was unchanged. These effects were observed across all areas of differing deprivation levels, with larger relative changes in deprived areas. However, the authors also observed that the degree of variation in effects between different towns indicates uncertainty regarding the likely impact of comparable investment in other towns.

Analysis of the impact of the Cambridge Busway found that people living nearer the busway were significantly more likely to commute by cycling, including people who had previously not cycled much at all (Panter et al. 2016).[23] The analysis found that people living 4 kilometres from the Busway were 34 percent more likely to have increased the amount of time cycling for their commute than those living 9 kilometres away. However, the study found no evidence of changes in recreational or overall physical activity arising from the Busway.

**City-based bicycle share schemes**

Some bicycle share schemes were described as stand-alone ways to encourage active travel and/or ways to reduce traffic congestion in cities or towns. Such schemes employ apps and/or physical docking stations that allow people to rent a bicycle for a short time period. Partly, they appear to be popular because they avoid the need for people to move a private bicycle around, eliminate the cost of buying the bicycle and maintaining it, and remove the cost and inconveniences of theft (Bachand-Marleau et al., 2012).

Fishman et al. (2014) compared four city bicycle share schemes.[24] They found an estimated net reduction in motor vehicle use of approximately 90,000 km per annum in Melbourne and Minneapolis/St. Paul and 243,291 km for Washington DC. London's bike rental scheme, however, recorded a net additional 766,341 km in motor vehicle use. This is considered to be partly because although many car journeys were estimated to be substituted, the scheme in London predominantly substitutes use of other public or active travel modes such as buses, personal bicycles or walking rather than car use. In London, only two percent of bike share journeys replace car journeys. The net increase therefore reflects the additional vehicle journeys required for trucks to redistribute the bicycles to where they are needed. These are also affected by London's strong 'tidal' commuter pattern and its comparatively lower level of car use for commuting.

This finding is consistent with other schemes. One study of a scheme in Montreal, Canada found a 24 percent switch from personal bicycles to rental ones and an eight to 10 percent decrease in walking. This suggests that those who use rental bicycle schemes may already be employing active travel for work and recreation (Fuller et al., 2013, cited in Scheepers et al., 2014). Their benefit in achieving additional carbon

[23] The authors used multivariable, multinominal regression model and adjusted for confounding sociodemographic, geographic, health, and workplace variables.
[24] Melbourne, Minneapolis/St Paul's, Washington DC and London.

reductions from motorised car transport is therefore not clear, although they clearly promote more active travel.

## 6.2 Cars to walking

**Interventions aimed at encouraging people to switch from cars to walking often focused on short, simple and regular journeys to work or school; and it was here that they achieved the greatest successes. Interventions were less successful in tackling complex and recreational travel using cars.**

### Workplace-based interventions

A systematic review by Scheepers, et al. (2014) included six workplace-based interventions that focused on encouraging a switch from cars to walking for commuting. A typical example of this was the *Walk in to Work Out* intervention based at three workplaces in Glasgow. The intervention targeted those who were considering active commuting or who were irregular active commuters. Employees participating in the scheme were given educational and practical information such as choosing routes, maintaining personal safety and a workplace map with distances from local stations. After six months, the intervention group walked 125 minutes per week for commuting, compared to 61 minutes for the control group (Mutrie, et al., 2002).

### School-based interventions

Several articles reported walk-to-school interventions targeted at pupils, parents and/ or the wider school community (e.g. Centre for Local Economic Strategies, 2015).

For example, Zaccari and Dirkis (2003) describe a holistic, multi-pronged approach which integrated the work of local councils, the school, families and the wider community in encouraging walking to school. Specifically, the authors describe the way in which the school implemented the travel policy, which encouraged parents as well as children to walk to school. They also included information about the policy in school newsletters and involved the community in the planning of children's routes to school.

They and other authors note that walk-to-school interventions were most successful once the safety concerns of parents about pathways and crossing on the route to schools were addressed, and where children lived close to the schools, or a 'walking bus' of school children passed close to their home (Boarnet et al., 2005; Heelan et al., 2009, cited in Chillón et al., 2011). The Centre for Local Economic Strategies (2015) found that proximity to primary schools facilitated walking to school (with 80 percent of those walking living 1km from their school), while longer distance tended to prevent children walking to school.

### Community led interventions

Community led interventions included those like the *Fitter for Walking Project* (Adams et all, 2015). This project spanned twelve local authorities in London, the North East of England, North West England, West Midlands and Yorkshire. Project Coordinators worked with the community to generate walking groups and identify barriers to walking in certain areas (Adams et al., 2015). The community led in making routes more aesthetically pleasing (cleaning paths and verges, planting bulbs, etc.). Overall, walking on the targeted routes increased by 15 percent compared to baseline, which was based on self-reporting and observational counts by a third-party two years post intervention. However, they note that walking on the routes had decreased in the first

follow up, one year after the intervention. They attribute this to ongoing renovations on some routes.

**Complex and recreational journeys**

While there was some evidence of switching from cars to active forms of travel, for the simpler, and more straightforward journeys described above; there was less evidence of switching out of cars for complex journeys and recreation. Complex travel included the use of cars by parents to drive their children to school on the way to work, and sometimes included shopping and social activities for themselves and their children on the same day. Arnott et al. (2014) conducted a study in which car drivers were asked to complete a prospective car use diary. They were asked to consider a reduction in spontaneous journeys by giving a reason for the journey, and to consider information provided about car use reduction strategies. The study showed no effect in reducing the frequency of car journeys as a driver, or in reducing the frequency of total car journeys.

## 6.3 Active travel safety concerns

**Personal safety and safety from heavy traffic were highlighted in various articles as potential deterrents for adults and children switching from cars to active travel. Cycling and walking routes separated from roads, clearly marked cycle lanes, better pathways and crossings, and cycling proficiency or road safety awareness campaigns successfully addressed these concerns.**

Increases in active travel were sometimes linked to traffic fatalities, especially among cyclists (Sloman et al., 2017). Many interventions aimed at encouraging cycling as an active mode of transport specifically tried to address these concerns so that they did not become a deterrent to switching to active travel all together. Notably, the biggest deterrent to the uptake of active travel was perceptions of safety of the local area and on local roads in relation to both crime and safety from heavy traffic while travelling. Several of these studies noted that support for active travel was dependent on perceptions of neighbourhood safety and the safety of specific routes. Kärmeniemi et al. (2018) found in systematic review that a decrease in perceived neighbourhood safety was associated with an average decrease of 22 minutes of active travel per week.

Parental views on the safety of their children were particularly important in whether they allowed them to walk to school. This included personal safety and safety from heavy traffic. By comparison, several studies reported by Chillón et al. (2011) emphasised that schools, parents and pupils were more likely to involve themselves in walk to school interventions if improvements to pathways, road crossings and pupil road safety awareness campaigns were included as part of an intervention (e.g. Boarnet et al., 2005; Merom et al., 2005; Rowland et al., 2003; Zaccari and Dirkis, 2003). Karmeneiemi et al. (2018) conclude that their systematic review indicates that improving the built environment, for instance improving pathways, parks and aesthetics of neighbourhoods, is effective in encouraging individuals out of their cars and to adopt public and active travel.

# 7 Differential impacts of interventions

This chapter outlines what the evidence says about the differential impact of interventions by location and demographic groups and considers whether studies have been inclusive in their design. There was a greater degree of evidence on interventions in urban areas. Overall there was limited evidence on the differential impacts on different socio-demographic groups reflecting the fact that most interventions targeted whole populations.

**Key findings**

- Most evidence focused on interventions targeted at general populations in urban or suburban settings reflecting the concentration of public and active transport provision in these areas. Nevertheless, the success of schemes in urban and suburban areas depends on wider contextual factors such as physical geography, existing transport patterns and infrastructure, the political environment and funding availability.
- There was very limited evidence on the level of mode switch in rural locations and by different levels of access to public and active travel. However, there was some evidence to suggest that increasing access to public transport in rural areas could increase the use of both public *and* active travel.
- Evidence of differences by socio-demographic group was also limited. Much of the evidence focused on people with higher education levels, either inadvertently or by design. There was less evidence regarding groups including disabled people, older people, deprived communities, minority ethnic groups, and women. Few interventions reviewed were inclusive of disabled people in their design and failed to consider this factor in their analysis.
- Younger people spend less time driving than older people and those that drive are more likely to switch to active and public transport in response to interventions. There is also evidence that each generation is driving less than the one before as they grow older. Although older people are more likely to use cars, when they do switch to other modes, this behaviour is often sustained to a greater extent than when younger people switch mode.
- There is evidence that deprived communities benefit from active transport initiatives, especially where they are involved early on in decision making. Unemployed people appear to benefit from initiatives encouraging use of public transport or active travel and changes in travel habits were sometimes sustained. There is also some evidence that the schemes may support access to employment.
- Certain groups, such as women and ethnic minorities, are less likely to shift to active travel, although the reasons for this are not explored within the reviewed articles.
- There is evidence that lifetime transitions (e.g. losing a job, having children, retiring) may be key moments in which mode shifts can be encouraged, but the evidence is mixed about the degree to which these are then sustained.

## 7.1 Urban and suburban areas

**There is greater evidence available on the impact of interventions in urban or suburban areas than in rural areas. This was because many of the studies focus on urban areas and involve case studies of specific towns or cities where mode switch interventions have been trialled.**

Urban areas tend to have higher levels of public transport infrastructure and a higher concentration of shorter journeys which may make them appear more suited for the types of interventions that have been employed to date. However, from the evidence reviewed it was clear that even within urban or suburban areas, several factors impacted on the overall effectiveness of interventions. These included physical geography, existing wider transport infrastructure, local funding, political context and funding sources. This is exemplified in the study by Schwanen et al. (2011) which compares case-studies of cycling schemes in Brighton and Oxford. The two cities were selected as comparable because they both have compact city centres and similar socio-demographic profiles, although Brighton has more hills. The study found that both saw an increase in cycling, but Brighton achieved a greater increase. The author attributes this success to the ability of Brighton to secure 'supra-local funding'[25] and the ability to demonstrate the apparent success of its schemes to lever further funding. The study also notes the greater level of local political commitment to public and active transport interventions in Brighton.

Cairns et al. (2017) also focused on Brighton in a study looking at the attractiveness of electric assisted bicycles (e-bikes). Brighton's urban environment – the fact that it is hilly and windy - could be potentially detrimental to the uptake of cycling but may be mitigated by e-bikes. E-bikes were loaned to individuals for a six-to-eight-week period and e-bike usage and behaviour change were measured. While overall the intervention reported a 20 percent reduction in car miles, it was noted that Brighton already had a lower level of car driving and a higher level of walking than other urban areas. The authors conclude that the impact on driving may be greater in areas with higher driving rates.

The importance of the wider context of interventions is also illustrated by Song et al. (2017). Their study examined the impact of new walking and cycling infrastructure on achieving mode switching across three different sites: Cardiff, Southampton and Kenilworth. They found differences in the overall level of switching with both Southampton and Kenilworth seeing substantial mode switches from car usage to active transport, with an 8 and 5 percent increase in active travel time respectively. In contrast, Cardiff saw a decrease in active travel time (-8 percent) and a small increase in car travel (0.7 percent). These differing effects are explained by the fact that the infrastructure development in Cardiff was fragmented without connected feeder routes and by the fact that the study was focusing on travel for utility (rather than recreation).

### 7.1.1 Comparing more rural and urban contexts

**There were fewer studies in this review that directly compared urban and rural areas. Those that did found that mode shift interventions were more effective in areas of high density with easy access to public transport infrastructure.**

Kärmeniemi et al.'s (2018) conducted a large synthesis of 51 studies of the built environment as a determinant of physical activity rates from high income countries in North America, Europe, Asia and Oceania. As part of this, they found four studies showing higher population density to be associated with increased physical activity.

[25] Funding from beyond local government level, such as from central government and the EU, was key to a number of these interventions.

Higher population density was associated with a small increased likelihood of walking trips in one study and modelling results from another found 1.54 higher odds of cycling for transport.[26]

Better access and proximity to public transport also increased the odds of walking by 1.8 times.[27] This suggests that increasing access to public transport in rural areas could reduce the amount of car usage and increase the use of public *and* active travel. This appeared to be the case in Heinen et al.'s (2015) study evaluating the introduction of the *Cambridge Busway* (a mixed bus and cycle/walk pathway). Living in a village that the Busway passed through was significantly associated with increased public and active transport compared with those living in urban areas on the Busway.

A further difference between urban and rural contexts may be the degree to which institutions (such as schools) in urban areas participate in programmes aimed at a switch to active transport. In their review of studies on walk to school programmes, Chillón et al. (2011) highlight a study by Merom et al. (2005) carried out in Australia looking at the *Walk Safely to School Day* programme. The study found that although the number of schools participating in the programme increased over time, rural schools were significantly less likely to participate, which may be linked to the fact that distances are likely to be longer in rural areas. Chillón et al. (2011) observe that few walk-to-school intervention studies include distance to schools as a variable in analysis or mention whether it is an inclusion criterion for participation. The authors consider this a key weakness since other literature considers distances of more than two or three miles outside the range of walking to school. Parent and pupil safety concerns when walking on roads (highlighted in chapter 5) may also be a significant factor when children walk to school as rural roads often have only narrow or no pavements.

## 7.2 Differences between socio-demographic groups

This section explores the evidence on effectiveness of interventions across different socio-demographic groups.

### 7.2.1 Age and sustainability across the life course

**Children were often the specific focus of active travel initiatives but there was little evidence of whether this behaviour was sustained over the life course. Comparing age cohorts shows that young people are less likely to drive than older people and each generation is spending less time driving as they grow older than their predecessors. Younger people are more likely to switch to sustainable modes of transport. However, older people are less likely to completely stop using public transport than younger people.**

**Children**

Children are often the specific focus of studies and there is a range of evidence looking at interventions that encourage walking to school. Many of these interventions have been designed with health outcomes (i.e. increased child physical activity) rather than with transport mode switch outcomes in mind, although these may often overlap (as discussed in chapter 2). Programmes such as these are thought to help embed

[26] Kärmeniemi et al (2018) p.7
[27] Ibid p.8

transport behaviour for later life[28] although no studies in the current review considered this systematically.

In Chillón et al.'s (2011) review of 14 studies in Australia, the US and the UK, looking at primary school children, they find that almost all interventions produce some positive effect on active transport but that the increase in active travel to school varied widely (from 3 percent to 64 percentage points). The authors calculated effect sizes for each study, comparing baseline with follow up figures, but found that only three studies had large or very large effect sizes.[29] The heterogeneity of the interventions involved, and the quality of the data generated limited the ability to identify which approaches were more effective. However, the authors identify some factors that play a role in effectiveness. These were:

- having engagement of a range of stakeholders (i.e. teachers and headteachers, parents and community institutions);
- having a targeted focus on active travel rather than a broader focus.

In the UK, the Centre for Local Economic Strategies (2015) evaluated the charity '*Living Streets' Walk to School* programme with primary school children. They found that there was less scope to influence older children's behaviour due to the larger catchment areas of secondary school (and therefore greater walking distance to schools) but felt that primary school interventions brought benefits across a range of areas including children enjoying walking to school. However, although the study reportedly draws on a survey of schools as well as qualitative interviews with stakeholders, the data presented in the report is limited, making it difficult to evaluate the strength of the evidence.

**Comparing age cohorts**

It should be noted that studies define 'young' and 'old' differently. In most studies younger groups usually refer to those aged 18 up to 30 but may include up to the age of 34. Older groups tend to cover those aged 55 and older.

Garikapati et al. (2016) use data from the longitudinal *Use of Time Survey* (based in the US) to compare different generations' usage of cars (at the same age). They found that younger generations spend less time driving than older generations. This can be partly attributed to young people's greater concentration in urban areas and health status. But also, each generation is driving less than their predecessors as they grow older. The authors speculate that that it could be as a result of changes to technology, attitudes or values or a result of socio-demographic characteristics.[30]

Other studies have found that younger people are more likely to switch travel modes than older people. In Kormos et al.'s (2015) study, university students were more likely than staff to reduce their car use in response to a social norm experiment conducted over a one-month period although the reasons why are not clear. Moreover, Pistoll and Cummins (2019), using data from the UK *Household Longitudinal Survey*, found that younger people were more likely to take up active transport or public transport changes over a five-year period than middle aged or older aged adults. They suggested that young adulthood may be a critical period for shaping transport habits. However, their study also found that odds of giving up active travel or public transport for those aged

[28] Centre for Local Economic Strategies (2015).
[29] Effect sizes were calculated using Cohen's d – see pp 9-13 for each study.
[30] More recent research in the UK has found that changes to young people's travel behaviour is driven by changes to young people's socio-economic and living situations. See Chatterjee et al. (2018).

55+ were just under half of those in the 16-34 age group. This demonstrates that the picture is not straightforward. In contrast, Heinen et al. (2015) found that older groups (51-60) living near the Cambridge Busway were more likely to show a decrease in active transport than those aged 31 to 40.

Some studies focus on the younger age groups that interventions have impacted. Tsirimpa et al. (2019) looked at behavioural shifts that came about after using an app-based reward scheme that encouraged use of multi-modal, sustainable journeys. The sample was drawn from individuals targeted by social media and participants had an average age of 38. Their modelling found that older age groups were more responsive to higher levels of monetary or other types of reward for adopting more sustainable, multi-modal travel. The authors do not provide explanations for this but note that it is an element to consider when designing reward interventions.

### 7.2.2 Differences among socio-economic groups

**There was some, limited evidence that deprived communities and unemployed people could benefit from interventions aimed at encouraging switch to sustainable modes of transport.**

Research shows that people in deprived communities are more likely to have health conditions such as obesity and heart disease and may benefit from an increase in active transport.[31] Nevertheless, few studies in the review included measures of wealth and deprivation among their analytic variables. Of studies that did, the evidence suggests that interventions did not have large differential impacts on different groups and take time to take effect. Goodman et al. (2013) drew on Census data to compare towns that had received substantial cycling investments compared with towns that had not. Overall, they found a significant increase in cycling in the intervention towns across all deprivation levels. However, the relative change to comparison groups was greatest in areas in the most deprived quintile.

Similarly, Adams and Cavill (2015) report on an active transport intervention in five deprived areas of the UK, which involved addressing infrastructure and environmental issues on pathways. While they did not have a control group with which to make comparisons, they found that walking levels increased in the second follow up (14-20 months later) but dipped in the first follow up (at 12 months). Considering the impact of greater wealth, Heinen et al. (2015) included home ownership among their model variables looking at changes in travel behaviour linked to the Cambridge Busway. While 21 percent of participants reported a decrease in active travel, those who owned a home were less like likely to decrease their active travel. However, the authors do not provide any explanation for this.

There was limited evidence on the impact of interventions on those who were unemployed. However, where it existed, it supported targeting unemployed people for interventions to switch to more sustainable modes. Song et al. (2017) found that losing a job was statistically significantly associated with changes in travel behaviour. The authors account for this by arguing that the disruption to routine can be a good moment to introduce changes, although other drivers such as a change in socio-economic circumstances may be more relevant. Sloman's (2017) evaluation of 12 UK projects found that some specifically targeted job-seekers by providing free or discounted travel, personalised travel planning /travel training, moped loans, and cycle services. While the authors urge caution with respect to the findings as they are mostly small-scale, they suggest that projects that have offered free or discounted travel have enabled job-

[31] Centre for Local Economic Strategies (2015).

seekers to attend training, interviews, and work placements that they otherwise would have been unable to attend. One intervention reported five percent of those it supported, obtained a job directly as a result of the intervention.[32]

**Several studies in the review involved groups that had higher education levels, either deliberately or inadvertently in their design.**

For instance, Kormos et al.'s (2015) study used university students and faculty as their target population. Similarly, Tsirimpa et al. (2019) found that 91 percent of their participants were educated to degree level or above. In other cases, such as the field experiment conducted by Heinen et al. (2015), the demographics of the local area, in this case, Cambridgeshire, meant that the population was more highly educated than the UK average.

The evidence on the impact of education level on travel mode shift is mixed. Song et al. (2017) found that those with higher levels of education were significantly more likely to change to sustainable modes of transport following the development of more active transport infrastructure locally. In contrast, in Heinen et al.'s (2015) analysis of the Cambridge busway, those with degree-level education were less likely to show a large increase in the proportion of commuting trips made using active transport. However, this could be partly attributable to this group's higher level of active travel before the introduction of the Busway.

### 7.2.3 Other demographic characteristics

**Other demographic characteristics that could be relevant in switching from cars to sustainable modes of transport included gender, disability, ethnicity. However, evidence in these areas is limited. There was some evidence on the impact of changes to household structure, resulting from lifetime transitions such as having a baby, but this was variable.**

Previous evidence reviews have highlighted that socially disadvantaged groups, such as ethnic minorities, women, older people, students and young people not in employment, education or training, are less likely to use cars and are more likely to face transport poverty and take fewer journeys.[33]

**Gender**

Few of the studies in the review included gender as a specific variable, meaning that the evidence in this regard is sparse. However, Song et al. (2017) in their study examining the impact of new active travel infrastructure in three different areas found that men were significantly more likely to switch towards walking and cycling than women. The authors suggest that this ties in with wider literature showing lower uptake of cycling by women. While these issues were not explored in the reviewed articles, previous research has suggested issues linked to perceptions of safety; childcare responsibilities and lack of confidence may contribute to this gender imbalance.34

**Disability**

[32] This was the large project covering Barnsley, Doncaster, Rotherham and Sheffield, see p. 129.
[33] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/843487/Transport_and_inequality_report.pdf p.27
[34] https://www.sustrans.org.uk/media/2930/2930.pdf

Among the reviewed evidence few studies appeared to have ensured their design was inclusive of those with disabilities or health conditions and did not report on differences between these groups and those who do not have a disability or long-term limiting illness. One exception was the study by Heinen et al. (2015), which found that higher self-rated physical health was associated with a lower likelihood of reducing public transport usage. However, the authors do not comment on potential reasons for this finding.

### Ethnicity

Similarly, few studies explicitly considered differences by ethnic groups or included this variable in their analyses. An exception was the study by Song et al. (2017) that explored exposure to new active transport infrastructure. They found that being a member of ethnic minority was significantly negatively associated with a switch towards active modes of travel using this new infrastructure.

### Household structure

Some studies have suggested that household structure is another factor that plays a role in the effectiveness of mode shift interventions, with those with children more likely to take up active transport. Heinen et al. (2015) found that having a child in the household meant participants were more likely to show a small increase in active travel following the building of new infrastructure, such as the Busway. Song et al. (2017) found that an increase in family size was positively associated with mode shift to active travel in the first year but that this changed in the second year, indicating that the change may not be sustained.

# 8 Conclusions

This review examined evidence on the effects of interventions designed to encourage people to switch from single use of carbon emitting vehicles to more sustainable modes of travel. This conclusion reflects on what lessons we can learn when considering the design and implementation of new initiatives. It also highlights where we need to better understand the relationship between such interventions and the travel behaviours of different groups of people and their transport needs.

**Understanding the impact of different types of intervention**

Interventions designed to encourage a switch to public or active modes of travel broadly fall into two types of activity that operate separately or in combination. The first seek to influence attitudes towards or incentivise certain travel behaviours within the existing transport infrastructure. The second develop the infrastructure, whether through a major scheme or localised improvements to make it easier to choose more sustainable options.

In terms of influencing behaviour, encouraging people to monitor their transport behaviour against social norms, as well as highlighting stories of successful switches appears most effective in sustaining active and public transport choices. Financial incentives, other rewards, or even penalties and shaping transport choices through transport planning apps, can also impact behaviour but only if they are sustained. Other strategies, such as smart ticketing and integrated travel planning apps in general, incentivise active and public transport by making it simpler to plan and potentially pay for journeys. In our review, it was difficult to disentangle impact, as such initiatives often form part of wider infrastructure development. But they show potential for further work on the optimal levels of incentives, how they can work through planning apps and their impact across different types of infrastructure developments. To date, there is little evidence on the behavioural impact of the Mobility as a Service (MaaS) approach but future evaluations could set out to identify the degree to which it encourages mode switch.

Focusing solely or mainly on the environmental or health benefits of using active or public transport does not appear to have a long-term impact on travel mode switch. This could be partly because of the difficulties faced by local authorities in capturing consistent carbon emission data and health outcomes beyond levels of physical activity in the local community. But also we found little evidence of measuring mental health outcomes as a potential benefit. So although carbon emission reduction and health improvements can be key objectives of sustainable transport projects, it can be hard to demonstrate these outcomes back to local residents and attribute them to the schemes.

A small number of infrastructure projects featured heavily in the reviewed literature having been studied and cited repeatedly for their innovative approaches. This included the Oxonbike scheme, a bike-sharing scheme in Oxford; the Nottingham Express Transit (NET), a new tram line; and the Cambridge Busway, a guided busway alongside a cycle/walking pathway. The innovations of such schemes was in the high degree of integration between active and public transport provision as well as existing provision. All of these infrastructure projects demonstrated success in terms of people switching to these modes of both active and public transport. However, it can be difficult to quantify that impact when interventions are part of larger and long-term transport innovation programmes. Studies of such major projects could be better supported to run over long time periods to measure sustained impact and to identify

comparable locations against which to benchmark trends in different modes of transport.

### Reducing individual car use

Interventions designed to restrict individual car use, by limiting parking and increasing charges, work best when accompanied by interventions to improve both public and active transport options and making sure those options are in place when car restrictions are introduced. Waiting until the car restriction scheme has raised funds to develop sustainable transport options or focusing solely on public transport may be less effective. Employers can have the most sustained impact on reducing car use with simple financial rewards for giving up the 'perk' of a car parking bay at work.

Where car preference is strong, or a more practical means of transport for the required journey, schemes to encourage car-pooling or sharing can be effective. While traditional schemes of companies offering cars for rent on a flexible basis or platforms enabling lift sharing are well established, the scale continues to grow as more manufacturers get involved in direct provision of their cars for hire. But these will continue to only be profitable to operate in urban areas.

Car-pooling and sharing can emerge in a wider range of areas as an unintended consequence of programmes to encourage a switch to public or active transport in urban hubs. Some car users may not respond to the incentives to use public or active transport but do adapt their behaviours to mitigate the disincentives for car use, such as higher parking charges. Both the design and evaluation of mode switch interventions need to consider this wider range of outcomes and the type of journeys that may be impacted.

### Switching to public transport

The evidence on switching from individual car use to public transport is more limited. It can be difficult to attribute declining car use to better availability of public transport if individual patterns have not been tracked over time or there is no available comparable area against which to consider trends. Using data sources such as the Department's National Travel Survey panel to track how individuals are switching their modes of commuting and leisure travel over time and investigating their reasons for doing so could give the Department high level longitudinal insight into mode switch trends that are lacking from cross sectional measures of total use of different modes of transport.

Evidence of switching from cars to public transport has been captured as part of the evaluations of the major infrastructure projects discussed earlier. The evaluation of the Cambridge Busway was able to demonstrate a switch from cars to the busway in response to the introduction of this new infrastructure. Its convenience and safety and the negative attributes of driving and parking in a crowded city were factors that encouraged this switch.

### Switching to active travel

The greater volume of evidence around active travel schemes probably reflects the smaller scale of these interventions which are easier to measure within a defined local community. However, even then, many studies could have been improved with support in the use of comparable areas or measures over a longer time-scale.

Interventions to encourage active travel were most successful when focussed on short simple journeys rather than integration into longer, complex, trips. Switches to cycling work best when the routes are separated from roads, when they involve workplace

provision to make it easier to commute by bike and when people are supported to purchase and maintain bikes or trial e-bikes before buying one. Bike share schemes are popular but in cities, such as London, where there is less commuting by car, switching tends to be from public transport or walking rather than from car usage.

Some people are discouraged from cycling by concerns about personal safety, congested routes (especially if they are shared with vehicles) and the need for better road awareness and cycling proficiency. Community involvement in the planning and design of new routes and their features can help offset some of these concerns but the routes must be well maintained to avoid a decline in use.

**How do interventions vary across locations and demographic groups?**

Reflecting the concentration of public and active travel provision and interventions in urban and suburban areas, there was little evidence on travel mode switch in rural areas. There is perhaps scope here to consider what lessons can be learned from car sharing and pooling schemes, that could be adapted for a rural context.

Whether urban or rural, the evidence demonstrates that an area based approach, particularly involving deprived communities in the design of schemes and integrating new infrastructure with existing routes, appears to pay dividends in both take up and continued use of active and public transport schemes.

In terms of demographic groups, age is an interesting consideration. There are clearly life stages at which people are more or less likely to use a car. Young people may not own a car or need one in an urban area, whilst parents of dependent children may depend heavily on car travel. However, the research shows that each age cohort is using their cars less than their predecessors. Supporting this continued switching to sustainable transport and preventing people reverting to car use if their circumstances change will be important for future interventions.

Take up of active travel modes in particular can appear to be concentrated among more educated and socially advantaged groups. There is little evidence to aid understanding of whether this is a result of the location of the interventions, their targeting or differential impact by socio-economic group. More evidence is needed to consider the experience and needs of disadvantaged groups across all types of travel mode switch. We know that rates of active travel are lower among groups such as women and ethnic minorities, but the reasons may be a complex interplay of individual perceptions, personal circumstances and location. We need to better understand this interplay and the barriers faced by disadvantaged groups in order to encourage greater public and active travel mode switch.

# 9 Appendix A. Methodology

This review used a rapid evidence assessment (REA) approach. An REA retains a systematic approach to the search and selection of evidence, ensuring as wide as possible data extraction in relation to specific research questions while being time and resource effective. The aim is to select the best of evidence that meets agreed substantive and methodological criteria. This section provides an overview of the criteria used in searching, screening and extracting evidence for inclusion.

## 9.1 Inclusion criteria

To be included in the review, studies had to meet the criteria set out below.

1. **Language**: Studies in English only. Search terms in English only.
2. **Publication status**: Both the published (journal) literature and unpublished or 'grey' literature such as policy research papers.
3. **Date of publication**: For the 30 selected articles, from 2010 to date.
4. **Country contexts**: UK, Europe, North America, Australia and New Zealand. Evidence reviews that include evidence relating to one or more of these countries will be includable.
5. **Population**: Any study that reports on modal shift of individuals from individual carbon producing forms of transport to public transport or to active forms of transport such as cycling or walking.
6. **Study design**: Quantitative and mixed-methods primary studies or secondary research that provide a quantitative estimate of intervention effect and that appropriately address the principal research questions of interest.
7. **Topic:** We will include studies that report on the effects of policies or interventions and Apps aiming to encourage people to switch from using individual carbon producing forms.

## 9.2 Search strategy

The search involved three main stages. The first step involved searching three academic databases, Scopus, PsychInfo and Web of Science, using a complex search string. The second stage involved searching online websites and repositories using simple search terms (see Table 1). The final step involved forwards and backwards citation tracking of key texts.

### 9.2.1 Table 1. Online websites and repositories

| Website name | Link |
|---|---|
| Google Scholar | https://scholar.google.co.uk/ |
| CIHT - Chartered Institute of | https://www.ciht.org.uk/about-us/about-ciht/ |

| | |
|---|---|
| Highways and Transportation | |
| SusTrans | https://www.sustrans.org.uk/ |
| Urban Transport Group | www.urbantransportgroup.org |
| Institute for Transport Studies (Leeds University) | https://environment.leeds.ac.uk/transport |
| Transport Studies Unit, Oxford University | https://www.tsu.ox.ac.uk/pubs/wpapers.html |
| UK Department for Transport | https://www.gov.uk/government/publications?departments%5B%5D=department-for-transport |
| Bus Users | https://www.bususers.org/publications/#position-papers |
| Transport and Environment | https://www.transportenvironment.org |
| What Work Centre for Local Economic Growth | http://www.whatworksgrowth.org/policy-reviews/transport/ |
| TRL: the future of transport | https://trl.co.uk/about-us |
| Centre for Transport and Society (UWE) | https://www1.uwe.ac.uk/et/research/centrefortransportandsocie.aspx |
| TfL | https://tfl.gov.uk/corporate/publications-and-reports/ |
| Highways England | https://highwaysengland.co.uk/research-publications/ |
| Institute for Future Technology and Cities - Coventry University | https://www.coventry.ac.uk/research/areas-of-research/institute-for-future-transport-and-cities/our-research/ |

## 9.3 Search terms

Based on the review aims and discussion with DfT the project team developed a list of key words. The search terms were grouped as follows:

- **The general context of the REA**, for example, travel, transport, transportation and journeys.
- **Mode of transport**, including cars, types of public transport, and types of active transport.
- **Modal shift**, including words associated with change or changing behaviour, and the variety of means to try to achieve change.
- **Methodology and effectiveness**, involving the type of study to be used and words associated with showing an effect.
- **Sub-issues and groups**, for example, issues related to access to transport by location and subgroups of interest outlined in the research questions.

## 9.4 Prioritisation of articles for selection

### 9.4.1 Initial searches

Based on the searches of the databases above the following number of articles were returned:

- **Academic databases** – initial removal of duplicates and screening by eye (to remove 'wild cards' or articles clearly outside the remit of the review) reduced the number of listed articles from 3,937 to **2,653 articles**.
- **Websites/ repositories** – 'grey literature' articles were identified using simple word searches or drop-down menus to find sections of the website/ repository most likely to contain articles relevant to the review. This produced **54 articles**.

These were added to the 2,653 articles, **giving 2,707 articles** at this stage. In line with the protocol agreed with DfT a screening tool was developed in order to long-list the most relevant articles based on title and abstract/ summary.

To screen the 2,653 articles identified from the academic databases we used automated, machine-learning prioritisation tool *Abstrackr.* This software learns from the selection choices that researchers make and moves articles that fit the selection choices to the top of the list, while moving those that don't fit the choices further down.

One thousand articles were screened in *Abstrackr* using the selection criteria above. The **top 100 were short-listed** for full-text screening. The 54 articles identified through websites/ repositories were reviewed by team members at a meeting, and 16 were added to the 100 identified using *Abstrackr* to provide **116 for full text screening**.

During this process the team noted some ***evidence gaps*** related to the overall aims and objectives for the review. Gaps in evidence were identified in the following areas:

1. How effective interventions were for different groups, particularly for disabled people.
2. Retiming journeys.
3. Whether shifts from carbon producing vehicles to public or active transport depended on the time of the day that the travel took place; the distance or duration of the journey; and/or by journey purpose

4. Evidence on sustainability of any the behaviour-change effects over time (including over the life course)

**Forwards and backwards citation tracking** of key texts was adopted at this stage to try to fill these gaps in evidence relating to these issues. This produced **a further 21 articles that were selected for full-text screening. In total 137 articles were selected for full-text screening.**

### 9.4.2 Full text screening

At full text screening stage, we used more detailed substantive and methodological criteria for selection based on review of the title, abstract, executive summary and relevant sections of the articles. Selection was based on the weight of evidence approach and combined basic screening criteria and substantive criteria. The substantive criteria were designed around the key research questions. At this point the article was given an overall score. On the basis of the scores, **30 studies** were selected for data extraction and synthesis. Details of the selected studies are inclured in Appendix B.

## 9.5 Limitations of the review

The REA found a good number of studies and reviews that examined interventions that encouraged a switch from cars to some forms of public transport and to active transport. Active transport was particularly well discussed, perhaps reflecting the smaller-scale, or more clearly defined nature of these interventions. A clear gap in the available evidence was the kind of 'big data' that might be expected to be available on the use of public transport that providers of services may obtain themselves. In some cases, this might be because initiatives are new or still developing. In others, however, it is possible that data about public transport usage has not been published in the public domain or is being withheld because it is commercially sensitive data in a franchised, competitive transport market. Evidence of a switch from cars to light railways, the *London Underground* and various metros was noticeably missing for literature in the public domain. Finally, in some cases, studies that met the inclusion criteria, nevertheless, had certain methodological weaknesses meaning that the evidence may not be as robust as was suggested.

# 10 Appendix B. Selected studies

### 10.1.1 Table 2: Selected studies

| Author and date | Population or populations | Methodological approach | Description of intervention |
|---|---|---|---|
| Adams and Cavill (2015) | UK. General population in 12 deprived local authority areas. | Mixed methods: 1) route counts at baseline pre-intervention (T1), 12 months later (T2) and 14-20 months later (T3). 2) surveys with route users pre and post intervention. 3) Post intervention residents survey. 4) Focus groups/stakeholder interviews. | Fitter for Walking project: interventions in a number of deprived neighbourhoods to improve walking routes in response to community barriers. Changes included: improving infrastructure of routes (e.g. lighting), environmental changes (e.g. street cleaning) and promotional activities. |
| Arnott et al. (2014) | International. Majority of participants in European countries. | Systematic review of transport behavioural change studies that include a control group. 15 articles reviewed covering 13 unique studies. | Range of behavioural interventions including education, planning, and techniques around intention formation to reduce car usage. |
| Audrey et al. (2019) | UK. Participants predominantly white, with degree level education | Cluster randomised control trial using physical activity data from accelerometers and GPS receivers | Ten-week Walk to Work intervention using behavioural change techniques: providing |

| | | | |
|---|---|---|---|
| | and higher than average income. | at baseline and 12 month follow up. | information, encouraging intention formation, identifying barriers and solutions, goal setting, self-monitoring, providing general encouragement, identifying social support, reviewing goals and relapse prevention. |
| Bird et al. (2013) | International | Systematic review of 46 studies | Range of behavioural and cognitive interventions to encourage walking and cycling. |
| Bird et al. (2018) | UK. Adults living within 5 km of three intervention study sites. | Cohort study of data from the iConnect study. Three surveys at baseline (pre-intervention), one year follow up (T1), two year follow up (T2). | New purpose-built active travel infrastructure (new pathways, bridges) in three areas (Cardiff, Southampton, Kenilworth). |
| Cairns et al. (2017) | UK – Brighton. Employees in selected workplaces. | Mixed methods: recorded miles from smart monitoring systems on e-bikes and interviews with participants. | Participants were loaned electric assisted bicycles for 8 weeks. |
| Centre for Local Economic Strategies (2015) | UK. Schools and school communities. | National survey of schools and stakeholder consultation | Walk to School outreach programmes designed with schools. |

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| Chillón et al. (2017) | UK, Australia, US. Children and adolescents (6-18 years old). | Systematic review of 13 studies | Range of interventions to encourage walking or cycling to school. |
| Disney et al. (2018) | UK – Nottingham. | Case study analysis | Development of Nottingham Express Transit, a light rail system integrated with existing public transport and local key destinations. |
| Fishman et al. (2014) | UK, Australia, US. | Meta-analysis of bike share schemes using data logs from bike share schemes and motor vehicle fleet usage data. | Existing bike rental share schemes in Melbourne, Brisbane, Washington DC, Minneapolis and London. |
| Fishman et al. (2015) | UK, Australia, US. | Mixed methods: data logs from bike share schemes and surveys with registered users. | Existing bike rental share schemes in Melbourne, Brisbane, Washington DC, Minneapolis and London. |
| Garikapati et al. (2016) | US. General population. | Longitudinal analysis of American Time Use Survey. | No intervention. |
| Goodman et al. (2013) | UK – various towns. General population. | Meta-analysis of 2011 Census data. | Looking at effectiveness of various town-wide interventions to encourage cycling by comparing 12 Cycling Cities and Towns |

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| | | | (2008-2011) and six Cycling Demonstration Towns with control towns matched for population size and density, deprivation. |
| Heinen et al. (2015) | UK – Cambridgeshire. General population. | Case study of Cambridge Busway. Survey with participants pre and post intervention. | Introduction of Cambridge Busway – a guided bus using a disused rail track with a separate pathway for walking and cycling connecting the centre of Cambridge with various villages. Study focused on changes to active travel for commuting. |
| Kärmeniemi et al. (2018) | High income countries: North America, Europe, Australia, New Zealand and Asia. | Systematic review of 51 studies | Range of studies looking at physical activity and the built environment. |
| Kesten et al. (2015) | UK – Cambridgeshire. General population. | Qualitative: 38 semi-structured interviews conducted 18-22 months after intervention. | Introduction of the Cambridge Busway – a guided bus using a disused rail track with a separate pathway for walking and cycling connecting the centre of Cambridge with various villages. Study focused mode switches for commuting behaviour. |
| Kormos et al. (2015) | Canada: university students and | Longitudinal field experiment using | Month long intervention aimed at encouraging a switch away from |

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| | faculty. | self-reported travel data | car use for commuting travel. Three experimental groups: control group, low and high social norm groups. Participants were presented with identical information about options for sustainable commuting plus fictitious descriptive social norm information which either over (high social norms) or under-reported (low social norms) other people's successful switches. |
| Panter et al. (2014) | UK – Cambridgeshire. General population. | Secondary analysis of Commuting and Health Study which involved surveys on commuting at baseline and 1 year follow up. | No intervention specifically evaluated. Study investigated whether perceptions of improvements to environment and active travel routes changed active travel commuting behaviour. |
| Panter et al. (2016) | UK – Cambridgeshire. Participants recruited through workplaces. | Self-reported commuting mode pre (2009) and post intervention (2012). | Development of Cambridge Busway – a guided bus using a disused rail track with a separate pathway for walking and cycling connecting the centre of Cambridge with various villages. Study focused on changes to active travel for commuting. |

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| Pistoll and Cummins (2019) | UK. General population. | Analysis of UK Household Longitudinal Survey | No intervention. |
| Prins et al. (2016) | UK – Cambridgeshire. Participants recruited through workplaces. | Survey at baseline (2009) and post intervention (2012). | Development of Cambridge Busway – a guided bus using a disused rail track with a separate pathway for walking and cycling connecting the centre of Cambridge with various villages. Study focused on changes to active travel for commuting. |
| Sahlqvist et al. (2015) | UK: Adults living within 5 km of three intervention study sites | Mixed methods: qualitative interviews with stakeholders, survey with residents of local areas, cohort survey data. | New purpose-built active travel infrastructure (new pathways, bridges) in three areas (Cardiff, Southampton, Kenilworth). |
| Scheepers et al. (2014) | UK, Europe, North America, Australia and New Zealand. | Systematic review of 19 studies | Range of interventions aimed at encouraging mode shift from car use to active travel. |
| Schwanen (2015) | UK: Oxford and Brighton | Qualitative case study comparison | Comparison of cycling innovations between 2005 and 2015 in Oxford and Brighton. Interventions include Oxonbike and range of cycling initiatives in Brighton. |

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| Sloman et al. (2016) | UK. General population. | Meta-analysis of 12 Local Sustainable Transport Fund Large Projects | Range of interventions funded by the Local Sustainable Transport Fund. Interventions included improvements to local public transport and active travel initiatives. |
| Song et al. (2017) | UK. Adults living within 5 km of three intervention study sites. | Cohort study of data from the iConnect study. Three surveys at baseline (pre-intervention), one year follow up (T1), two year follow up (T2). | New purpose-built active travel infrastructure (new pathways, bridges) in three areas (Cardiff, Southampton, Kenilworth). |
| Swift et al. (2016) | UK. Employees in workplaces with Cycle to Work scheme | Survey of users of the scheme and rapid evidence review | The Cycle to Work scheme is a government programme that offers employees a reduction in the cost of a new bike for work from reduced income tax and National Insurance. It has been in operation since 2007. |
| Tsirimpa et al. (2019) | UK, Birmingham and Austria, Vienna for real world study. | Mixed methods: 1) modelling of hypothetical transport decision-making based on online questionnaire survey responses and 2) real word data from application with registered users across two locations. | Real world intervention involved an award programme delivered through a route planning app offering rewards for using more sustainable multimodal trips. Rewards were monetary (Vienna) or tickets or shopping vouchers (Birmingham). There was a two- |

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| | | | week baseline period and then a four-week reward period and average travel time spent per week by mode was compared. |
| Veitch et al. (2017) | Australia: various disadvantaged neighbourhoods. | Follow up sample from the Resilience for Eating and Activity Despite Inequality (READI) cohort. Surveys with children and mothers taken at T1 (2010) and T2 (2012). | No specific interventions: study examined independent mobility and active travel of children and examined factors that may impact on this. |
| Weber et al. (2018) | UK, Australia, US. | Baseline and follow up surveys after each year plus data on frequency and length of cycling time. | Love to Ride app from 3 large-scale campaigns in the UK, Sydney and Atlanta. |

# 11 Appendix C. Bibliography


Adams, E. J., & Cavill, N. (2015). Engaging communities in changing the environment to promote transport-related walking: Evaluation of route use in the 'Fitter for Walking'project. *Journal of Transport & Health*, *2*(4), 580-594.

Alcott, R., DeCindis, M.M., 1991. Clean air force campaign 1989–1990: programs, attitudes, and commute behavior changes. Transp. Res. Rec. 1321, 34–44.

Arnott, B., Rehackova, L., Errington, L., Sniehotta, F. F., Roberts, J., & Araujo-Soares, V. (2014). Efficacy of behavioural interventions for transport behaviour change: systematic review, meta-analysis and intervention coding. *International journal of behavioral nutrition and physical activity*, *11*(1), 133.

Audrey, S., Fisher, H., Cooper, A., Gaunt, D., Garfield, K., Metcalfe, C., Hollingworth, W., Gillison, F., Gabe-Walters, M., Rodgers, S., Davis, A. L., Insall, P., & Procter, S. (2019). Evaluation of an intervention to promote walking during the commute to work: a cluster randomised controlled trial. *BMC public health*, *19*(1), 427.

Bachand-Marleau, J., Lee, B.H.Y., El-Geneidy, A.M., 2012. Better understanding of factors influencing likelihood of using shared bicycle systems and frequency of use. Transp. Res. Rec. 2314, 66–71. http://dx.doi.org/10.3141/2314-09.

Bird, E. L., Baker, G., Mutrie, N., Ogilvie, D., Sahlqvist, S., & Powell, J. (2013). Behavior change techniques used to promote walking and cycling: A systematic review. *Health Psychology*, *32*(8), 829.

Bird, E. L., Panter, J., Baker, G., Jones, T., Ogilvie, D., & iConnect Consortium. (2018). Predicting walking and cycling behaviour change using an extended Theory of Planned Behaviour. *Journal of Transport & Health*, *10*, 11-27.

Boarnet M. G., Anderson C. L., Day K., McMillan T., Alfonzo M. (2005a). Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. *American Journal of Preventative Medicine*, 28, 134-140.

Boarnet M. G., Day K., Anderson C., McMillan T., Alfonzo M. (2005b). California's Safe Routes to School Program: Impacts on Walking, Bicycling, and Pedestrian Safety. *Journal of American Planning Association, 71*, 301-317.

Brockman, R., Fox, K.R., (2011). Physical activity by stealth? The potential health benefits of a workplace transport plan. *Public Health, 125*, 210–216.

Cairns, S., Behrendt, F., Raffo, D., Beaumont, C., & Kiefer, C. (2017). Electrically-assisted bikes: Potential impacts on travel behaviour. *Transportation research part A: policy and practice*, *103*, 327-342.

Centre for Local Economic Strategies (2015). Walk to School Outreach – Final Phase Evaluation. July 1015. Report for Living Streets.

Chatterjee, K., Goodwin, P., Schwanen, T., Clark, B., Jain, J., Melia, S., Middleton, J., Plyushteva, A., Ricci, M., Santos, G. & Stokes, G. (2018). *Young People's Travel – What's Changed and Why? Review and Analysis*. Report to Department for Transport.

UWE Bristol, UK. www.gov.uk/government/publications/young-peoples-travel-whats-changed-and-why.

Chillón, P., Evenson, K. R., Vaughn, A., & Ward, D. S. (2011). A systematic review of interventions for promoting active transportation to school. *International journal of behavioral nutrition and physical activity*, *8*(1), 10.

Disney, J., Rossiter, W., & Smith, D. J. (2018). Nottingham Express Transit: The role of green innovation in the drive for sustainable mobility through improved public transport. *The International Journal of Entrepreneurship and Innovation*, *19*(1), 56-68.

Fishman, E., Washington, S., & Haworth, N. (2015). Bikeshare's impact on active travel: Evidence from the United States, Great Britain, and Australia. *Journal of transport & health*, *2*(2), 135-142.

Fishman, E., Washington, S., & Haworth, N. (2014). Bike share's impact on car use: Evidence from the United States, Great Britain, and Australia. *Transportation Research Part D: Transport and Environment*, *31*, 13-20.

Fuller, D., Gauvin, L., Kestens, Y., Morency, P., Drouin, L., (2013). The potential modal shift and health benefits of implementing a public bicycle share program in Montreal, Canada. Int. J. Behav. Nutr. Phys. Act 10, 66.

Goodman, A., Panter, J., Sharp, S. J., & Ogilvie, D. (2013). Effectiveness and equity impacts of town-wide cycling initiatives in England: a longitudinal, controlled natural experimental study. *Social science & medicine*, *97*, 228-237.

Garikapati, V. M., Pendyala, R. M., Morris, E. A., Mokhtarian, P. L., & McDonald, N. (2016). Activity patterns, time use, and travel of millennials: a generation in transition?. *Transport Reviews*, *36*(5), 558-584.

Heelan, K. A., Abbey, B. M., Donnelly, J. E., Mayo, M. S. & Welk, G. J. (2009). Evaluation of a walking school bus for promoting physical activity in youth. J Phys Act Health, 6, 560-567.

Heinen, E., Panter, J., Mackett, R., & Ogilvie, D. (2015). Changes in mode of travel to work: a natural experimental study of new transport infrastructure. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 81.

James, B., & Brög, W., (2001). Increasing walking trips through TravelSmart individualised marketing. World Transp. Policy Pract. 7, 61–66.

Jordan, K. C., Erickson. E. D., Cox, R., Carlson, E. C., Heap, E., Friedrichs, M., Moyer Mileur, L. J., Shen, S. Y. & Mihalopoulos, N. L. (2008). Evaluation of the Gold Medal Schools Program. *J Am Diet Assoc, 108*, 1916-1920.

Kärmeniemi, M., Lankila, T., Ikäheimo, T., Koivumaa-Honkanen, H., & Korpelainen, R. (2018). The built environment as a determinant of physical activity: a systematic review of longitudinal studies and natural experiments. *Annals of Behavioral Medicine*, *52*(3), 239-251.

Kesten, J. M., Guell, C., Cohn, S., & Ogilvie, D. (2015). From the concrete to the intangible: understanding the diverse experiences and impacts of new transport infrastructure. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 72.

Kormos, C., Gifford, R., & Brown, E. (2015). The influence of descriptive social norm information on sustainable transportation behavior: A field experiment. *Environment and Behavior*, *47*(5), 479-501.

Meland, S., (1995). Generalised and advanced urban debiting innovations: the GAUDI Project. 3. The Trondheim toll ring. *Traffic Eng. Control 36*, 150–155.

Merom D, Rissel C, Mahmic A, Bauman A (2005). Process evaluation of the New South Wales Walk Safely to School Day. *Health Promot J Austr, 16*,100-106.

Mutrie, N., Carney, C., Blamey, A., Crawford, F., Aitchison, T., Whitelaw, A., (2002). ''Walk in to Work Out'': a randomised controlled trial of a self help intervention to promote active commuting. *J. Epidemiol. Community Health, 56*, 407–412.

Noland, R.B., Ishaque, M.M., (2006). Smart bicycles in an urban area: evaluation of a pilot scheme in London. *J. Publ. Transp. 9*, 71–95.

O'Fallon, C., (2010). Bike now: exploring methods of building sustained participation in cycle commuting in New Zealand. *Road Transp. Res., 19,* 77–89

Panter, J., Griffin, S., & Ogilvie, D. (2014). Active commuting and perceptions of the route environment: A longitudinal analysis. *Preventive medicine, 67,* 134-140.

Panter, J., Heinen, E., Mackett, R., & Ogilvie, D. (2016). Impact of new transport infrastructure on walking, cycling, and physical activity. *American Journal of Preventive Medicine, 50*(2), e45-e53.

Pistoll, C. T., & Cummins, S. (2019). Exploring changes in active travel uptake and cessation across the lifespan: Longitudinal evidence from the UK Household Longitudinal Survey. *Preventive Medicine Reports*, *13*, 57-61.

Prins, R. G., Panter, J., Heinen, E., Griffin, S. J., & Ogilvie, D. B. (2016). Causal pathways linking environmental change with health behaviour change: natural experimental study of new transport infrastructure and cycling to work. *Preventive medicine*, *87*, 175-182.

Rowland, D., DiGuiseppi, C., Gross, M., Afolabi, E., & Roberts, I. (2003). Randomised controlled trial of site specific advice on school travel patterns. *Arch Dis Child, 88*, 8-11.

Scheepers, C. E., Wendel-Vos, G. C. W., Den Broeder, J. M., Van Kempen, E. M., Van Wesemael, P. J. V., & Schuit, A. J. (2014). Shifting from car to active transport: a systematic review of the effectiveness of interventions. *Transportation research part A: policy and practice*, *70*, 264-280.

Schwanen, T. (2015). The bumpy road toward low-energy urban mobility: case studies from two UK cities. *Sustainability*, *7*(6), 7086-7111.

Sloman, L., Cairns, S., Newson, C., Anable, J., Pridmore, A., & Goodwin, P. (2017). Meta-analysis of Outcomes of Investment in the 12 Local Sustainable Transport Fund Large Projects: Interim report. Report to the departern for transpirt.

Song, Y., Preston, J., Ogilvie, D., & iConnect Consortium. (2017). New walking and cycling infrastructure and modal shift in the UK: a quasi-experimental panel study. *Transportation research part A: policy and practice*, *95*, 320-333.

Staunton, C. E., Hubsmith, D. & Kallins, W. (2003). Promoting safe walking and biking to school: the Marin County success story. Am J Public Health 2003, 93:1431-1434.

Swift, S., Green, M., Hillage, J., & Nafilyan, V. (2016). Impact of the Cycle to Work Scheme Evidence Report. Institute for Employment Studies.

Sahlqvist, S., Goodman, A., Jones, T., Powell, J., Song, Y., & Ogilvie, D. (2015). Mechanisms underpinning use of new walking and cycling infrastructure in different contexts: mixed-method analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 24.

Shoup, D.C., (1997). Evaluating the effects of cashing out employer-paid parking: eight case studies. *Transp. Policy, 4*, 201–216.

Topp, H. & Pharoah, T., (1994). Car-free city centres. *Transportation, 21*, 231–247.

Tsirimpa, A., Polydoropoulou, A., Pagoni, I., & Tsouros, I. (2019). A reward-based instrument for promoting multimodality. *Transportation research part F: traffic psychology and behaviour*, *65*, 121-140.

Veitch, J., Carver, A., Salmon, J., Abbott, G., Ball, K., Crawford, D., Cleland, V. & Timperio, A. (2017). What predicts children's active transport and independent mobility in disadvantaged neighborhoods? *Health & place*, *44*, 103-109.

Weber, J., Azad, M., Riggs, W., & Cherry, C. R. (2018). The convergence of smartphone apps, gamification and competition to increase cycling. *Transportation research part F: traffic psychology and behaviour*, *56*, 333-343.

Wen, L.M., Orr, N., Bindon, J. & Rissel, C., (2005). Promoting active transport in a workplace setting: evaluation of a pilot study in Australia. *Health Promot. Int., 20*, 123–133.

Zaccari, V. & Dirkis, H. (2003). Walking to school in inner Sydney. *Health Promotion Journal of Australia, 14*, 137-140.