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Best practice in active travel and its associated benefits

Literature review

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Executive summary

Introduction

The purpose of this literature review is to assess best practice in active travel, covering what works in terms of having the greatest impact on improving rates of walking and cycling. The resulting review will highlight what has been found to work, and what has not, as well as case studies of successful interventions in order to create a framework for success. In addition, it will outline the range of economic, health and environmental benefits that are associated with active travel.

There is a growing body of international grey and academic literature on both best practice and the associated benefits of active travel. In many instances the evidence lacks the necessary robustness to definitively say what the quantifiable result of infrastructural and behavioural interventions would be on a larger scale. Similarly, the majority of the evidence concerning the benefits of active travel is based on case-studies, limiting cross-comparison and generalisability due to the variation in methodology and data collected. As a result, while there is a consensus on the benefits associated with active travel, the literature generally refrains from quantifying them.

Despite these limitations, the direction of causality is clear in terms of both infrastructural and behavioural interventions, and this report focuses on the actions associated with success and the benefits that can accrue as a result of active travel, rather than on quantifying them.

What works?

The literature noted many different interventions that were successful in increasing walking and cycling to some extent. The interventions considered most impactful are outlined below.

- Success in walking interventions came predominantly from behavioural interventions, with programmes targeting patients' health or poor health outcomes showing significant improvement through increases in walking levels. Infrastructure was only seen as improving safety, with mixed land use and density being more important factors to induce walking for transport.
- Access to public transport was seen as a strong determinant of walking for transport. Residents with 30 or more bus stops in a 1.6km radius of their homes were twice as likely to walk for transport as those who had 0-14 bus stops, and having a train station within a 1.6km radius increasing the odds of walking by 50%

- It was heavily emphasised in the literature that the best point to target behavioural interventions to achieve modal shift was during 'trigger points' in people's lives. Examples being: periods of transition in employment or education; entering parenthood, especially motherhood; people recovering from ill health; people with increased leisure time; and people moving home.
- Bike sharing improved cycling levels in cities with low levels of cycling modal share, with density of docking stations being important for the programme to achieve success. Although it has been noted that the majority of the shift to bike share comes from public transport and walking.
- Cycle-lanes that form a continuous network are a necessary condition for encouraging modal shift to cycling. However, provision of infrastructure is insufficient on its own, and has to linked with behavioural or policy interventions to make cycling more attractive in order to achieve a modal shift. Once modal shift has been achieved the cycle lanes are used heavily by cyclists, further reinforcing their status as necessary for modal shift.
- One of the key factors in modal shift was the attractiveness of cycling as compared to motor vehicles. Higher levels of motor vehicle congestion and less parking availability makes cycling more attractive. This ties in with another finding that indicates that directness and journey time are important in achieving modal shift.
- Several workplace interventions were successful in encouraging active travel uptake. These include personal travel plans timed with trigger points, inter office active travel competitions and decreased parking availability.
- Interviews with experts who had led successful modal shifts in UK and international cities noted several key components of success. Long term projects, of 5-10 years, where considered essential in driving sustained modal shift, with the projects focussed on building a network of cycle lanes where funding allowed, or on implementing a range of behavioural measures to create a cycling culture where funding was harder to obtain. They also noted that the mix of revenue to capital for projects was not especially important, but stated that any project must always come with some revenue spend.
- Some interventions can work but often fail to achieve their goals. Off-road cycle paths is one such intervention that in some instances can work but often fails to achieve modal shift due to low awareness and being a less direct route than using the main road.
- Similarly, there are interventions which have been found to have a negative impact on particular groups. Evidence on shared spaces interventions has shown how the design choice used can be detrimental and cause serious issues for people with visual impairments. In one case, this led to visually impaired people stating that they would no longer be able to use the area independently.

Whilst these interventions are noted as having positive effects, the quantifiable effect of the interventions is lacking. As such, the responses from expert interviewees in the literature provide some of the best notes on ways to improve an intervention's chance of success.

Successful projects

There are a selection of successful projects which are useful examples to emulate. In particular the Cycling Cities and Towns project in England, a continuation of the Cycling Demonstration Towns , are good examples of success in Britain. Between 2007-2011 the 12 intervention areas saw an average increase in cycling of around 20%. This was built off the back of the Cycling Demonstration Towns and Sustainable Travel Towns that noted that longer term projects with established teams and plans gave significant results.

Other examples of success are the Sustainable Travel Towns in England and the Smarter Choices Smarter Places in Scotland. Both programmes worked to improve bus services as well as advertising campaigns and personal travel plans to improve active travel. Both programmes saw a significant shift away from cars towards walking and bus use, with the Sustainable Travel Towns in England also seeing an increase in cycling. The results suggest that while behavioural interventions can increase walking trips, access to a good bus network is key to allow walking as a means of travel for longer journeys.

What is the recommended path to success?

Long term projects

Long term projects are considered the most successful, with a recommended minimum of five years but an optimal time frame placed at 10 years. Stop-start funding was noted as being ineffective in achieving modal share both because of the incomplete infrastructure and because of the short term funding resulting in some longer term revenue projects not being pursued.

Dedicated teams

Dedicated teams for a project are considered best practice. Evidence from the Sustainable Travel Towns suggests that teams can take six months to a year to recruit and train in advance of a project, further reinforcing the need for a long term project. These teams are best placed to understand the particular local challenges and come up with more appropriate local solutions and intervention packages.

Focussing on strong citizen participation

Focussing on areas that have strong citizen participation and local authority support, along with well-prepared policies, appears to be the most successful. This indicates that project funding should go to areas where there is a desire to see long term difference and would support a well-planned project, further reinforcing the need for longer term projects.

Revenue spend successful when coupled with quality improvements

Revenue spend is most successful when coupled with improvements in quality, although this could include newly created facilities rather than simply improving on what is available. This is particularly apparent in Doncaster where failure to improve the bus service due to the issues surrounding its two providers severely hampered the drive for sustainable travel compared to other peer cities. It is also noted that when there is insufficient budget to create a comprehensive network, revenue spending is a good policy to create a culture and attitude ready for cycling when the funding is available.

Making motor transport less attractive needed for modal shift.

A major point in the literature is that while quality improvements and infrastructure are necessary conditions for modal shift, they are not sufficient to induce the modal shift due to the availability of cars. Instead that has to come from other sources with one particularly noted area being the attractiveness of cars. If motor transport is less attractive, modal shift happens. This can be achieved by increasing parking tariffs, reducing availability of free workplace parking, and extending the area of paid on-street parking, thereby reducing the availability of parking but not alleviating congestion.

Value of time

The value of time is an important consideration, with evidence showing that active travel and bus travel needs to be sufficiently fast compared to private motorised vehicles to encourage modal shift.

Ensuring that cycle lanes have the minimal interruptions

Ensuring that cycle lanes have the minimal interruptions makes cycling more attractive, with less stops shown to lead to a higher cycling share. This in combination with improving the perception of cycling both in terms of quality and safety (regardless of the validity of that perception) helps increase modal share.

Successful active travel policy

Successful active travel policy is heavily dependent on external factors such as demographics, land use mix, population density and topography amongst other things. This suggests that there is a justification for different intervention mixes in different cities to overcome these factors.

The range of potential policy packages is very broad

The range of potential policy packages is very broad, but a typical package could include: the creation of local bicycle statistics/metrics; marketing to improve co-existence of pedestrians and cyclists; route promotion marketing; innovative parking solutions; healthy cycling and walking campaigns; cycle website improvements; and safety strategy improvement. The literature also recommends supportive land use planning as well as restrictions on car use.

Spending

Several papers outline what the general spend in towns is to achieve cycling uptake. The Sustainable Travel Towns project had an average spend of £19-£29 per head of population per year over a five year period (Urban Transport, 2011), although these funds also include walking and bus spend. A similar project in Scotland (Transport Scotland, 2013) spent between £5-£18 per person per year over three years which included walking and bus spending. The Cycling Demonstration Towns (DfT, 2009) spent around £10 per person per year for the first five years, where other English local authorities were spending roughly £1 per head. The follow up to Cycling Demonstration Towns including the Cycling Cities and Towns projects (Sustrans, 2017), was found to cost on average £14 per head of population per year for the five years prior to the report.

Finally, Sustrans estimates that to achieve a doubling of cycling journeys in England there would have to be a spend of roughly £17 per person per year over a 10 year period (2016). The evidence suggest that a spend per person in the treatment areas ranging between £10-£30 per annum over 5-10 years, would be reasonable and in keeping with past successful projects. However, due to the nature of the data it would be unwise to extrapolate a certain spend with a certain effect.

What are the associated benefits?

The majority of the benefits associated with active travel are as a result of improved health outcomes. Provided that it is sufficiently frequent and intensive, physical activity through active travel is associated with a reduction in all-cause mortality and in the incidence or severity of a number of health conditions including: stroke, obesity, type II diabetes, cardiovascular disease, colon and breast cancer, hypertension, depression and anxiety. In older adults it is further associated with improved levels of functional ability and reduced incidence of dementia.

Health benefits are subject to a dose-response relationship such that larger risk-reduction is accrued at higher levels of physical activity, with a capped maximum risk-reduction generally placed at five years of consistently high levels of physical activity. There is a consensus that a mode shift to active travel results in substantial health benefits at an individual level. This is the case irrespective of baseline activity levels or geographical context, and outweighs any increased risk in terms of pollution exposure or road safety. Men, older adults (generally 45 years and greater) and members of ethnic minorities are generally found to benefit more from active travel than the rest of the general population.

Additionally, active travel can result in substantial savings at an individual level when compared to the use of motorised vehicles or public transport, especially for short journeys. Active travel modes are the lowest producers of emissions and air pollution per passenger-km.

Despite the clear health and environmental benefits of active travel at an individual level, it is important to note that their impact on a societal level are minimal unless a consequential mode shift can be achieved. Should the number of active travellers substantially increase, a number of economic benefits could emerge such as health-care savings, retail spending, tourism, increased productivity and reduced absenteeism.

Conclusion

The evidence indicates that high quality, joined-up infrastructure and behavioural interventions at trigger points in people's lives are the most effective measures to

encourage an uptake in active travel. However, the quantitative effect of these interventions is much less clear, in part due to the effect of external factors such as local weather, topography and population density. It is often noted in the literature that infrastructure is a necessary but insufficient condition on its own for a modal shift to active travel. Other factors such as the attractiveness of motor transport, environmental factors, and linked behavioural interventions all play an important part in the success of a project. In particular with walking, mixed land use and density play a more important role in determining modal share.

One of the most prevalent issues in encouraging active travel is journey time compared to motor transport. Individuals are more likely to switch to active travel modes, including mixed modes with public transport, when their journey time is reduced compared to making the trip using private motorised vehicles.

Off-road cycle paths do not appear to bring an improvement in cycling modal share, and are noted as not being attractive to female cyclists. Additionally, shared spaces can have benefits for pedestrians but with poor implementation they can adversely impact others.

There are substantial gaps in the literature, notably on the effect of active travel infrastructure on people with disabilities. In addition, there is a lack of evidence on the optimal mix of infrastructure and behavioural interventions, with some of this likely due to the highly context-dependent nature of successful interventions.

Given the lack of quantifiable data, the responses by expert interviewees in the literature provide some of the best notes on ways to improve an intervention's chance of success. They note that the most successful projects are those with a minimum term of five years, with stop-start funding being associated with poor results. They also note that while the size of the revenue spend is not as important, it is imperative that all capital projects come with at least some revenue spend. Finally they note that cycle infrastructure should be built as a comprehensive and continuous network and not as discrete and disconnected routes. If it is not possible to build a comprehensive network it would be better to invest the money in revenue spend to create a groundswell of support for cycling so that when the infrastructure is finally built the uptake will be a lot quicker.

Best practice in infrastructural and behavioural active travel interventions

This paper was produced in 2020, prior to the COVID-19 Pandemic, following a broad literature search conducted on IDOX and Google in conjunction with the Scottish Government Library. The review does not include any research undertaken during since 2020. The research identified was a mixture of large scale reports produced for government bodies and peer-reviewed academic literature.

The purpose of this section is to assess best practice in active travel, covering what works in terms of having the greatest impact on improving rates of walking and cycling. The resulting review will discuss what has been found to work, and what has not, as well as case studies of successful interventions in order to create a framework for success.

The evidence of what works, both in terms of infrastructure and behavioural interventions, is quite expansive but in many instances lacks a robustness necessary to be able to definitively say what the quantifiable result would be on a larger scale. The direction of causality for many of the interventions are clear, however, the quantitative effect of these interventions is much less clear, in part due to the effect of external factors such as local weather, topography and population density. As a consequence, the findings of this report focus on the actions associated with success rather than trying to quantify success.

This section will begin with what works, separated into infrastructure and behavioural interventions with tables detailing different interventions and their success. It will then move on to look at what the literature states does not work and where there are gaps in the literature which should be kept in mind. The section will further look at successful case studies in several different cities focussing on what they did in order to succeed with another section looking at possible comparison cities for Scotland to consider in order to draw lessons. Finally the review will detail what the literature suggests as being important factors in order to achieve successes in policy interventions and attempt to create a roadmap for policy makers to follow.

Infrastructure: what has been found to work?

The purpose of this section is to lay out what is known to be successful with infrastructure related schemes and how we can learn from this.

- Walking – Infrastructure was found to have little effect barring increasing the perception of safety for walking with children. Rather, land-use mix, walkable distances and access to public transport were found to be greater predicators of walking.
- Bike Sharing Schemes – Bike sharing schemes have been shown to increasing cycling modal share in areas with low cycling uptake. However, success is often linked to existing cycling infrastructure and shared cycling docking density with most new trips coming at the expense walking and public transport rather than motor vehicles.
- Cycling Lanes – The evidence suggests that individual lanes have a negligible effect, rather significant effects are found where a continuous connected network is formed. They also note that cycling infrastructure is a necessary but not sufficient condition to achieve modal shift in isolation, although once modal shift has been achieved it is heavily used by cyclists.
- Cycling and Congestion – Evidence from Germany suggests that the speed of motor vehicle traffic has a large effect on cycling uptake, with slower moving traffic and higher congestion resulting in a greater increase in leisure cycling. Cycling speed and congestion was also found to have an effect, suggesting that the value of time influences modal shift significantly.
- Multi Modal Integration and Cycle Parking – Integrating cycling with the public transport system in the Netherlands was found to increase cycling to train station as well as train modal share with a much more muted effect for buses.
- Gender Gap – Female cyclists self-report a preference for segregated on-road cycle paths. This appears to be corroborated by a study drawing on data from a travel app to analyse cycle route choice by gender that observes female cyclists changing their route to include segregated on-road paths.
- Cycling City and Towns (CCT) Evidence – Evidence from a large cycling scheme in England noted that awareness of off-road cycle paths was lacking, and that advanced stop lines were popular with regular cyclists but less so with motorists. However, new cyclists were still observed dismounting for junctions instead. They also noted that whilst cycling parking was helpful in encouraging cycling, cycle theft was not tackled and remained high on people's minds with one respondent stating it prevented them from cycling into town.
- Expert Interviewee Advice – Advice from several cycling practitioners noted that interventions should be planned to last at minimum 5 years, with shorter schemes having little practical value. They also noted that whilst the mix of

revenue to capital spend was not especially relevant, revenue spend should always be a part of any capital spend.

Walking

Infrastructure has a much more muted effect on walking than cycling (Forsyth & Krizek, 2009). When analysing travel diaries and built environment using GIS, Forsyth and Krizek (2009) noted that land-use mix was a significant predictor of walking trips, and that built environments with destinations closer together was correlated with higher rates of walking for transportation. In general, infrastructure investments may be useful in changing the perceptions of walkability among children and their parents. However, for adults the relationship between infrastructure and increased travel walking is not strong (Forsyth & Krizek, 2009).

Knuiman et al. (2014) also found that density and land use were among the key predicators of walking for travel, although they also note that the number of destinations that are accessible as well as the number of bus and train stops within 1.6km were significant predicators. Individuals who had 30 or more bus stops within 1,600 m of their homes were almost twice as likely to walk for transportation than those who had 0–14 bus stops. The presence of a train station within 1,600 m increased the likelihood of walking for transportation by approximately 50%.

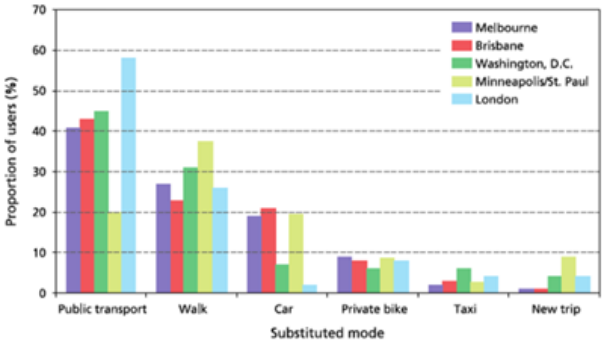
Bike sharing schemes

There has been some success in individual cycling projects, particularly in bike sharing schemes. A paper looking at the successes in cycling projects in Spain by Marqués, et al. (2015) and Anaya & Castro (2012), notes that their success was fairly uneven but the one main factor that was noted as a difference between those succeeding and those not was the density level of the bike stations as well as other present infrastructure. It appears that further increasing the density and having a cycle friendly city aided in the schemes becoming successful, suggesting that there needs to be a critical mass in order for the schemes to become successful. The literature from Spain recommends a docking station every 300 metres in order for a bike sharing scheme to have a strong chance of success (Anaya & Castro, 2012).

The Danish Cycling Embassy (2012) also notes that cities such as Lyon, Paris and Barcelona managed to boost bicycle traffic significantly by introducing public bikes, but they attribute this to the fact that hardly anyone used a bicycle before.

However, it is important to consider where these new journeys come from. Fishman, et al. (2015) analysed data from cycle hire schemes and concluded that where bike share trips replace existing trips, the main mode shift comes from public transport, then walking, followed by cars, private bikes, and finally taxis as shown in Figure 1.

Figure 1 – Cycle hire trips by original mode of transportation



Source: (Fishman, et al., 2015)

Cycling lanes

The Danish Cycling Embassy (2012) notes that "Danish bicycle counts show that installing a cycle lane on a single road has a negligible effect, a mere 0.5% increase. If, however, an entire network of cycle lanes is established in an urban area without cycle tracks the number of cyclists will increase." As such it seems that fixed infrastructure interventions have very little impact in isolation but when combined have a significantly larger impact. This is echoed by other works and evidence reviews (Pucher, et al., 2010; DfT, 2016). Pucher, et al. (2010) goes on to say that some specific programs which appear to have a negligible impact when examined in isolation can have a significant impact when implemented comprehensively. Indeed the most compelling evidence came from communities that implemented a fully integrated package of strategies to increase cycling such as city wide continuous segregated lanes. These can be seen under 'Successful Projects'.

Interestingly it appears there is a significant lag in effect from any cycling infrastructure. Goodman, et al. (2014) found that living nearer the infrastructure did not predict changes in activity levels at 1-year follow-up but did predict increases in activity at 2 years relative to those living farther away. This feeds in to other studies that suggest that infrastructure is a necessary but not sufficient condition for increases in cycling. Rather it is disruption in people's lives due to new work or moving house that has an effect which is more successful in areas which already have infrastructure, thus explaining the lagged effect.

Beenackers, et al. (2012) looked at built environment factors effect on cycling uptake when moving to a new home in Australia. They found that residential density, number of recreation destinations nearby and access to a park were all positively associated with cycling uptake for transport, with parks in particular resulting in a strong influence towards cycling. However, the survey did not include cycling

infrastructure either due to the lack of infrastructure at the location or simply by omission. Regardless it shows that the environment factors are significant in helping trigger points be effective.

Using longitudinal panel data, Song, et al. (2017) found that self-reported use of cycling infrastructure (such as casual or leisure cycling) was significantly associated with a modal shift towards active travel after controlling for personal and household characteristics, but that passive exposure (residential proximity to the infrastructure) was not directly associated with a modal shift. Other studies have argued that the provision of dedicated cycling facilities is critical for achieving a higher level of cycling, based upon aggregate international data (Pucher, et al., 2010). Song, et al.'s (2017) study suggests that while infrastructure provision may not be a sufficient condition to achieve modal shift, it may well be a necessary condition, as those who casually used cycling infrastructure became more regular cyclists over those who did not.

Dill (2009) used GPS to collect trip route data from 166 regular cyclists in Portland, Oregon, over seven days (1,800 trips). The cyclists were selected from a sample of cyclist survey respondents who were stratified by geography and sex, and then randomly selected to receive GPS trackers. It was found that almost half the miles of bicycle travel 'occurred on-roads with bicycle lanes, [separated] paths, or bicycle boulevards', facilities that made up only 8% of the available road network. A follow-up survey indicated that the top reasons for choosing paths were directness and avoiding traffic.

Cycling and congestion

Goestzke & Rave (2011) looked at the effect of city congestion on cycling modal share. They note that the more congested roads are, the more people use bicycles for shopping and errands. These shopping trips are most affected by changes in average motor vehicle speed. The evidence suggests that a 10% increase in mean automobile speed, for example from the a mean of 20 km per hour to 22 km per hour, would halve the modal split for shopping cyclists, from about 27% to 13.5%. However, commuter cyclists did not appear to be responsive to the change in average motor vehicle speed.

Other factors affecting the success of network systems include a reduction in the stops along a cycle route increases cycling. Rietveld & Daniel (2004) found evidence from Holland that suggests that routes which do not require cyclists to make stops increase cycling mode share: 0.3 fewer stops per km along a route was associated with a 4.9% higher share of cycling. As is shown above the mean speed is an important factor in modal shift, keeping car speeds stagnant while improving bicycle speeds appears to increase the cycling share.

Multi modal integration and cycle parking

Cycling integration into the public transport system can increase use of both systems. A pilot project in the Netherlands in the 1990s found that there was a significant increase in both public transport use and bicycling, but mainly for bicycle trips between home and the suburban rail station (access trip) and far less for bicycle trips between the terminal station and the activity end of the trip (egress trip) (Pucher, et al., 2010). This was achieved by the increased provision of bicycle parking both at working and at public transport hubs (Martens, 2007).

They also found that bike lockers at bus stops were hardly used by bus passengers which they attributed to the large number of bus passengers being students and the high price of lockers relative to the value of the bike (Martens, 2007), suggesting that cheaper bike parking at bus stops would be better or simply focus on providing bike lockers at train stations. An interesting point to note is that standard cycle parking is more popular among users than bicycle lockers, which tend to be under-utilised (although it is worth noting that the evidence for this comes from Holland and may not apply to the UK).

Gender gap

Women self-report a preference for segregated on-road cycle lanes over mixed traffic cycling (Pucher, et al., 2010; Moore, 2019). However the preference for segregated cycling paths does not extend to off-road cycle paths, with safety concerns being cited as a possible reason. This appears to be reflected in analysis conducted by Strava where they investigated the effect of new segregated lanes on route choice. However, the analysis should be heavily caveated as it fails to disclose key data such as the sample size and demographics, as well as drawing data from a voluntary app which could lead to selection bias.

A study that utilised Strava data of cyclists in New York showed that women are a lot more attracted to segregated safe cycling paths than mixed traffic (Moore, 2019). “Strava’s study analyzed 11,416 bike trips by women in Queens between 2015 and 2019. The results were clear: Making streets safer increased women’s use of them dramatically. In 2019, women made nearly 40% more trips on 43rd and nearly 50% more trips on Skillman than they had in 2018 (two streets with new segregated lanes)” (Moore, 2019). Although this increase was predominantly displacement from other streets, it was noted that these streets were being avoided prior to this, suggesting that the new lanes allowed for more direct cycling for many cyclists, thus making cycling a more attractive prospect. Additionally it was noted that men’s ridership did not change after the bike lane upgrades. A separate review by Strava in

Philadelphia found the same results, with female cyclists moving to the segregated cycle paths while male cyclists continued on their previous routes (Bunn, 2019).

Expert interviewee advice

Slowman, et al. (2014) conducted interviews with those responsible for cycling in Seville and Odense amongst other successful cycling towns. The table below outlines the experts' opinions on best practice, indicating among other things that:

- The programme duration should be at least five years. Long-term funding settlements - whatever the proportion of revenue and capital – are considered of greater value than short term settlements. Five years was considered the absolute minimum programme time with short-term investment programmes considered to have no value.
- Larger urban areas may require a higher proportion of capital investment than smaller urban areas due to their need for quality infrastructure, with smaller towns expected to only need some minor adaptations to streets such as 20mph zones or traffic calming. If the conditions for cycling are already fairly suitable the priority should be on behavioural spend.
- Overall scale of Investment: Smaller budgets might involve a higher proportion of revenue than larger budgets as there is little point in building a section of path that is not connected to the rest of the cycle network. In this situation revenue measures would be better suited to create a groundswell of support in preparation of future larger spends.
- Cultural starting point is important. The proportion of revenue funding may need to be higher in places which lack a cycling culture.
- The proportion of revenue funding may change during the course of the programme. Being high at the early and late stages of a long-term (20-30 year) programme due to behaviour interventions, but lower in the middle period due to infrastructure interventions.
- Both capital and revenue are important, although the exact split was considered less crucial.

Cycling Cities and Towns evidence (CCT)

Cycling Embassy (2012) carried out research with regular and new cyclists to gauge reaction to interventions introduced through the Cycling Cities and Towns programme. The table below lays out the reaction to hard interventions, noting that cycling infrastructure was well received by cyclists, but proved unpopular with car drivers e.g. advanced stop lines. Cycle parking was found to be useful but there was still significant concerns regarding theft and vandalism with one respondent stating it prevented them from cycling into town.

Cycling infrastructure and facilities

Residents tended to have noticed new cycling infrastructure in their town (both on- and off-road) and valued the improved cycling experience that resulted. Although improved infrastructure was generally viewed positively, there remained negative perceptions of discontinuous routes, narrow lanes and lack of routes segregated from traffic.

It also had an impact on social/cultural and journey perception issues (with visible investment in cycling presenting an image of cycling as a supported, feasible and popular option)

Advanced Stop Lines (ASL)

Non-cyclists: ASL were unpopular as cyclists were sometimes perceived as an obstruction to motorists. There were reports of cyclists damaging vehicles or appearing in vehicle blind spots whilst approaching the turning box.

Cyclists: ASL were positively viewed and enhanced the cycling experience for regular cyclists by reducing potential risks.

Despite the positive views of cyclists, some New Regular cyclists were unsure how to use ASL and reported dismounting and using pedestrian facilities to cross a road.

Awareness of the investment in off-road cycling facilities

In Stoke and Woking, where investment focused on improving canal tow paths, non-cyclists tended to be unaware of the improvements as they were not visible to drivers. Knowledge of off-road cycling facilities was often gained by word of mouth when friends, families and/or colleagues had discussed their experiences of using the facility as a cyclist or pedestrian.

In contrast, in Blackpool, Southend and Southport where strategies included investment in dedicated off-road cycle lanes on the sea front, awareness of the investment was generally high and this was mainly due to improvements being highly visible to all residents.

Signage

In all CCTs, infrastructure has been supported by the provision of enhanced signage, often with average cycle times rather than miles to destination. Continuing Regular Cyclists were those most likely to be aware of cycle route signage and so often noticed new signage when travelling on their current cycle routes.

Awareness of route signage was low amongst other cyclist groups. Overall, few participants expressed strong views regarding cycle route signage. Despite being regarded as a 'good idea' in principle, most perceived the signs being aimed at visitors or tourists rather than residents.

Cycle Parking

Across all CCTs there was a noted increase in the number of parking facilities in the city/town centres, workplaces, schools and rail stations and this was often attributed to local authority policies to encourage cycling.

The provision of cycle parking facilities within the workplace had contributed to a small number of participants cycling to work (alongside other factors).

Finding a place to park your bicycle was therefore not a problem for many cyclists; however, cycle security was a concern in most CCTs, particularly Chester, Colchester and York, where bicycle theft was perceived as high and many had experienced theft or vandalism. Improvements to cycle parking security were therefore important to many participants.

Conclusion

Infrastructure investments for walking were not seen as particularly necessary, with land planning and strong public transport connections considered more important in achieving modal share.

The evidence for cycling was more comprehensive, suggesting that infrastructure works best as a comprehensive package and not as a system of small improvements. As such the literature does not suggest singular measures but rather a raft of measures to increase cycling, although what share each of the measures should have is not stated. The one exception to this is in the style of cycling lane, with the literature strongly pointing to segregated on or near traffic lanes as being the best to attract female and casual cyclists.

Additionally the evidence suggests that the infrastructure is a necessary but not sufficient factor in isolation to increase cycling. Instead, natural disruptions in the form of moving home, or changing job, along with other modes journey times and environmental factors play a greater role in achieving modal shift. Some of these happen organically and are lagged with time, which can be overcome with some behavioural measures such as personalised travel plans, others will inhibit modal shift if not overcome such as adverse topography and weather.

Behavioural interventions: what has been found to work?

The purpose of this section is to lay out what is known to be successful with behavioural interventions and how we can learn from this.

- School Behaviour – The evidence on school behaviour change was of lower quality, with researchers suggesting the most effective known strategy is walking school buses. (A walking school bus is when an adult leads a walk to school, picking up children along the way.) Usually focussed on children who are too young to walk independently Although they note that there are issues with scaling this up and extending it to every school day. Similarly a successful intervention in London resulted in more walking and less bus congestion, but the basis of success was unlikely to extend to other schools.
- Trigger Points – It has been noted in the literature that the optimum point to achieve modal shift is during significant moments in people's lives; such as moving home, starting a new job or having a child.
- Workplace Nudge: Education and Parking – The evidence suggests that education on the advantages of cycling was insufficient to change workplace commutes. However, lack of parking appeared to be enough to shift commutes to public transport or active travel.
- Financial Incentives – Evidence here echoes previous evidence suggesting that cycling facilities are a necessary but not sufficient condition for modal shift. However, financial incentives such as £2 per day were found to be sufficiently attractive to encourage modal shift.
- Cycling Cities and Towns Evidence – Evidence from a large cycling scheme in England noted that cycling events and adult cycle training did encourage some new cyclists, while children's cycle training did not overcome some parent's fears of children cycling on their own. Additionally maps detailing off-track cycle ways were difficult to read due to the scale and had low awareness.
- Department for Health Evidence Review – An evidence review for the DfH noted that personalised travel plans as well as walking incentivised by the health sector were seen as successful in achieving more active travel. Additionally workplace competitions and travel plans were seen to achieve some modal shift, with the inter workplace competitions seeing significant increases in cycling amongst participants.

School behaviour

Jones, et al. (2019) reviewed a raft of school behaviour changes and found that walking school buses (WSB) and educational strategies are the most effective for increasing relevant outcomes, although overall the study quality was weak. Nikitas, et al. (2019) ran a qualitative survey of parents about their opinions on WSB. The arrived consensus was that morning walks could work but afternoon walks were less likely due to the risk of no one being home. Additionally it would only be expected to operate once or a few times a week, in order to prevent the loss of 'special time' and due to low levels of volunteering. They did note that some parents who currently drive would be interested in the WSB suggesting it could achieve modal shift: however, the research was purely focussed on ascertaining parents' views on WSB as opposed to measuring impact. As such it appears that walking school buses have some scope for success, but it would largely be school specific and take into consideration local circumstances with distance, family circumstances and after school activities.

Gyergyay (2013) investigated the effect of an intervention to increase walking to school, with tap in points along the walk giving students periodic rewards if they consistently tapped in on their walk to school. The intervention was focussed on a congested peak time bus route, where the walk (16 mins.) was faster than the bus journey (21 mins.). After the intervention the number of people who could not board the bus due to congestion was down 50%, along with a 48% reduction in the time spent by Transport police dealing with the overcrowding. The shift to walking continued after the intervention had ended with significant increases in positive perceptions of walking. This further reinforces that walking to school interventions are school specific, but it does suggest that some behavioural interventions can have significant long term effects.

Further, Villa-Gonzales, et al. (2018) point out that the current literature surrounding active travel to schools is of poor quality, and while many of the studies have small effects these cannot be generalised to the school system at large. This highlights that the evidence in school behaviour change is mixed and not necessarily scalable.

Trigger points

Several papers identified optimal groups or times to intervene with behaviour change projects (Forsyth & Krizek, 2009; Cycling Embassy, 2012; Audrey, et al., 2019). They noted that people were more or less responsive to the idea of active travel depending on their current life stage and recent life events. For example, represented amongst the groups who experienced a significant change in circumstances include: new entrants to the workplace; people changing the nature or

location of their work; parents of young children, especially mothers; people recovering from ill health; and people with increased leisure time (e.g. following retirement).

This suggests that behavioural interventions should be designed to coincide with events or changes that have a significant impact on people's lives in order to have the greatest effect. This could include but is not limited to where usual travel routes are known to be disrupted such as major road works; development of new industrial/housing estates; social prescribing due to health conditions; and commencement of new employment or new term of academic learning, etc.

Workplace nudge: education and parking

Audrey, et al. (2019) found through an intensive study that simply providing education on cycling at work was insufficient to achieve any statistically significant change in active travel. However, they did find that walking and public transport use were both positively associated with a lack of free car parking at work. Previous qualitative research has suggested that, where removing parking might be perceived as punitive, employers would prefer this to be imposed from outside the workplace. This might, for example, be a directive from a more distant 'head office' or because of policies imposed by the local or national government.

Financial incentives

Wardman, et al. (2007) look at revealed and stated preference research for commuting by cycling, with their main conclusion being that cycling will not happen without intervention largely as a result of increases in car availability. They found that cycle facilities are necessary but insufficient to achieve modal shift, and that other incentives such as financial are key to making the change. "When a package of measures is considered, including modest financial incentives (£2 per day), cycle facilities for around half the journey to work and good parking and shower facilities at work, cycling emerges as a much more significant mode and has an appreciable impact on car share." While direct financial incentives are less likely to become the norm, the research does indicate that there has to be more intervention rather than simply providing the facilities. This could be in the form of incentives for cycling or penalising motorists.

Cycling Cities and Towns evidence (CCT)

Cycling Embassy (2012) carried out research with regular and new cyclists to gauge reaction to interventions introduced through the Cycling Cities and Towns programme. The table below lays out the reaction to soft interventions, noting that

cycling events were seen to encourage some first time cyclists, as was cycling training for adults. Cycling training for children was noted to have high awareness with parents but some parents still did not want to let their children cycle unaccompanied. Lastly, maps, which were considered a good idea in practice, had low awareness and issues with reading the scale.

Cycling Events

In most CCTs, participants were aware of different cycling events, varying from professional races to fun days. The most common event mentioned across all CCTs was the Tour of Britain series, which since 2008 has passed through Blackpool Colchester, Stoke and York. This event has had an impact on participants' awareness of cycling.

In the last few years, a few Non Regular Cyclists had taken part in a cycling event as either a cyclist or spectator for the first time and this had encouraged them to cycle more. In some CCTs, cycling events (such as Blackpool's Ride the Lights) were seen as having wider economic benefits as the events attract visitors/tourists to the town/city.

Cycling Training (Adults)

Across all CCTs, few participants were aware of adult cycle training programmes or activities as most participants could already ride a bicycle. A small number of participants had taken part in cycle training with one participant in Leighton-Linslade stating that it had enabled her to return to cycling.

Despite awareness of cycle training being low, some participants had concerns about their cycling ability and how this limited the amount or type of cycling they do, particularly women and less confident cyclists.

Cycling Training (Children)

Cycle training for children was recalled by nearly all participants with children.

However, despite their children undertaking Bikeability, a few parents were still reluctant to let their children cycle unaccompanied due to road and personal safety concerns.

Parents often could not distinguish between Bikeability (cycle training) and Bike It (cycle breakfasts, events, etc.) but there were indications that Bike It had taken place in children's schools.

Maps

Only a small number of participants reported receiving a map through the post. The maps themselves received mixed views.

Despite few being aware of where to obtain maps, all participants thought that cycle maps were a good idea, particularly for off-road cycle paths/greenways and continuous on-road cycle lanes to key destinations.

Of those that had looked at a map, several participants found the maps difficult to read and the routes hard to follow and this was mainly due to scale issues (for example, difficulty in ascertaining the actual route on a map).

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Department for Health evidence review

Analysis by the Department for Health (2011) reviewed the success of a raft of behavioural interventions aimed at increasing rates of walking and cycling. It noted that personalised travel plans were successful in achieving modal shift, especially when targeting people in transitional points. Walking incentivised by social prescribing was also seen as successful in achieving some increased walking, first for leisure and then for errands. Active travel to school had achieved successes too, although starting from a low baseline. Additionally workplace competitions and travel plans were seen to achieve some modal shift, with the inter workplace competitions seeing significant increases in cycling amongst participants.

Personalised Travel Plans (PTP)

Between 2 and 7 percentage point reductions in car miles are secured in most schemes. Personal Travel Planning works best when targeted at people who are in a transitional point in their lives, such as going to university, moving house or changing job. Greater value is obtained when PTP schemes are delivered at the same time as infrastructure improvements.

Adult Cycle Training

60% of people who train increase their cycling a 'lot' after their training. The main journey purposes being commuting and leisure. Early pilots in Bristol suggested that approximately 25% of people reduced their car use to 'some extent'. 81% of people attending cycle maintenance courses also cycle more.

Walking for Health – Health service walks targeted at poor health areas

Participants were asked, after 12 months, what types of walks they did more of since they joined. 17% of people said they did more everyday walking around their own neighbourhood and 9% walked more for shopping purposes.

Walks Information Packs – Mailed information packs of walking routes

41% of people said they did more everyday walking in their local neighbourhood as a result of using the walking packs.

This low cost intervention, which was designed for relatively inactive people, showed that once people gained the confidence of leisure walking they begin to habitually walk more for other purposes.

Active Travel to School

A 3 percentage point increase in the number of young people walking to school across the South West was achieved in the 2 years between 2007/08 and 2009/10.

'Bike It' – Sustrans working with schools to increase cycling

The 2009/10 'Bike It' programme achieved a more than doubling of the proportion of young people cycling every day from 3.7% to 8.7% of those surveyed. There was also a near doubling of the proportion of young people cycling to school once or twice a week from 10.6% to 18.2%.

Low levels of cycling offer the potential for large increases in cycling given the right culture and environmental conditions. While some new cyclists will have previously walked there is still a significant shift from car to bike.

Step-o-meters – Loaned by health officials to inactive patients

71% of users who were loaned a step-o-meter said they walked more after 6 weeks.

Walking to Work – Organised at workplaces

25% of the initial target group, who were contemplating or preparing to actively commute at baseline, were regularly walking to work one year later. People who changed their behaviour reported a variety of methods of creating active journeys including: adding walking to bus journeys by getting off the bus early; declining a regular lift in others people's cars; using public transport more and parking further away from normal destinations.

Workplace Challenges – Competition between workplaces to increase cycling to a set level for 2-3 weeks

Non cyclists take up cycling: 34% of 'non cyclists' were cycling once a week or more, 3 months after the Challenge. Occasional cyclists start to cycle regularly: 31% of 'occasional cyclists' were cycling regularly 3 months after the Challenge. More people cycling for transport purposes: 28% of 'occasional cyclists' were cycling to work at least once a week, 3 months after the Challenge,

Workplace Travel: Single Businesses – Workplace travel plans

Employers nearly doubled the proportion of staff commuting by bus, train, cycling and walking. There was also a reduction in the number of commuter cars by 14%, amounting to a reduction in commuter car journeys by 18%.

Very low cost for employers. Incentives for employers include reduced parking costs, as a contribution to 'Corporate Social Responsibility' or by securing planning permission for new developments with travel planning being a condition of the permission.

Workplace Travel: Multi-Business Sites – Workplace travel plans

Area Travel Plans can reduce the number of peak period cars on the Strategic Road Network by 50-150 vehicles. Multi-company schemes should be a good way of engaging with smaller employers who do not have the skills or resources to implement a scheme on their own.

‘Signs Only’ 20 mph Speed Limits

Average speed reduction of 1mph, but where average ‘before’ speed was greater than 24 mph then average speed reduced by 7mph. Evidence from early adopter local authorities shows these 20mph limits are popular, with demand from residents exceeding the scale of proposals.

Conclusion

Some populations represent low hanging fruit in terms of responding to education or infrastructure interventions. Those who have recently moved in particular appear to be more open to travel change, although recruiting these people has proven to be difficult (Forsyth & Krizek, 2009). This suggests that behavioural interventions may be best planned to coincide with events or changes that have a significant impact on people’s lives in order to have the greatest effect.

Most of the soft measures detailed provide boosts to walking or cycling in specific cases. However, the literature does not recommend a specific mix of soft projects, rather saying that a comprehensive measure is needed, which is left to local officials to decide what it includes (Pucher, et al., 2010).

Gaps in the evidence base

There is little literature that looks at how cycling infrastructure and schemes affect people with disabilities, with the exception of some looking at the negative effect of shared spaces. For example, Clayton (2016) calls for more research on how much of an obstacle cycling infrastructure is to people with disabilities (e.g. bollards) and if there is an optimal way to mitigate this. Additionally, no literature was found on how the loss of parking from cycling infrastructure, narrow paths and/or mixed space around bus stops affects those with disabilities.

The Department for Transport (2016) also points out that that there appears to be a relative shortfall in evidence about how different groups in society – e.g. by demographic or health status– respond to different interventions. Evidence of change tends to be based on an aggregate level rather than differentiating for subgroups.

While the literature does point out what good investments decisions are, such as a mix of revenue/capital and segregated cycle paths where possible, it does not answer what the optimal mix of investments are. Both the Department for Transport (2016) and Pucher, et al. (2010) acknowledge that there is a gap in knowledge as to

what mix of infrastructure is optimal, and suggest that in actual fact the optimal mix might vary between different circumstances. As such tailoring the interventions to local circumstances rather than trying to achieve a certain mix would be the most beneficial approach.

The expected effects of the policy interventions are also not fully known given their success depends on local circumstances. Hence, it is difficult to scale these effects to a national level which is why little evidence exists.

The National Institute for Health and Care Excellence (NICE, 2012) compiled their own list of gaps in the literature which are still relevant today.

- Lack of evidence on whether or not interventions to increase walking or cycling for transport or leisure result in a decrease or increase in participation in other types of physical activity.
- Lack of evidence on whether people who cycle or walk for recreational purposes, eventually adopt it as a form of transport.
- Lack of UK evidence on whether differences in urban and rural settings and environments impact on the implementation and effectiveness of interventions to increase walking or cycling.
- Lack of evidence on the barriers to, and facilitators for, inter-sector and inter-agency collaboration to promote walking and cycling. Barriers may include the working cultures of different professionals.
- Lack of UK evidence on the extent to which the provision of a free bus service impacts on walking levels.
- Lack of UK evidence on the impact that an individual's perception of distance has on their view of how viable cycling or walking is as a mode of transport. There is also a lack of evidence on what interventions can effectively change someone's perception of distance as a barrier to walking and cycling.

What doesn’t work?

The Department for Transport’s (2016) rapid evidence review on walking and cycling found that only a handful of interventions were identified as being ineffective. These interventions either lacked a clear focus on the target behaviour of walking or cycling; or were too elaborate and costly for the target audience. Interestingly, mandatory helmet laws were reported in one study as having reduced cycling.

Off-road cycle paths

The National Cycle Network alone was found to be insufficient in encouraging modal shift, with women in particular expressing concern about security and isolation

(Jones, 2012). Survey data suggested that other cyclists value the additional route option from local traffic free paths, but that they were keen to see supportive on-highway measures along the existing road network that connects them more directly with their everyday activity. As directness has been shown to be a strong factor in cycling, traffic free cycle paths which take longer deviations are often less attractive. Cycling Embassy (2012) also noted that there is often poor awareness of off-road cycle paths as they cannot be seen from the road, likely due to the fact people plan their travel based on current road networks. This suggests that due to the low awareness of them and them being less attractive to cyclists than direct routes, off-road cycle paths can be less effective in achieving modal shift than alternate cycling infrastructure.

Shared space effect on people with visual impairments

Bryan, et al. (2015) finds that there are issues related to shared spaces for people with visual impairments, with 81% of visually impaired respondents to a survey reporting that their independent mobility would be negatively affected by the introduction of shared surfaces. Thomas (2008) confirms this with a before and after survey of shared space that found that blind and partially sighted people had their confidence detrimentally affected and most reported they would no longer be able to use the area independently.

Bryan, et al. (2015) noted that the primary concerns of people with visual impairments were:

An over-focus by shared space designers on the reduction of traffic speeds, with less attention to vehicle flow. Visually impaired stakeholders discussed the difficulties that remain with high traffic flows, even if they are travelling at lower speeds;

- The extension of the shared space concept beyond implementation in low flow residential areas, to its use in busy urban areas and shopping streets;
- The misinterpretation by designers that the implementation of a shared space requires a shared surface. In particular the removal of kerbs results in the absence of a well-established and crucial means for people with visual impairments to orient themselves and navigate, in addition to aiding in the identification of a crossing point (e.g. a dropped kerb);
- The over-reliance on eye contact to manage pedestrian-vehicle interactions in shared space;
- The misunderstanding of the capabilities of the visually impaired pedestrian within shared spaces. For example, stakeholders mentioned apparent assumptions that all visually impaired pedestrians had sufficient residual sight

to identify that they were in a shared space area, can navigate without kerb delineation of the roadway, and are able to detect vehicle presence, vehicle movement, and their desired crossing start and end points;

- The provision of informal crossings or absence of any crossing facility in shared space. A number of visually impaired stakeholders and their advocates felt that informal crossings were a good idea, yet expressed concern that in some cases they were being applied in areas were the vehicle flow was too high for them to function effectively. Furthermore, anecdotal evidence suggested that the recommended design principles for informal crossings are not being applied consistently. The absence of beige or buff-coloured tactile paving for the assistance of blind and partially sighted pedestrians was mentioned as a particular concern, as it could prevent visually impaired individuals from identifying where these crossing points are. Two visually impaired stakeholders argued that informal crossings were insufficient for their needs and that controlled pedestrian crossings should be available for use in shared space, preferably with audible and tactile signals.

This suggests that while shared space might have benefits for the population at large, it can negatively affect people with visual impairments. As such care has to be taken when implementing shared space so as to not negatively affect people with visual impairments.

Barriers to cycling investment

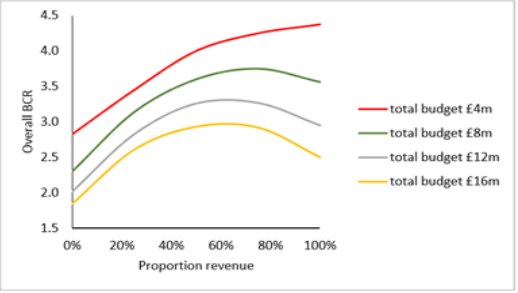
Aldred, et al. (2019) surveyed a wide range of stakeholders involved with cycling investment to identify the key barriers to cycling investment in England. The top three concerns were: financial/funding barriers, lack of political leadership, and public opposition. They argue that the stop start funding model, the lack of ring-fenced funding for long term projects, and the small transport planning teams that local authorities have in place make it very difficult to ensure a good programme is delivered. They also note that political and public considerations are major stumbling blocks, with councillors often unwilling to spend their political capital on low priority projects. Additionally the general public's attitude to cars must be overcome to ensure a scheme's success, with such problems as "[a]nti-social parking and the widespread unwillingness to tackle it" being key issues from the public sphere. This is in line with the advice given by expert interviewees found in Slowman, et al.'s paper (2014) referenced earlier.

What are successful projects?

Revenue to capital ratios

Slowman, et al. (2014) investigated what the recipe for success was for sustainable travel, especially with respect to the share of revenue and capital spend. They found that the optimal spend on revenue was variable, depending on the size of the project and stage, but a general 40:60 revenue:capital ratio being a good rule of thumb. As shown in Figure 2, revenue is expected to be curved over the period of the project; for example, early high revenue spend to build culture, low revenue spend in the mid-point during the capital build and a high revenue spend at the end to increase uptake of infrastructure. There is also the expectation that government grants may be more revenue heavy as the Local Authority would front more of the capital costs but the overall project spend would still resemble the 40:60 revenue: capital rule of thumb. Figure 2 shows the optimal benefit to cost ratio modelled from hypothetical data using real world examples.

Figure 2 – Benefit to cost ratio by revenue to capital ratios



Source: (Slowman, et al., 2014)

Transport for London (TfL) international comparison

In 2014, TfL commissioned an international comparison of cycling infrastructure best practice. Much of the differences between the UK and international practice relate to the treatment of cyclists at junctions and crossings. In many jurisdictions, their legislation allows turning on the nearside on a red light as well as cyclists and pedestrians crossing together at informal crossings. It is argued these policies reduce the delays in cycling which is one of the significant factors in cycling uptake. While in the US all vehicles can turn right on a red light (barring NYC), in certain areas in France they have instead opted to give this exemption to only cyclists. Other

legislative differences include creating 'home-zone' areas where cyclists have the priority in traffic over motor vehicles, or allowing cyclists to travel against the traffic flow in a one way street.

TfL's research looks at a range of options and considers if they would be legally permissible in the UK and if they would be worth implementing. It also notes important differences between UK cycle infrastructure and the infrastructure of successful cycling cities, which they attribute to being caused by not taking cycle traffic seriously. These include:

- Part-time cycle lanes, where vehicles can use or park on the lane at certain times of the day, were found very rarely.
- Cyclists Dismount signs only found in the UK.
- Token cycle lanes which were too narrow were only found in the UK.
- They did not find cyclists having to give way to motor traffic at side street crossings or car park accesses etc. in international cities.
- They did not find any arbitrary or abrupt ends to cycle lanes/tracks.
- They did not observe any cycle lanes/tracks ending with a hazardous merge into busy general carriageways.

Smarter Choices Smarter Places – Scotland

In Scotland a sustainable travel pilot programme, Smarter Choices Smarter Places, showed promising results (Transport Scotland, 2013). The programme was estimated to have cost £15 million in total and saved residents £9 million a year in travel savings, between £10.6-£46 million in health savings depending on the model and £0.9 million worth of emissions reduced over the course of the programme from 2009-2013. Table 1 shows the changes in the Smarter Choices Smarter Places (SCSP) areas with most of the benefits coming from increased walking and reduced car driving

Table 1: Percentage point change in trip mode shares

SCSP	Walking	Cycling	Bus	Car driver	Car passenger	Train	Taxi
Barrhead	+14.8	+0.3	-0.6	-18.9	+1.6	+0.2	+2.8
Dumfries	+7.6	+0.7	-0.9	-7.4-	-1.3	+0.2	+0.8
Dundee	+2.4	+0.8	-4.3	-1.9	+2.7	+0.3	-0.1
Glasgow East End	+5.1	-0.4	-6.5	-1.6	+3.5	-1.1	+0.5
Kirkintilloch/ Lenzie	+5.1	-0.3	+7.4	-11.4	+1.3	-1.0	_1.4

Kirkwall	+0.3	-0.5	-0.1	-3.1	+3.0	0.0	-0.1
Larbert/Stenhousemuir	+21.4	+0.4	+0.8	-19.4	-5.0	-0.1	+2.3

Notes shading shows observed change is statistically significant

The darker the hue the more supporting evidence there is for the direction of change Source: (Transport Scotland, 2013)

Recommendations from the Sustainable Travel Towns

In England, a similar programme was undertaken through the Sustainable Travel Towns (Urban Transport, 2011). The Sustainable Travel Towns succeeded in increasing walking and cycling with a reduction in car driving. Darlington was also a Cycling Demonstration Town which resulted in higher cycling uptake than the average. There were also several recommendations that came from the Sustainable Travel Towns programme (Sloman, et al., 2010):

Interventions targeted at specific modes are most effective when accompanied by improvements in quality. This was evidenced by the failure of personal travel planning and other promotional work to reverse the decline in bus use in Darlington in the absence of service improvements.

Delivery of effective Smarter Choice Programmes is staff-intensive. The teams delivering the programmes in the three towns were between six and 10 full-time equivalent staff, and all the towns acknowledged that these were not upper limits and they could readily have made use of greater capacity. It took time to recruit an effective team and bring new recruits ‘up to speed’ (with recruitment of a full team typically taking between six months and a year). This pointed to the importance of planning for a long-term programme (i.e. at least the length of the programmes in the three towns), rather than expecting to achieve results within a couple of years.

This is echoed by an investigation of success in the Netherlands by Harms, et al. (2015). They found that improving the organization and implementation of cycling policies seems to positively impact the effectiveness of cycling policy. Specifically, formulating and implementing interventions that can be measured and monitored; having a high degree of adaptability of policy, allowing opportunities for experimental measures; and having high levels of citizen participation and the presence of strong leaders (like mayors or other public figures). This suggests that an established team

with local knowledge and connection would likely be more successful than a prescribed intervention.

Case study: Seville

Seville achieved significant success in increasing modal share between 2004-2011, spending €32 million to build 120km of continuous segregated cycling network. The network was built on the premise of being accessible to everyone and visible to all from the road, with its quick building (the first 77km built over 2 years in 2006) being considered part of the success as the cycle routes were not taken over by mopeds or pedestrians instead. The resulting modal shift was around 9% of the all journeys being made by bike in 2011, up 5% in 2007 and negligible figures pre-program (Marqués, et al., 2015).

Cycling Demonstration Towns (CDT), Cycling Cities and Towns (CCT)

In tandem with the Sustainable Travel Town Programme the CDT programme was developed which was subsequently expanded to the CCT programme (Sustrans, 2017). The average result by 2011 was 24%-29% increase in cycling in the towns as counted by automatic cycle counters. Figures 3-4 and Table 2 show the changes in the target areas.

“The results vary across the towns. The analysis has not identified a clear pattern of which factors determine the extent of impact, but obvious factors that differed between the towns included the nature and extent of delivery (including the capital and revenue split), the target groups, the profile and extent of support for the initiatives that were introduced, changes in political support at different stages of the programme, baseline levels of cycling and baseline levels of car dependence, amongst other factors. The varied degrees of success are not necessarily surprising, as we know that travel behaviour is complex and difficult to influence, and that cycling is strongly influenced by contextual issues.” (Sustrans, 2017)

Figure 3 – Change in counts recorded by automatic cycle counters in six Cycling Demonstration Towns

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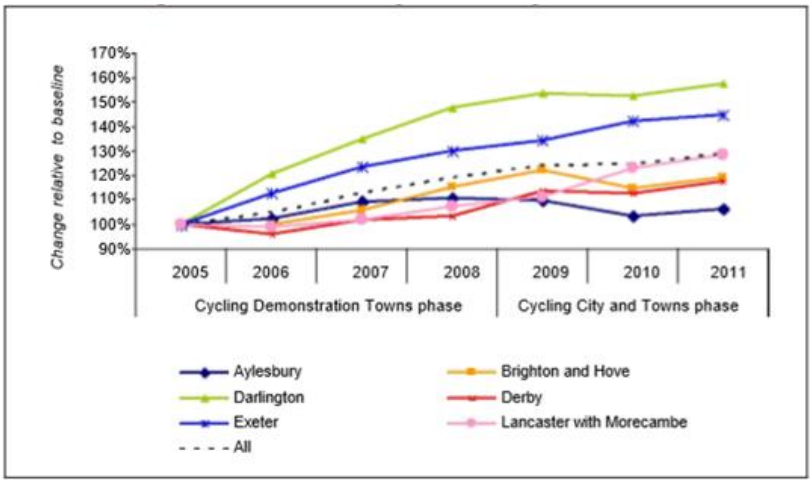

Showing change relative to base line for cycling demonstration towns phase an cycling city and towns phase in Aylesbury, Darlington, Exeter, Brighton and Hove, Derby and Lancaster with Morcambe Source: (Sustrans, 2017)

Figure 4 – Change in counts recorded by automatic cycle counters in 12 Cycling Cities and Towns

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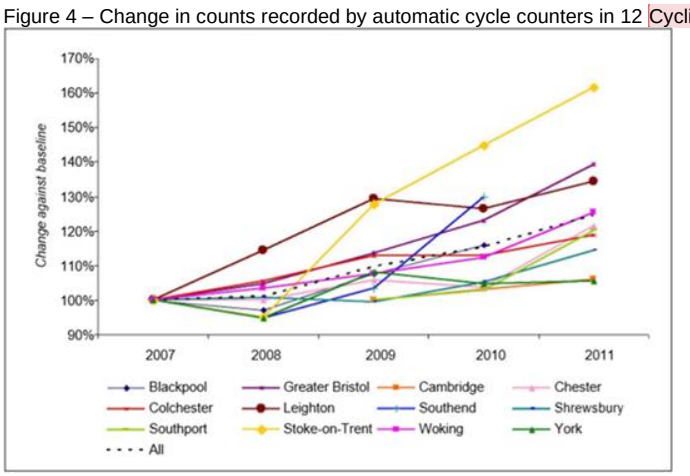

Showing change against base line in 2007, 2008, 2009, 2010 and 2011 in Blackpool, Colchester, Southport, Greater Bristol, Leighton, Stoke-on-Trent, Cambridge, Southend, Woking, Chester, Shrewsbury and York Source: (Sustrans, 2017)

Table 2 – Total change in counts recorded by automatic cycle counters in six Cycling Demonstrations Towns and 12 Cycling Cities and Towns

CDTs/CCTs	Count in final year compared to baseline*	Absolute change in average daily count per counter between baseline and final year*	Number of automatic counters showing an increase in cycling

All CDTs~	**-**	**129%**	**81 (of 118)**
Aylesbury	106%	+4 (68 to 72)	9 (of 19)
Brighton and Hove	119%	+97 (503 to 600)	7 (of 13)
Darlington	159%	+29 (50 to 79)	12 (of 19)
Derby	117%	15 (85 to 100)	+ 10 (of 15)
Exeter	145%	+44 (99 to 143)	21 (of 26)
Lancaster w Morecambe	129%	49 (170 to 220)	+22 (of 26)
All CCTs~	**124%**	**-**	**137 (of 193)**
Blackpool	109%	+7 (87 to 95)	4 (of 9)
Cambridge	109%	+44 (495 to 540)	9 (of 17)
Chester	121%	+34 (163 to 197)	6 (of 10)
Colchester	119%	+21 (111 to 132)	9 (of 14)
Greater Bristol	140%	+104 (260 to 364)	29 (of 31)
Leighton	135%	14 (40 to 55)	+ 5 (of 13)
Shrewsbury	115%	+17 (118 to 135)	16 (of 21)
Southend	117%	+32 (185 to 217)	4 (of 7)
Southport	130%	15 (50 to 65)	+10 (of 10)
Stoke-on-Trent	162%	+19 (31 to 51)	13 (of 17)
Woking	126%	+26 (99 to 125)	8 (of 10)
York	106%	13 (209 to 222)	+24 (of 34)

Baseline=2005 for all CDTs except Brighton and Hove, for which it is 2006; baseline=2007 for all CCTs except Cambridge and Southport, for which it is 2009. 'Final year'=2011 for all CDTs, and for all CCTs except Blackpool and Southend, for which it is 2010. For 'count in final year compared to baseline', baseline=100%. Change figures reported are from the analysis without the use of a factor for poor weather conditions (see full monitoring report for figures illustrating adjusted data).

~ Percentage changes for 'all CDTs' and 'all CCTs' are the unweighted mean of the percentage change values for each town

Source : (Sustrans, 2017)

What is the best comparison for Scottish cities?

Matching Scotland's environment

Few cities and countries that have advocated increased active travel match Scotland's natural environmental factors. While some match certain environmental factors in topography, rainfall and wind, few match all simultaneously. Further there are demographic and density issues beyond this which complicate any comparison further. Rather it would likely be best to consider a range of cities, each with some similar factors that Scotland has in environment and observe how they have managed a modal share.

This is important as Böcker & Dijst (2013) find that more rain reduces the level of cycling, although the reduction is not linear and affects recreational cycling more than commuting. They also find that wind affects cycling but from evidence in the Netherlands, only persistent heavy wind has any significant effect on modal share, again suggesting the effect of wind is not linear.

Harms, et al. (2015) and Knuiman et al. (2014) also note that external 'context' circumstances seem to impact the effectiveness of active travel significantly, especially demographic changes such as increases in total population, number of households, proportion of one-person households and students. Although this would likely have to be taken into account for a city by city basis in Scotland.

Topography

In terms of topography, two good examples of cycling success are Vancouver and Portland. Both have worked on building a comprehensive network and expanding it, with cycling in Vancouver increasing from 4%-10% between 2011-2015 (Mclaughlin, 2017) and cycling in Portland increasing from 1.8%-7% between 2000-2015 (Portland, 2017). However, both of these cities have more sunny days during the year and less wind than Glasgow or Edinburgh. Despite this, little has had to be done in these two cities to overcome their issue of topography, although it has likely muted the size of modal shift possible.

Weather

Norway has a similar topography and a closer number of rain days to Scotland, but most of its cities have much less wind than Scotland with the exception of Stavanger. Cycling modal share in Norway is already above Scotland's at 4%, with the case study cities sitting between 3-9% and Stavanger sitting at 7% (Lunke, et al., 2018). Of particular interest is the seasonal modal share, with all seasons bar winter sitting equal or higher than the average modal share for each city (see Table 3). Although it should be noted that walking share is closer to Scotland's at 22% of all journeys in 2013/14.

Table 3: Cycling share by season in 2013/14. Percentage. NTS 2013/14

Study cities	Winter	Spring	Summer	Autumn
Oslo	2	7	10	11
Trondheim	7	11	12	11
Bergen	2	5	4	3
Stavanger	6	9	8	10

Source: (Lunke, et al., 2018)

Whilst Stavanger is probably the best cycling comparison city, it is more likely a range of the cities above would be useful to pick out best practice in overcoming shared problems. Interestingly the fall in winter cycling might be more pronounced in Norway due to their colder winters, thus suggesting a possible advantage in Scotland over these comparison cities.

What is the recommended path to success?

Road to success

Long term projects are considered the most successful, with a recommended minimum of five years, but an optimal time frame placed at 10 years. Stop-start funding was noted as being ineffective in achieving modal share both because of the incomplete infrastructure and because of the short term funding resulting in some longer term revenue projects not being pursued.

Dedicated teams for a project are considered best practice. Evidence from the Sustainable Travel Towns suggests that teams can take six months to a year to recruit and train in advance of a project, further reinforcing the need for a long term

project. These teams are best placed to understand the particular local challenges and come up with more appropriate local solutions and intervention packages.

Focussing on areas that have strong citizen participation and local authority support, along with well-prepared policies, appears to be the most successful. This indicates that project funding should go to areas where there is a desire to see long term difference and would support a well-planned project, further reinforcing the need for longer term projects.

Revenue spend is most successful when coupled with improvements in quality, although this could include newly created facilities rather than simply improving on what is available. This is particularly apparent in Doncaster where failure to improve the bus service due to the issues surrounding its two providers severely hampered the drive for sustainable travel compared to other peer cities. It is also noted that when there is insufficient budget to create a comprehensive network, revenue spending is a good policy to create a culture and attitude ready for cycling when the funding is available.

Making motor transport less attractive is needed for modal shift. A major point in the literature is that while quality improvements and infrastructure are necessary conditions for modal shift, they are not sufficient to induce the modal shift due to the availability of cars. Instead that has to come from other sources with one particularly noted area being the attractiveness of cars. If motor transport is less attractive, modal shift happens. This can be achieved by increasing parking tariffs, reducing availability of free workplace parking, and extending the area of paid on-street parking, thereby reducing the availability of parking but not alleviating congestion.

Value of time is an important consideration, with evidence showing that active travel and bus travel needs to be sufficiently fast compared to private motorised vehicles to encourage modal shift.

Ensuring that cycle lanes have the minimal interruptions makes cycling more attractive, with less stops shown to lead to a higher cycling share. This in combination with improving the perception of cycling both in terms of quality and safety (regardless of the validity of that perception) helps increase modal share.

Successful active travel policy is heavily dependent on external factors such as demographics, land use mix, population density and topography amongst other things. This suggests that there is a justification for different intervention mixes in different cities to overcome these factors.

The range of potential policy packages is very broad, but a typical package could include: the creation of local bicycle statistics/metrics; marketing to improve co-existence of pedestrians and cyclists; route promotion marketing; innovative parking

solutions; healthy cycling and walking campaigns; cycle website improvements; and safety strategy improvement. The literature also recommends supportive land use planning as well as restrictions on car use.

Spending

Several papers outline the general spend in towns required to achieve cycling uptake. The Sustainable Travel Towns project had an average spend of £19-£29 per head of population per year over a five year period (Urban Transport, 2011), although these funds also include walking and bus spend. A similar project in Scotland (Transport Scotland, 2013) spent between £5-£18 per person per year over three years which included walking and bus spending. The Cycling Demonstration Towns (DfT, 2009) spent around £10 per person per year for the first five years, where other English local authorities were spending roughly £1 per head. The follow up to Cycling Demonstration Towns including the Cycling Cities and Towns Programmes (Sustrans, 2017), was found to cost on average £14 per head of population per year for the five years prior to the report.

Finally, Sustrans estimates that to achieve a doubling of cycling journeys in England there would have to be a spend of roughly £17 per person per year over a 10 year period (Sustrans, 2016). The evidence of cases suggest that a spend per person in the treatment areas ranging between £10-£30 per annum over a decent period of time, between 5-10 years, would be reasonable and in keeping with past successful projects. However, due to the nature of the data it would be unwise to extrapolate a certain spend with a certain effect.

Conclusion

The evidence indicates that high quality, joined-up infrastructure and behavioural interventions at trigger points in people's lives are the most effective measures to encourage an uptake in active travel. However, the quantitative effect of these interventions is much less clear, in part due to the effect of external factors such as local weather, topography and population density. It is often noted in the literature that infrastructure is a necessary but insufficient condition on its own for a modal shift to active travel. Other factors such as the attractiveness of motor transport, environmental factors, and linked behavioural interventions all play an important part in the success of a project. In particular with walking, mixed land use and density play a more important role in determining modal share.

One of the most prevalent issues in encouraging active travel is journey time compared to motor transport. Individuals are more likely to switch to active travel

modes, including mixed modes with public transport, when their journey time is reduced compared to making the trip using private motorised vehicles.

There are some interventions that are known to not be as successful or need to be carefully thought out when being implemented. Off-road cycle paths being one area that does not appear to bring an improvement in cycling modal share, and is noted as not being attractive to female cyclists. Additionally, shared spaces can have benefits for pedestrians but with poor implementation they can adversely impact others e.g. those with visual impairments.

There are substantial gaps in the literature, notably on the effect of cycling infrastructure on people with disabilities. In additional, there is a lack of evidence on the optimal mix of infrastructure and behavioural interventions, with some of this likely due to highly context-dependent nature of successful interventions.

Given the lack of quantifiable data, the responses by expert interviewees in the literature provide some of the best notes on ways to improve an intervention's chance of success. They note that the most successful projects are those with a minimum term of five years, with stop-start funding being associated with poor results. They also note that while the size of the revenue spend is not as important, it is imperative that all capital projects come with at least some revenue spend. Finally they note that cycle infrastructure should be built as a comprehensive and continuous network and not as discrete and disconnected routes. If it is not possible to build a comprehensive network it would be better to invest the money in revenue spend to create a groundswell of support for cycling so that when the infrastructure is finally built the uptake will be a lot quicker.

Economic, health and environmental benefits of active travel

This section builds upon the review of best practice in active travel interventions by exploring the evidence on the economic, health and environmental impact of active travel. It focuses on evidence of outcomes of active travel itself rather than research attributing benefits to urban design and active travel infrastructure (such as pedestrianised spaces or bicycle lanes). While the search was conducted for all active travel modes, there is clear focus in the literature on cycling over walking, the exception being health-related studies which tended to cover both.

On an individual level, it is clear that active travel can result in substantial benefits, primarily related to improved health and wellbeing. On a societal level however, there is a consensus that unless a modal shift to active travel can be achieved, the benefits to society are not as consequential as those to the individual. Finally,

despite the clear benefits of active travel, “the literature is less forth-coming about the ways in which these may be realistically captured [as] the nuanced impacts […] are difficult to harness into substantiated and replicable metrics” (Rajé & Saffrey, 2015, p. 5).

Economic benefits

Reduced absenteeism

There is evidence that individuals engaging in physical activity through active travel or other forms of exercise, take fewer days of sickness absence than their non-active counterparts (Rissel, et al., 2012; Flint, et al., 2014; Petrunoff, et al., 2016). Research found that cyclist commuters take an average of between one and three days less all-cause sickness absence than their non-active commuter colleagues (Davis & Jones, 2007; Hendriksen, et al., 2010; Davis, 2014; Department for Transport, 2016; TRL, 2018). The effect is subject to a dose-response relationship, such that the more individual’s cycle, the less days they take in sickness absence (Hendriksen, et al., 2010). Importantly, the evidence indicates that significant differences in absenteeism between non- and active commuters are only apparent in the long term, possibly requiring at least a year of sustained exercise levels, prior to which any difference is not statistically significant (Davis & Jones, 2007).

At a societal level, reduced absenteeism would result in savings for employers, both through reduced sickness pay and increased levels of productivity. There may also be health co-benefits through associated health-care savings.

Market share

Translating active travel modes into a value of the cycling or walking industries is complicated due to the absence of robust quantitative data on retail sales and employment (Grous, 2011; Confederation of the European Bicycle Industry, 2017; Transform Scotland, 2018). The value of walking appears to be absent from the literature but attempts have been made to estimate the value of the bicycle industry drawing on available sources of information. These include HMRC’s import statistics which are limited to units and their monetary value (Confederation of the European Bicycle Industry, 2017), consultations with industry representatives (Grous, 2011), or data available on the EU bicycle market from which the UK’s share (and sometimes subsequently Scotland’s) is extrapolated (Transform Scotland, 2018).

The UK manufactures about 80,000 bicycles per annum (Brompton and Pashley holding the largest shares) with the majority of the merchandise sold principally imported from Asia (Confederation of the European Bicycle Industry, 2017). Grous

(2011) estimates a £2.9 billion gross cycling contribution (£230 per cyclist) to the UK economy in 2010 through the combination of bicycle and accessory sales and cycling employment. This is the most frequently cited monetary estimation in the literature, however Küster & Blondel (2013) point out that COLIBI/COLIPED data contradicts the average bicycle cost used in the Grous report (€280 instead of the €505 used in the analysis) which more than halves the estimated turnover. This is a result of studies often obtaining a value for the average cost of a bicycle from the range of prices on popular retail websites.

Transform Scotland (2018) estimated Scotland's share of the UK's cycling industry based on an evaluation of the secondary information in the literature and the assumption that Scotland has an 8.45% share of the UK market (reflecting the percentage share of the UK population). They report that in 2015, the Scottish cycling industry was worth between £75 - £251 million in bicycle sales and £30 million in accessory sales in 2015. In addition Scotland produced an estimated £0.58 - £1.94 million in bicycle manufacturing and £1.2 million in the manufacture of accessories.

Retail spending

International case study evidence indicates that retailers consistently underestimate how much cyclists and pedestrians contribute to their sales (Department for Transport, 2016). The literature suggests that while cyclists and pedestrians spend less per visit than motorists, they make more frequent visits (Clifton, et al., 2013; Department for Transport, 2016; Transport for London, 2016). Whether this results in higher overall spending than motorists is disputed (Rajé & Saffrey, 2015; Department for Transport, 2016) but it suggests that active travellers make up an important portion of the sales for small businesses (Transport for London, 2016; Living Streets, 2018).

Additionally, bicycle parking is more space-effective than car parking and case study evidence indicates that it generates a higher value per hour/m2 than the equivalent space devoted to cars (Lee & March, 2010). However this effect is likely to be more pronounced in city centres which are more accessible and characterised by a higher concentration of retail space than in other locations (Department for Transport, 2016).

Valuing the difference in spending between active travellers and other transport users is complicated by the variation in the methodology and data collected across case studies, limiting cross-comparison and generalisability. As a result, meta-analyses and reviews generally refrain from citing specific monetary figures to substantiate the positive impact that active travellers have on retails sales (Department for Transport, 2016).

Cycle freight

Cycle freight refers to the process of transporting merchandise through the use of a bicycle. A number of bicycle designs are available that are equipped with cargo holds into which loads can be secured for transportation, although the term also encompasses couriers using traditional bikes. The case for cycle freight is disputed with some case study evidence suggesting that it can offer a cheaper (in terms of maintenance cost and fuel savings), quieter and more environmentally-friendly alternative to motorised vehicles for certain types of businesses (Transport for London, 2018; Cycle Logistics, 2017). However other case studies indicate that there are a number of challenges to achieving the expected productivity gains. These include the costs of delivery being underestimated, the unreliability of riders, and the limited viability for payloads under a certain size and weight (Transport for London, 2009).

Tourism

There appears to be a link between the proportion of a population that cycles for utility purposes and its propensity for cycle tourism (Rajé & Saffrey, 2015; European Parliament, 2012). While this may currently limit the growth of domestic cycle tourism in Scotland, data collected by the Great Britain Tourism Survey and reported by Visit Scotland (2017a, 2017b) gives an indication of the magnitude of cycling and walking tourism. They report that between 2013-2015, an estimated 383,000 cycling trips and 5,127,000 walking trips took place, with an estimated expenditure of £1.9 billion. The spending is not uniformly distributed however, with the North and East parts of the country appearing to receive a higher share than the rest of Scotland. This is in line with research indicating that there is a significant difference in the economic distribution made by tourists depending on the type of visitor they are and the region they are visiting. Tourists for whom walking and cycling constitutes the primary purpose of a trip may visit more rural areas and may stay longer than other tourists, thus possibly contributing more extensively to these local economies (Rajé & Saffrey, 2015).

However, assessing the economic impact of cycle tourism is complicated by the difficulty in obtaining quantified information on spending behaviour and international vs domestic cycle and walking tourism (Transform Scotland, 2013). Additionally, the available data doesn't currently discriminate between trips that have cycling or walking as their primary purpose as opposed to those where it only constitutes one of the activities engaged in (Bryden, et al., 2010). Consequently, the estimates found in the literature vary greatly on the elements included and the level of impact considered (e.g.: UK-wide, Scotland-wide, activity-specific).

For example, (Transform Scotland, 2013) found that estimates of direct expenditure from cycle tourism can fall between £106 and £228 million depending on which elements are included in the calculations. A later report estimated the total value of leisure cycle tourism at £345 million and mountain bike tourism at £141.4 million (Transform Scotland, 2018). However part of the data was based on survey information which asked cyclists along a route to estimate their spending during the trip, the duration of their stay, and of the trip devoted to cycling as a primary purpose. Additionally, it is not possible to determine to what extent spending is being displaced from other activities, thus not resulting in net economic growth. Transform Scotland stresses that growth in cycle tourism is expected to come from such displacement (Transform Scotland, 2013).

Individual level savings

Finally, on an individual level, active travel modes represent substantial savings compared to the cost of owning or driving a car, and even possibly of using public transport. Davis (2014) states that "the operating and maintenance costs of a bicycle are around 5% of the equivalent cost for a motor vehicle. Walking is, arguably, almost cost neutral." Additionally, cycle scheme website estimates that an individual cycling a 10 mile round-trip commute, 50 weeks of the year can expect to spend £365 per annum compared to £625-1320 if using public transport or £3727 if driving a car. While this is based on London prices, it provides an indication of the potential savings from engaging in active travel and suggests substantial savings if scaled up to a population level.

Health benefits

There is strong evidence that health benefits comprise the majority of the benefits accrued from engagement in active travel. The effect is most pronounced at an individual level (Rabl & de Nazelle, 2012), but results in benefits to society through the associated savings to the NHS. The negative impact of insufficient physical activity on both physical and psychological health has been conclusively established. Evidence is strongest for the heightened risk of several chronic health conditions, including: cardiovascular disease (CVD), stroke, obesity, colon and breast cancer, type II diabetes, osteoporosis, depression and anxiety (TRL, 2018; Davis, 2014). In older adults, it has also been linked to reduced levels of functional ability (World Health Organisation, 2017).

Research demonstrates that active travel can contribute to meeting the recommended minimum levels of physical activity across all age groups provided that it be sufficiently frequent and intensive (Rissel, et al., 2012; Flint, et al., 2014; Petrunoff, et al., 2016). It has been suggested that integrating active travel into a

commute is a sustainable way of engaging in exercise which is important as maintaining consistent levels of physical activity is crucial to accruing the associated health benefits.

Men and members of ethnic minorities are estimated to benefit more from active travel than the general population. Additionally, adults over the age 45 are estimated to benefit more overall from a mode shift to active travel than younger people (Mueller, et al., 2015), due to older adults being at increased risk of developing chronic health conditions. Unfortunately, the research suggests that this age group is less likely to participate in active travel (Department for Transport, 2016). However Halfords (2018) reports that 62% of e-bikes in the UK are sold to people aged 55 years and above, with 79% of those sales made by new customers to the cycling range. As research suggests that e-bikes can contribute to meeting some of recommended levels of physical activity, this could have promising implication for widening access of the health benefits of active travel to individuals with reduced mobility or physical ability (TRL, 2018).

Physical health

Meeting the recommended levels of physical activity is associated with a reduction in all-cause mortality (Shaw, et al., 2020). A number of studies use the World Health Organisation's (WHO) HEAT tool when calculating the reduction in all-cause mortality as a result of active travel. Compared to a non-walker or cyclist's relative risk of all-cause death of 1.0, an individual walking 168 minutes a week (52 weeks/year) at an average of 4.8 km/hour yields a relative risk of death of 0.88 (World Health Organisation, 2017). The relative risk for cycling is 0.90, based on a scenario of 100 minutes/week (52 weeks/year) at an average speed of 14 km/hour (World Health Organisation, 2017).

The HEAT tool assumes a linear association between physical activity and health outcomes, however health benefits are subject to a dose-response relationship. As such higher levels of physical activity result in a larger percentage of risk reduction in all-cause mortality and the stated causes of morbidity. Additionally, while any amount of physical activity is beneficial, with substantial health gains at lower levels of activity, improved health outcomes are not immediate but require maintained levels of physical activity over time to accrue (Kyu, et al., 2016). Based on the latest available evidence, a five-year period of sustained levels of physical activity is generally considered to be necessary to reap the maximum health benefits. Finally, the evidence suggests that the decrease in risk reduction for both morbidity and mortality is minimal at very high levels of physical activity (3000-4000 metabolic MET minutes/week) (Kyu, et al., 2016). Consequently, WHO (2017) caps the percentage risk reduction in all-cause mortality after five years at 30% for walking (scenario assumes 460 minutes/week) and 45% for cycling (447 minutes/week).

Meeting the recommended levels of physical activity is also associated with a reduction in the incidence or severity of several health conditions including: CVD, type II diabetes, obesity, colon and breast cancer, and stroke (Mueller, et al., 2015). In older adults it is additionally linked to reductions in hypertension, falls (which includes resulting fractures), hospitalisation for CVD events, and improved muscular and strength function (LaCroix, et al., 1996; Vogel, et al., 2009). Kyu et al. (2016) recently conducted a meta-analysis on existing research in order to quantify the dose response association between total physical activity and the risk of five of the most prevalent chronic diseases: breast and colon cancer, diabetes, ischemic heart disease and ischemic stroke. The results indicate that the effect physical activity has a strong association with decreased risk of contracting diabetes and that substantial risk-reduction can be obtained at lower levels of physical activity (see Table 4).

Table 4. Risk of contracting five chronic diseases by level of physical activity.

Health Condition	low active (600-3999 MET minutes/week)	moderately active (4000-7999 MET minutes/week)	highly active (≥8000 MET minutes/week)
Breast cancer (women only)	-3%	-6%	-14%
Colon cancer	-10%	-17%	-21%
Diabetes	-14%	-25%	-28%
Ischemic heart disease	-16%	-23%	-25%
Ischemic stroke	-16%	-19%	-26%

Source: (Kyu, et al., 2016)

Celis-Morales, et al. (2017) monitored 263540 adult commuters aged between 40-69 across 22 sites in the UK over a median follow up period of five years. They found that cycling is associated with higher levels of risk-reduction in all-cause mortality, and both CVD and cancer incidence than walking, though significant reductions are found for both (see Table 5).

Table 5. Average risk reduction by mode of travel (blank cells denote no significant associations found)

Causes of Mortality	Walking	Cycling	Mixed including walking	Mixed including cycling
All-cause mortality		-41%		-24%
CVD mortality	-36%	-52%		
CVD incidence	-27%	-46%		
Cancer mortality		-40%		-36%

Cancer incidence		-45%		-32%

Source: (Celis-Morales, et al., 2017)

It is important to note that the impact from active travel on health outcomes will vary depending on an individual's baseline levels of physical activity. This is often not taken into account in studies such as Celis-Morales et al.'s (2017) which only looks at the amount of physical activity undertaking through active travelling (Department for Transport, 2016). This may result in inflating the impact of active travel on mortality and morbidity percentage risk reduction estimates. In addition, studies don't systematically consider whether active travel may be replacing other forms of physical activity and therefore whether it constitutes an increase in total physical activity levels of instead a substitution. Substitution could result in a net reduction in the amount of time spent physically active and thus a reduction in the dose proportional health benefits. For example, replacing a walked commute with a cycled one produces less benefits per mileage travelled as the intensity and duration of an actively travelled trip is key to accruing increased health benefits.

Despite these limitations to existing research, these is a consensus that a mode shift to active travel results in substantial health benefits at an individual level, irrespective of baseline activity levels, geographical context or the varying assumptions on health pathways adopted within models (Humphreys, et al., 2013; Mueller, et al., 2015; Department for Transport, 2016).

Mental health

The evidence for the impact of physical activity and active travel on mental health and wellbeing is less clear. In older adults it has been associated with reduced incidence of dementia (Vogel, et al., 2009). Large and sustained amounts of walking appears to reduce loss of grey matter in older age with possible corollary benefits in terms of lowering levels of cognitive decline and dementia (Erickson, et al., 2010).

Active commuters also self-report increased levels of psychological wellbeing (Martin, et al., 2014), and physical exercise has been found to be beneficial to the management and treatment of anxiety and depression (Fox, 1999; Paluska & Schwenk, 2000). The impact on academic performance is also contested as while there is stronger evidence that physical activity has beneficial effects on maths performance, the impact on overall academic performance is inconclusive (Davis, 2014; Singh, et al., 2019).

Negative impacts

Pollution exposure

Increased exposure to pollutants is cited as an impact of a modal switch to active travel (Rojas-Rueda, et al., 2013), the extent of which is context-dependent (Rabl & de Nazelle, 2012; MacNaughton, et al., 2014). However literature indicates that individual generally do not factor this into their decision making when taking up active travel and, more importantly, that the overall health benefits accrued outweigh this negative impact (Rabl & de Nazelle, 2012).

Increased risk

There is conflicting evidence regarding the impact of a mode shift to active travel on individual levels of risk exposure. Walking and cycling are considered high risk modes and increases in active travel are generally estimated to result in an increase in traffic fatalities or injuries. However a majority of research agrees that this can only be evaluated on a case-by-case basis due to the estimations of risk being highly context-dependent (Mueller, et al., 2015; Department for Transport, 2016).

Some evidence suggests that risk for cycling casualties may decline in communities where cycling is a higher mode share. This relationship between number of walkers or cyclists on the road and the likelihood of being involved in an incident with a motorist is known as the “safety in numbers effect” (Jacobsen, 2003). While this effect has been found irrespective of geographical context and time periods, there is no consensus on how or indeed at what number of active travellers it occurs (Mueller, et al., 2015). In addition, the results may be affected by under-reported cases of minor injuries.

Once again however, the overall health benefits are widely considered to outweigh any changes in the levels of risk at an individual level (Rabl & de Nazelle, 2012; Mueller, et al., 2015; Department for Transport, 2016)

Health economics

While health benefits are widely considered to account for between half and two thirds of the monetised benefits of active travel schemes and interventions, meta-analysis and reviews tend to refrain from venturing a monetary estimate of health care savings (Department for Transport, 2016). This is a result of a number of factors: the variation in health conditions and health pathways considered; the variation in levels and forms of activity included in the study sample; a large number of case-study evidence relying on small sample sizes; and a variation in the sample

demographics. Furthermore, the resulting predicted savings are often based on an assumed substantial increase in active travel numbers or are too specific to be representative at a national level.

Environmental benefits

The principle measurable environmental benefit of active travel consists of a reduction in levels emissions and pollution compared to motorised travel. While a lifecycle approach prevents any travel mode from being completely emission-free due to the impact of road, break and tire wear and the emissions arising from the production of vehicles, active travel modes are by far the lowest producers (Royal College of Physicians, 2016; Neves & Brand, 2019).

Based on 2015 data, the average European car produces an estimated 129.1 grams of CO2e per passenger-km in urban settings and 104.8 in rural ones (World Health Organisation, 2017). This is a conservative estimate as it doesn't take into account the increased impact per mile from short journeys, especially in cold weather (Neves & Brand, 2019). By contrast, e-bikes produce an estimated 5.4 grams of CO2e per passenger-km in urban areas through energy supply emission factors (World Health Organisation, 2017).

Active travel modes also result in the lowest CO2e emissions during vehicle manufacture. Compared to the average car requiring 4.7 tonnes of CO2e per vehicle, translating into 19.9 grams per passenger-km, bicycles and e-bikes require 0.10 and 0.19 tonnes of CO2e per vehicle (4.9 and 9.3 grams per passenger-km) respectively (World Health Organisation, 2017).

Despite the clear reduced environmental footprint of active travel modes, it is important to note that at a societal level, the benefits of active travel in terms of pollution reduction are minimal unless a consequential mode shift can be achieved (Rabl & de Nazelle, 2012; Mueller, et al., 2015). If this can be realised however, there are associated benefits for public health including reductions in all-cause mortality, respiratory disease, CVD, certain types of cancer and adverse birth outcomes (Mueller, et al., 2015). Additionally, as pollution exposure is more hazardous to children, older adults, people with existing chronic health conditions and people living in more deprived areas (which may experience higher pollution levels), these groups stand to accrue a larger health benefit (Royal College of Physicians, 2016).

Suggested reading material and additional material

Top recommended reading

Academic paper that looks at Seville's success, how it planned and spent, as well as the laid out its cycle network.

TfL research on international best practice in cycling infrastructure. Considers the legality of different interventions in a UK policy context.

Danish cycling embassy, good resource to see Danish suggested best practice.

Latest Rapid Evidence review from DfT, more succinct than the prior report.

Evidence review on the barriers to investing in cycling in England.

Ancillary reading

- Rapid Evidence review for DfT, asks and tries to answer a range of questions:

- RQ1 What are the range of different interventions that can be used to impact on walking and cycling and how much do they cost?
- RQ2 How effective are different interventions?
- RQ3 How can we most effectively target cycling and walking interventions?
- RQ4 Where do new or extended cycling and walking trips come from?
- RQ5 What impact can cycling and walking investment have on physical activity and health, and the associated costs of this?
- RQ6 What are positive and/or negative local economic impacts of cycling and walking interventions?

UK Cycling embassy, qualitative research on residents opinions.

DfT guidance laying out how to make an economic case for cycling infrastructure.

TfL report which looks to calculate the maximum possible modal shift given current travel patterns, which would give an idea on the possible uptake in certain locations.

TfL report showing the cyclical trend in cycling in London, important to note when consider pre and post evaluations.

Gives an in depth report on the Sustainable Travel Towns in England, their spending and breakdowns thereof, as well as the results and other useful metrics.

Academic report for DfT on the best framework to evaluate cycling projects, suggests a figure of between £1-4 million for evaluations depending on size and level of robustness for a comprehensive evaluation.

Academic paper on the Mini-Hollands in London boroughs, still very early on in the project so more to watch the space.

Norwegian Cycling report by their transport authority. Looks at towns, trends and modal levels. Useful if considering Norway or certain Norwegian towns as comparison cities for Scotland.

References

Aldred, R., Croft, J. & Goodman, A., 2019. Impacts of an active travel intervention with a cycling focus in a suburban context: One-year findings from an evaluation of London's in-progress mini-Hollands programme. Transportation Research Part A, pp. 147-169.

Anaya, E. & Castro, A., 2012. Balance General de la Bicicleta Publica en Espana. Fundacion ECA Bureau Veritas.

Audrey, S. et al., 2019. A workplace-based intervention to increase levels of daily physical activity: the Travel to Work cluster RCT. Public Health.

Beenackers, M. et al., 2012. Taking Up Cycling After Residential Relocation: Built Environment Factors. American Journal of Preventive Medicine, 42(6), pp. 610-625.

Böcker, L. & Dijst, M., 2013. Impact of Everyday Weather on Individual Daily Travel Behaviours in Perspective: A Literature Review. Transport Reviews.

Bryan, M., Daryl, H. & Kasia, S., 2015. The Impact of Street Accessibility on Travel and Independence of Disabled People. Lisbon, University of Leeds.

Bryden, D. M. et al., 2010. Assessing the economic impacts of nature based tourism in Scotland , s.l.: Scottish Natural Heritage Commissoned Report No. 398.

Bunn, H., 2019. How safer biking infrastructure works for women: quantifying the impact of protected bike lanes on accessibility across gender, s.l.: Strava Metro.

Celis-Morales, C. A. et al., 2017. Association between active commuting and incideny cadriovascular disease, cancer, and mortality: prospective cohort study. The British Medical Journal, Volume 357, p. j1456.

Clayton, W., 2016. Cycling and Disability: A Review. UWE Bristol, Jan.

Clifton, K. et al., 2013. Consumer behaviour and travel choices: A focus on cyclists and pedestrians. Washington, 92nd Annual Meeting of the Transportation Research Board.

Confederation of the European Bicycle Industry, 2017. European Bicycle Market: Industry & Market Profile 2017 edition, Brussels: CONEBI.

Cycle Logistics, 2017. Monitoring and Evaluation Report Cyclelogistics Ahead Project 2014-2017, s.l.: Cycle Logistics EU.

Cycling Embassy, U., 2012. Evaluation of the Cycling City and Towns Programme: Qualitative Research with Residents

Danish, C. E., 2012. Collection of Cycle Concepts 2012

Davis, A., 2014. Claiming the Health Dividend: A summary and discussion of value for money estimates from studies of investment in walking and cycling, London: Department for Transport.

Davis, A. & Jones, M., 2007. Physical activity, absenteeism and productivity: an Evidence Review, Wokingham: TRL.

Department for Health, 2011. 'Soft measures - hard facts' - The value for money of transport measures which change travel behaviour: A review of evidence.

Department for Transport, 2009. Analysis and synthesis of evidence of the effects of investment in six Cycling Demonstration Towns.

Department for Transport, 2016. Investing in Cycling & Walking: Rapid Evidence Assessment, London: Department for Transport.

Dill, J., 2009. Bicycling for Transportation and Health: The Role of Infrastructure. Journal of Public Health Policy, pp. 95-110.

Erickson, K. I. et al., 2010. Physical activity predicts gray matter volume in late adulthood: the cardiovascular health study. Neurology , 75(16), pp. 1415-1422.

European Parliament, 2012. The European Cycle Route Network Eurovelo, Brussels: Directorate General for Internal Policies.

Federal Ministry for the Environment, 2012. Reducing Carbon Emissions through Transport Demand Management Strategies: A review of International examples.

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, pp. 135-142.

Flint, E., Cummins, S. & Sacker, A., 2014. Associations berween active commuting, body fat, and body mass index: population based cross sectional study in the United Kingdom. The British Medical Journal, Volume 349, p. g4887.

Forsyth, A. & Krizek, K., 2009. Promoting Walking and Bicycling: Assessing the Evidence to Assist Planners. Built Environment.

Fox, K. R., 1999. The influence of physical actvity on mental well-being. Public Health Nutrition, 2(Suppleent 3a), pp. 411-418.

Gatersleben, B. & Appleton, K., 2007. Contemplating cycling to work: Attitudes and perceptions in different stages of change. Transport Research Part A: Policy and Practice, pp. 302-312.

Goetzke, F. & Rave, T., 2011. Bicycle Use in Germany: Explaining Differences between Municipalities with Social Network Effects. Urban Studies.

Goodman, A., Sahlqvist, S. & Ogilvie, D., 2014. New Walking and Cycling Routes and Increased Physical Activity: One- and 2-Year Findings From the UK iConnect Study. Am J Public Health.

Grous, A., 2011. The British cycling economy: 'gross cycling product' report, London: London School of Economics.

Halfords, 2018. Hello 'Silver Cyclist''. https://www.halfordscompany.com/news/product-news-from-halfords/hello-silver-cyclist/ [Accessed 20 January 2020].

Harms, L., Bertolini, L. & Brommelstroet, M. t., 2015. Performance of Municipal Cycling Policies in Medium - Sized Cities in the Netherlands Since 2000, s.l.: s.n.

Hendriksen, I., Simons, M., Hildebrandt, V. & Garre, F. G., 2010. The association between commuter cycling and sickness absence. Preventive Medicine, 51(2), pp. 132-135.

Humphreys, D. K., Goodman, A. & Ogilvie, D., 2013. Associations between active commuting and physical and mental wellbeing. Preventie Medicine, 57(2), pp. 135-139.

Jacobsen, P. L., 2003. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. Injury Prevention, 9(3), pp. 205-209.

Jones, R. et al., 2019. Interventions promoting active transport to school in children: A systematic review and meta-analysis. Preventive Medicine.

Jones, T., 2012. Getting the British back on bicycles - The effects of urban traffic-free paths on everyday cycling. Transport Policy, pp. 138-149.

Küster, F. & Blondel, B., 2013. Calculating the economic benefits of cycling in EU-27, Brussels: European Cyclists' Federation.

Kyu, H. H. et al., 2016. Physical activity and risk of breast cancer, colon cancer, diabetes, ischemic heart disease, and ischemic stroke events: systematic review and dose-response meta-analysis for the Global Burden of Disease Study 2013. The British Medical Journal, Volume 354, p. i3857.

LaCroix, A. Z. et al., 1996. Does Walking Decrease the Risk of Cardiovascular Disease Hospitalizations and Death in Older Adults?. Journal of the American Geriatrics Society, 44(2), pp. 113-120.

Lee, A. & March, A., 2010. Recognising the economic role of bikes: sharing parking in Lyngon Street, Carlton. Australian Planner, 47(2), pp. 85-93.

Living Streets, 2018. The pedestrian pound, London: Living Streets.

Lunke, E., Aarhaug, J., Jong, T. d. & Fyhri, A., 2018. Cycling in Oslo, Bergen, Stavanger and Trondheim: A study of cycling and travel behaviour, s.l.: s.n.

MacNaughton, P. et al., 2014. Impact of Bicycle Route Type on Exposure to Traffic-Related Air Pollution. The Science of the Total Environment, Volume 490, pp. 37-43.

Marqués, R., Hernández-Herrador, V., Calvo-Salazar, M. & García-Cebrián, J., 2015. How infrastructure can promote cycling in cities: Lessons from Seville. Research in Transportation Economics, pp. 31-44.

Martens, K., 2007. Promoting bike-and-ride: The Dutch experience. Transportation Research Part A: Policy and Practice, pp. 326-338.

Martin, A., Goryakin, Y. & Suhrcke, M., 2014. Does active commuting improve psychological wellbeing? Longitudinal evidence from eighteen waves of the British Household Panel Survey. Preventive Medicine, Volume 69, pp. 296-303.

Mclaughlin, M., 2017. Defining Connected Bike Networks, s.l.: s.n.

Mertens, L. et al., 2019. Individual, social, and physical environmental factors related to changes in walking and cycling for transport among older adults : a longitudinal study. Health & Place, pp. 120-127.

Moore, D., 2019. Women love bikes—so why don't they cycle to work?. s.l.:Quartz.

Mueller, N. et al., 2015. Health impact assessment of active transportation: A systematic review. Preventive Medicine, Volume 76, pp. 103-114.

Neves, A. & Brand, C., 2019. Assessing the potential for carbon emissions savings from replacing short car trips with walking and cycling using a mixed GPS-travel

diary approach. Transportation Research Part A: Policy and Practice, Volume 123, pp. 130-146.

NICE, 2012. NICE - Guidance.

Nikitas, A., Wang, J. & Knamiller, C., 2019. Exploring parental perceptions about school travel and walking school buses: A thematic analysis approach. Transportation Research Part A: Policy and Practice, pp. 468-487.

Paluska, S. A. & Schwenk, T. L., 2000. Physical Activity and Mental Health. Sports Medicine, 29(3), pp. 167-180.

Petrunoff, N., Rissel, C. & Wen, L. M., 2016. The effect of active travel interventions conducted in work settings on driving to work: A systematic review. Journal of Transport & Health, 3(1), pp. 61-76.

Portland, B. A. C., 2017. TSP Stage 3 Mode Split, Portland: s.n.

Pucher, J., Dill, J. & Handy, S., 2010. Infrastructure, Programs, and Policies to Increase Bicycling: An International Review. Preventive Medicine.

Rabl, A. & de Nazelle, A., 2012. Benefits of shifts from car to active transport. Transport Policy, Volume 19, pp. 121-131.

Rajé, F. & Saffrey, A., 2015. The Value of Cycling, London: Department for Transport.

Rietveld, P. & Daniel, V., 2004. Determinants of bicycle use: do municipal policies matter?. Transportation Research Part A: Policy and Practice, pp. 531-550.

Rissel, C., Curac, N., Greenaway, M. & Bauman, A., 2012. Physical Activity Associated with Public Transport Use - A Review and Modelling of Potential Benefits. International Journal of Environmental Research and Public Health, Volume 9, pp. 2454-2478.

Rojas-Rueda, D., Nazelle, A. & Nieuwenhuijsen, M. J., 2013. Health impact assessment of increasing public transport and cycling use in Barcelona: A morbidity and burden of disease approach. Preventive Medicine, 57(5), pp. 573-579.

Royal College of Physicians, 2016. Every breath we take: The lifelong impact of air pollution, London: Royal College of Physicians.

Shaw, C., Blakely, T., Atkinson, J. & Woodward, A., 2020. Is mode of transport to work associated with mortality in the working-age population? Repeated census-

cohort studies in New Zealand 1996, 2001 and 2006. International Journal of Epidemiology, Volume dyz257.

Singh, A. S. et al., 2019. Effects of physical activity interventions on cognitive and academic performance in children and adolescents: a novel combination of systematic review and recommendations from an expert panel. British Journal of Sports Medicine, 53(10), pp. 640-647.

Sloman, L. et al., 2010. The Effects of Smarter Choice Programmes in the Sustainable Travel Towns: Summary Report, s.l.: s.n.

Slowman, L. et al., 2014. Finding the Optimum: Revenue/Capital Investment Balance for Sustainable Travel, s.l.: Sustrans, WSP, Transport for Qualty of Life.

Song, Y., Preston, J. & Ogilvile, D., 2017. New walking and cycling infrastructure and modal shift in the UK: A quasi-experimental panel study. Transportation Research Part A: Policy and Practice, pp. 320-333.

Sustrans, 2016. The investment required to achieve the Government's ambition to double cycling activity by 2025.

Sustrans, 2017. Summary of Outcomes of the Cycling Demonstration Towns and Cycling City and Towns Programmes.

Thomas, C., 2008. Proceedings of the Institution of Civil Engineers - Municipal Engineer, s.l.: Municipal Engineer.

Thomas, R. & Bertolini, L., 2014. Beyond the Case Study Dilemma in Urban Planning: Using a Meta-matrix to Distil Critical Success Factors in Transit-Oriented Development. Urban Policy and Research.

Transform Scotland, 2013. Cycle Tourism: Opportunities for the Scottish Economy, Edinburgh: Transform Scotland.

Transform Scotland, 2018. The Value of Cycling to the Scottish Economy, Edinburgh: Cycling Scotland.

Transport for London, 2009. Cycle freight in London: A scoping study, London: Transport for London.

Transport for London, 2014. International Cycling Infrastructure Best Practice Study. Available at: http://content.tfl.gov.uk/international-cycling-infrastructure-best-practice-study.pdf [Accessed Dec 2019].

Transport for London, 2016. Town Centres Report, London: Transport for London.

Transport for London, 2018. Cycle Freight Study, London: Transport for London.

Transport Scotland, 2013. Monitoring and Evaluation of the Smarter Choices, Smarter Places Programme.

TRL, 2018. Innovative active travel solutions and their evaluation, Wokingham: TRL.

Urban Transport, 2011. Cycling in the City Regions - Annex 1: Modelling the Impact of the Step Changes in the Delivery of Measures to Support Cycling in PTE Areas: Technical Report.

Villa-Gonzalez, E., Barranco-Ruiz, Y., Evenson, K. & Chillon, P., 2018. Systematic review of interventions for promoting active school transport. Preventive Medicine, pp. 115-134.

Visit Scotland, 2017. Insight Department: Cycling Tourism in Scotland, Edinburgh: Visit Scotland.

Visit Scotland, 2017. Insight Department: Walking Tourism in Scotland, Edinburgh: Visit Scotland.

Vogel, T. et al., 2009. health benefits of physical activity in older patients: a review. The International Journal of Clinical Practice, 63(2), pp. 303-320.

Wardman, M., Tight, M. & Page, M., 2007. Factors influencing the propensity to cycle to work. Transportation Research A, pp. 339-359.

Weston, R. et al., 2012. The European Cycle Route Network EuroVelo, Brussels: European Parliament .

World Health Organisation, 2017. Health economic assessment tools (HEAT) for walking and for cycling: Methods and user guide on physical activity, air pollution, injuries and carbon impact assessments, Geneva: World Health Organisation.

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