Handbook of Travel Behaviour

Chapter 19: Interactions between Health and Travel Behaviour

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Abstract

There are complex and reciprocal relationships between health and travel behaviour. In this chapter we provide an overview of the multiple ways in which travel behaviour influences health outcomes, of both populations and individuals. We also review the ways in which health status influences travel behaviour, and some of the challenges of models that assume heterogeneity of the population in terms of travel behaviours. Throughout the chapter we pay particular attention to inequalities, considering how health outcomes of different population groups are impacted differently by travel behaviour, and how the health status of differing groups impacts their ability to travel and participate in society. Our review is intended as a broad overview of multi-faceted, multi-scale and reciprocal links between travel behaviour and health

Keywords: inequalities, health, wellbeing, ‘noncommunicable disease’, pandemic, ‘active travel’

<a> INTRODUCTION

Travel behaviour has a wide range of impacts on health and inequalities (Glazener et al. 2021), while health status in turn impacts travel behaviour (Mindell et al. 2014). There are complex and reciprocal relationships between travel behaviour and health outcomes. The way in which we travel, how far, and time spent travelling each impact upon a wide range of health outcomes. This occurs both at the individual level (for example, our own physical and mental health can be directly impacted by the way in which we choose to travel), and at the population level: the way in which we travel collectively also impacts on the physical and mental health of others. Conversely, our health status can also affect when, where, and how we are able to travel.

Globally, non-communicable diseases (NCDs) cause 41 million deaths each year (71% of all deaths), 31 million of which are in low- and middle-income countries (LMICs). The global total includes around 18 million deaths from circulatory diseases (heart disease, stroke, and other cardiovascular diseases); 9 million from cancers; 4 million from respiratory diseases; and 1.5 million from diabetes. Although in high-income countries these are considered diseases of older people, NCDs are a major cause of 'premature' deaths - before the age of 70 years: 85% of such deaths occur in LMICs. The same four diseases account for more than 80% of all premature deaths from NCDs (WHO 2021a).

Among the many modifiable behavioural and metabolic risk factors for developing or dying from NCDs, a number are directly or indirectly affected by travel behaviour (Figure 1). For example, 1.6 million deaths globally are attributed to insufficient physical activity (Murray et al. 2020; WHO 2021a). Walking and cycling, often referred to as 'active travel', provide opportunities for physical activity. As most people using public transport walk (or cycle) at one or both ends of the journey, some include public transport within the term 'active travel'. Physical inactivity is the fourth leading cause of global mortality (Laeremans et al. 2017). People who walk or cycle are more likely to meet the recommendations for physical activity, even among people who are already physically active (Sahlqvist et al. 2012; Laeremans et al. 2017). Walking or cycling to and/or from public transport can also be sufficient to meet these recommendations (Besser and Dannenberg 2005). While the amount of physical activity for a given distance is less than with use of conventional cycles, studies have shown that e-bike users go further and thus expend similar amounts of energy overall to regular cyclists (Castro et al. 2019). Transport is a significant contributor to air pollution, which causes and exacerbates respiratory diseases (asthma, chronic obstructive pulmonary disease), heart disease, stroke, lung cancer, obesity, diabetes, and dementia (RCP and RCPCH 2016). Noise from transport increases blood pressure and thus hypertension (high blood pressure) prevalence; reduces concentration; and interferes with educational attainment (a major predictor of adult health) (Stansfeld 2015).

Road traffic deaths and injuries are also a significant contributor to the global burden of ill health. Around 1.3 million road travel crash deaths occur annually, with road travel injuries being the leading cause of death for people aged 5-29 years. In addition, many of the 20-50 million people injured on the roads worldwide each year suffer from residual disability (WHO 2022).

In addition to these physical health conditions, travel behaviour impacts mental health in a number of ways. For example, community severance, the barrier effect of busy roads or infrastructure, reduces access to the goods, services, and social networks important for good health and wellbeing (Leigh-Hunt et al. 2017; Anciaes et al. 2019). While active travel can improve mental health (Kroesen and De Vos 2020), delays and congestion on roads and public transport are also associated with heightened stress and anxiety while travelling.

These impacts of travel behaviour patterns on health are felt unevenly across the population. Globally, and within most countries, benefits of motorised travel are experienced by more affluent people, while the harms fall primarily on more deprived and vulnerable groups, particularly the poor, the young, and older adults (Cohen et al. 2014).

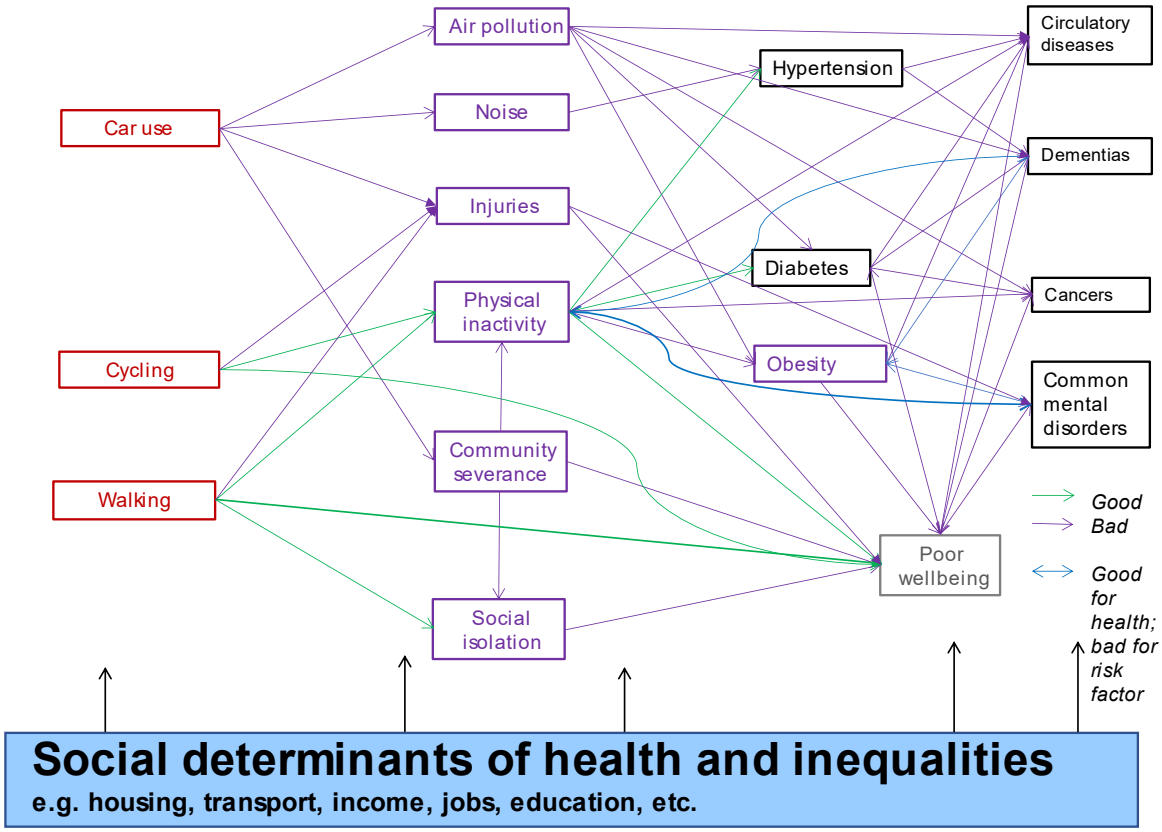
However, although travel behaviours can influence health outcomes and health inequalities negatively, travel is important for our health and wellbeing. Important benefits of travel include providing access to education, jobs, people, services, and goods, each of which is important for health. Travel can provide access to leisure facilities or can be a leisure pursuit itself.

Those with health conditions can find it more difficult to travel and are often excluded by the design of streets and transport systems. For example, inaccessible environments mean that those with physical impairments are excluded from travelling. Mental health issues or cognitive impairment from learning disability or cognitive decline from dementia can make navigating transport systems and interacting with other people – staff or passengers – difficult. Poor health is often associated with lower income, and low incomes can reduce the ability to afford travel. Inequalities in the ability to travel leads to social exclusion and further perpetuates inequities (Boniface et al. 2015).

In this chapter we review the multifaceted and reciprocal relationships between travel behaviour and health. First, we outline the ways in which travel behaviour impacts on physical and mental health at the individual and population level. Then we consider the ways in which poor health can influence travel behaviour, including the adverse health consequences of social isolation from not being able to travel. The intention is that this chapter can be used as an introduction to the multifaceted, multi-scalar and reciprocal relationships between travel behaviour and health. We provide brief summaries of the key connections and issues, but do not cover the issues in depth.

We take ‘travel behaviour’ to include how far, how often, and by which mode people travel. We focus primarily on travel mode, with trip length and frequency affecting the extent of the health impacts on individuals themselves and on others.

Figure 1. Impacts of travel behaviours on ill health and poor wellbeing.



Footnote: The arrows indicate common consequences but not the relative importance of different sequalae nor of the health effects of different modes. Public transport has been omitted from this figure as it causes less air and noise pollution and community severance than private car use but more than walking and cycling; and often provides some physical activity but less than walking or cycling.

<a> HOW TRAVEL BEHAVIOUR AFFECTS PHYSICAL AND MENTAL HEALTH AND WELLBEING

This section outlines the multifaceted ways in which travel behaviour, in aggregate across the population, influences population level health and the ways in which how an individual travels can impact their own health. The following sub-sections outline different ways in which travel behaviours impact on health. We then discuss the implication of this for transport planning practice.

<b> Global climate change

Carbon emissions are one of the prime drivers of climate change. In 2016, transport accounted for 16% of global greenhouse gas emissions globally, with 12% coming from road traffic, 1.9% from aviation, 1.7% from shipping, and 0.4% from rail travel (Ritchie and Roser). However, transport accounted for 29% of carbon emissions in the USA in 2019 (EPA 2021). Carbon dioxide emissions per person km travelled depend strongly on the travel mode

used, with air travel almost an order of magnitude higher than motorised land travel. The occupancy of the vehicle also affects this.

The health impacts of climate change are already being seen globally. Severe floods across Europe, landslides in Germany, and massive fires in Australia and the USA have caused deaths and homelessness (Zhang et al. 2020). As global temperatures rise, infectious diseases spread more quickly and further, as conditions become favourable for both the disease-causing organisms (pathogens) and the vectors that carry them. For example, dengue fever is now found across wider areas as the mosquito species that carry it become established in more countries. Heatwaves also kill, with poverty, ageing, and pre-existing chronic disease being factors associated with higher mortality (Jay et al. 2021).

<b> Air pollution

Transport contributes substantially to particulate matter (PM), in varying amounts geographically. In 2019, there were more than 4 million deaths worldwide attributed to outdoor particulate ($PM_{2.5}$) air pollution (HEI 2020). Ambient particulate air pollution has been increasing globally at >1% pa, accounting in 2019 for 4.5% of Disability-Adjusted Life Years lost worldwide (Murray et al. 2020). It was estimated in 2010 that the costs of air pollution's health impacts in the UK was at least £8 to £20 billion pa (PHE 2018). It has been recognised for several decades that short-term exposure to particulate air pollution causes premature mortality and early and additional hospital admissions for cardiorespiratory conditions and exacerbates asthma. Long-term exposure is now recognised as increasing the development of, and mortality from, coronary heart disease, stroke, diabetes, chronic obstructive pulmonary disease (COPD), pneumonia, and lung cancer (HEI 2020). Oxides of nitrogen, particularly nitrogen dioxide (NO_2) have also been associated with asthma. More recent evidence links air pollution with causing these diseases but also in causing chronic inflammation, the mechanism thought to underlie the effect of air pollution on increasing obesity and diabetes. Dementia, neurodevelopment of children, and neonatal deaths have also been linked to air pollution, particularly NO_2 (RCP and RCPCH 2016; PHE 2018; HEI 2020). There is also some evidence linking long-term $PM_{2.5}$ exposure with depression and possibly with anxiety, and between short-term exposure and suicide (Braithwaite et al. 2019). Ambient air pollution has also been linked to increase use of both community and inpatient mental health services (Newbury et al. 2021).

Air pollution is worse in the Global South, and in poorer regions within countries (HEI 2020). Poorer people are not only more exposed to air pollution from motor traffic, they are also more susceptible to its adverse health impacts, as they are more likely to have pre-existing cardiorespiratory conditions and/or to be at the extremes of age. There are also indications that areas with higher $PM_{2.5}$ or NO_2 levels have higher COVID-19 mortality rates: ongoing studies are investigating whether air pollution was associated with greater infection rates or case fatality rates (e.g. because of higher prevalence of pre-existing diseases increasing susceptibility) (HEI 2020).

Although everyone is exposed to air pollution, regardless of how they travel, exposure also depends on individual travel behaviour. Pollution concentrations are highest inside vehicles (regardless of use of windows or air conditioning), as air intake is usually sited close to the

exhaust pipe of the vehicle in front. Private vehicles are worst, followed by buses. Concentrations nearer the side of the road, where people walk and cycle, are generally less but active travel requiring exertion can increase the frequency and/or depth of respiration, so the dose inhaled may be higher. Particulate levels in metro systems are also high but most of this is due to large particles which do not penetrate into the lungs or are inert metals, particularly iron. Thresholds are set to be safe for exposure of workers, who spend many hours on subway platforms; exposure of travellers is for far shorter times (Cohen et al. 2013; Roy et al. 2019). In a study of school drop off in Canada, ambient $PM_{2.5}$ concentrations increased most at the drop-off location but also in the playground and at the school door. Emissions from private vehicles equated to more than 19 buses idling for 15 minutes (Adams and Requia 2017).

<b> Road travel injuries

Globally, road traffic crashes account for around 1.3million deaths every year and many more suffer injuries as a result of road traffic collisions (WHO 2022). Travel behaviour affects not only the individual's risks but also those of other road users. Drivers and males impose a much higher risk on other road users (including their own passengers) than cyclists do (Scholes et al. 2018). The highest risks per bn km travelled imposed on other road users are imposed by buses and lorries (Aldred et al. 2021).

Those in lower socio-economic groups and in low and middle income countries, children and young adults, and males are more at risk of road traffic injuries and death. Over 90% of fatalities happen in low and middle income countries. Where few people drive motor vehicles, but there is little or no pedestrian infrastructure, vulnerable road users are afforded little protection from fast-moving traffic. Use of poorly or non-regulated shared vehicles in low income countries, whether overcrowded formal or informal public transport (generally unprotected pick-ups) also contributes to injury risk (Chatukuta et al. 2021).

The relationships between mode of travel and demographic factors are not straightforward. For example, in England, the fatality risk from road travel varies more by age and sex than by whether people are driving, cycling or walking. Young men aged 17 (the legal threshold for driving) to 20 are safer cycling than driving, for example. Rates increase by an order of magnitude in older cyclists and pedestrians (Feleke et al. 2018).

Pedestrian falls, trips and slips that do not involve a vehicle are excluded from official road travel injury statistics in most countries. Falls frequently occur due to the condition of the pavement, often combined with failing balance in older people (Watkins et al. 2020; Lee 2023). In the few countries where research exists, hospital admissions for falls in older pedestrians are of a similar magnitude to, or greater than, those from collisions between vehicles and pedestrians (Mindell et al. 2012; Methorst et al. 2017; Schepers et al. 2017; Oxley et al. 2018). Pedestrian injuries are also more likely to affect those living in deprived areas (Corfield et al. 2016; Feleke et al. 2018; O'Toole and Christie 2018).

Relationships between travel behaviour and injury rates can be complex and paradoxical, meaning that what is safest in the short term from an individual perspective may not be the best long term for population health. For example, while travel by car can be safest in some circumstances this is only because we have created environments which favour the use of car

and make travel by other modes difficult and sometimes dangerous. Improvements to safety of vehicles to protect the occupants can reduce the severity of occupants' injury in the event of a crash, but may also make a crash more likely as people may compensate by driving less carefully: while vehicle occupants are better protected, safety is reduced for other road users.

<b> Assault and harassment

Injury is not caused only by road traffic collisions and by falls on the pavement or within public transport systems. In many countries, sexual assault makes travel very hazardous, particularly for women and especially when walking and on public transport (Kash 2019; Orozco-Fontalvo et al. 2019; Malik et al. 2020; Quinones 2020). Assault may also occur following an episode of 'road rage', in which an impatient or angry driver (or less commonly, passenger) intentionally injures, sometimes fatally, or attempts to injure another road user.

Experience of or concerns about assault and harassment can impact travel behaviour in terms of the modes of travel used or times at which people travel. In some countries, including Japan, female-only train coaches are provided to reduce risks of sexual harassment but some feel this is not the right response and the inappropriate behaviour of other passengers needs to be addressed more directly. The World Bank is now sponsoring a number of projects to prevent potential violence and harassment that girls and women often face when using public transport across the world (World Bank 2016). This is particularly important since women tend to use public transport than men. In many societies, gender differences in roles in society and the family persist, but transport planning has until recently been 'gender-blind', often focusing on the needs of commuters, who are mainly young and middle-aged men, generally from the majority ethnic group. Women are more likely to have caring responsibilities and to 'chain' their trips, combining their own commuting, if they have a paid job, with accompanying children, shopping, and visiting parents, at the same time as having less access to a car and having goods to carry and/ or children to escort. Fear of sexual harassment or violence on the street or in public transport can affects their travel behaviour choices and their mental health (Sagaris and Tiznado-Aitken 2020).

<b> Noise pollution

Roads and streets are usually noisy places. In Europe, transport noise is the second worst environmental risk factor (Sørensen et al. 2020). Environmental noise (from road, rail, and aviation travel) interferes with sleep (Basner and McGuire 2018), activating the endocrine and sympathetic systems, increasing biological risk factors for various NCDs. Noise increases blood pressure, contributing to heart disease and stroke; and also interferes with mental health (Basner et al. 2017). According to the World Health Organization, road traffic noise is a risk factor for ischaemic heart disease, among other conditions (WHO 2011).

The health impacts of environmental noise are independent of air pollution (Stansfeld 2015). Annoyance with daytime noise was associated with subsequent onset of symptoms of anxiety and of depression and sleep disturbance; night time noise annoyance was associated with anxiety. Sleep disturbance was associated with both day and night traffic noise. These effects

were worse in women, in younger people, and in people from lower socio-economic circumstances (Beutel et al. 2020).

Noise also affects concentration and can interfere with education. Children exposed to aviation noise at school perform worse in tests than their similar peers not exposed to such noise at school: a 5dB increase in aviation noise exposure was associated with a one to two month delay in reading age, that was not due to air pollution (Stansfeld et al. 2005). This effect of noise pollution on education is important in the longer term, as educational achievement is one of the key determinants of adult health.

<b> Community severance

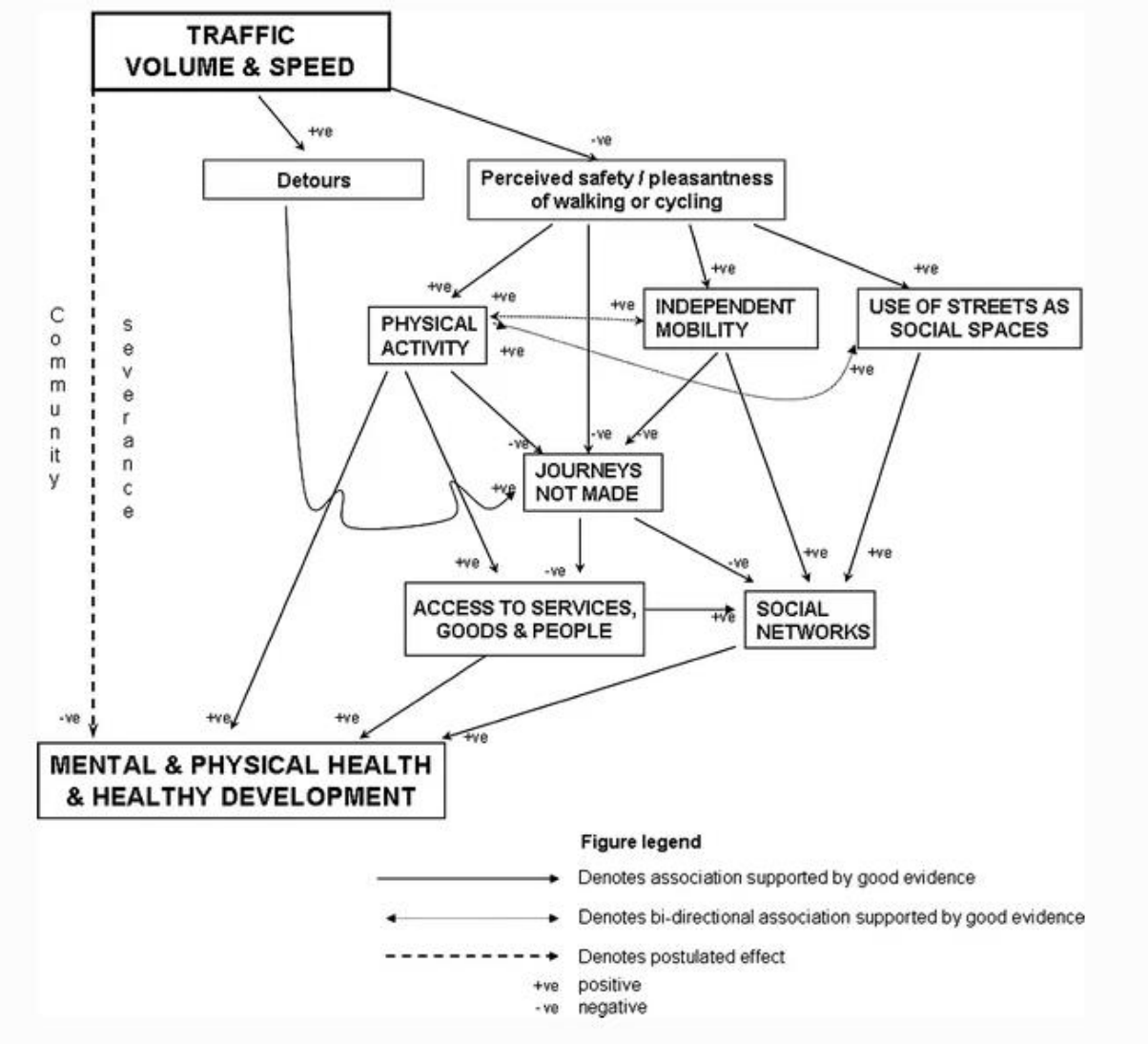
The barrier effect of busy roads causing 'community severance' is a prime example of travel behaviours impacting other people (Figure 2). Where many people choose to drive, and/or drive fast, it can become very difficult to cross the road. This prevents local residents, and those using that area, accessing goods, services, and people (Mindell and Karlsen 2012). Such access is very important for a healthy life. Having larger social networks, including casual contacts with acquaintances ('loose ties'), not just relationships with family and friends, is beneficial for health, reducing mortality and ill health (Holt-Lunstad et al. 2010). Appleyard and Lintell demonstrated 50 years ago that the higher the motor traffic levels in the street, the fewer friends and acquaintances people have (Appleyard and Lintell 1972). Other people's motor vehicles also affects the size and location of where individuals consider 'home territory', and their likelihood to spent time in the street, using the street as a social space, not just for travel (Appleyard and Appleyard 2021).

Recent studies have shown that community severance is associated with worse mental wellbeing (Anciaes et al. 2019) and also with poor self-related health, in a dose-response manner (Higgsmith et al. 2022).

Broader effects of busy roads include the deterrent effect on active travel. Even using public transport can be affected, as the passenger will usually need to cross the road to get to or from the bus stop. Affected individuals thus do not travel, or need to travel by other modes – a problem particularly for those who are too young, too poor, or too incapacitated to drive, affecting people's independent mobility. The cost of local community severance across Great Britain has been valued at £31.9 billion, 1.6% of GDP (Anciaes et al. 2022).

Community severance has been increasing in urban areas in Africa, as the number of motor vehicles increases as the road network is upgraded. This reinforces socioeconomic inequalities, exacerbated by the general lack of pedestrian infrastructure. Where infrastructure exists, it is alongside main roads, very close to fast traffic with attendant risks of injury and exposure to noise and air pollution. Public transport systems can also cause severance. Following the introduction of the Addis Ababa Light Rail Transit system, local residents noted a reduction in social interactions (Anciaes and Bradbury 2022).

Figure 2. How community severance from busy roads can affect health



Source: Figure 2 in Mindell JS, Karlsen S. Community severance and health: What do we actually know? J Urban Health. 2012;89:232-246. Published with permission of SpringerLink.

<b> Physical activity

As outlined in the introduction, travel behaviour, specifically mode used, can impact on opportunities for physical activity.

Physical inactivity reduces wellbeing and increases obesity, diabetes, heart disease, stroke, some cancers, depression, and blood pressure (Kyu et al. 2016). High blood pressure accounted for almost 11 million deaths (19% of all deaths) globally in 2019 (Murray et al. 2020). Mode of travel behaviour is one way in which physical activity can be achieved; reduced opportunities for active travel can account for low levels of physical activity. Time spent sitting in cars is associated with greater cardiovascular risk (Sugiyama et al. 2020). The extent to which sedentary behaviour is inherently harmful or is an indicator for less time spent in light activity is debated.

Longitudinal studies have shown that people who change their commuting behaviour from car to walking or cycling lose weight; those who change to using buses also lose weight but less (Sugiyama et al. 2013; Martin et al. 2015). Commuters who change behaviour in the opposite direction, from active travel to car use, put on a similar amount of weight (Martin et al. 2015). This benefit of active travel occurs even among people who are sufficiently active without including their travel behaviour (Sugiyama et al. 2013).

<b> Mental wellbeing

Physical activity from active travel is also beneficial for mental health and wellbeing (Martin et al. 2014; Singleton 2018), although cycling for travel can increase fear levels (Singleton 2018). Physical activity reduces the risk of developing depression and can also help to treat depression (Rimer et al. 2012).

Travel can also affect an individual's mental health if it provokes anxiety (Mackett 2021), which might occur as a result of pre-existing mental health conditions. In some cases, the cost of travel or fears for safety may be a cause of anxiety and stress (Curl et al. 2018).

There are benefits for cognitive function and for mental wellbeing from cycling. A trial of cycling, in which participants were asked to cycle at least three times per week for at least 30 minutes each time, found improvements in cognition among both regular pedal cyclists and those using e-bikes, and improved mental health in e-bike users. The authors postulated that it was not only the physical activity but also the opportunity to spend time outdoors (Leyland et al. 2019).

Car use has been called "the stress that doesn't pay" suggesting that while there are potential perceived benefits, these are not worthwhile in the long term (Stutzer and Frey 2008). For example, the use of car as a commute mode is associated with lower levels of commute wellbeing than other modes (Smith 2017).

<b> Towards healthier travel behaviour

This section has outlined multiple ways in which travel behaviour patterns influence health outcomes for individuals and population. We have highlighted how our collective behaviours,

and most typically reliance on private motor vehicles, leads to population health challenges and inequities. However, travel is important for promoting health and wellbeing, and facilitating access to important destinations. In the sections above we focussed predominantly on how the ways in which we *do* travel can be harmful to health. However, being unable to travel due to poor health or poor access to transport can lead to social exclusion and poor social capital, which impact on health (Mackett and Thoreau 2015). Yet, in many cases, travel by modes other than car can be difficult, and those with the ability to travel by car enjoy benefits of easier access to a wide range of opportunities. Uneven patterns of accessibility across the population can therefore be associated with inequitable health outcomes, as different people are afforded different opportunities depending on the mode(s) of transport available to them. This is most obvious in access to healthcare, for example, where those with poor access are more likely to miss appointments or be unable to attend due to the cost or non-availability of transport (Hartley et al. 2021). Lack of access to other destinations, such as employment, education and opportunities for social interaction, also impact on health outcomes by limiting opportunities (Mullen et al. 2020).There are strong links between employment, education levels and mental wellbeing (Farber and Páez 2009; Bambra 2010; Kenyon 2011; Mackett and Thoreau 2015).

Those who have fewest affordable and available options and who travel least often suffer most from the transport-generated harms due to excess travel of others. Susan Claris, of Living Streets UK, refers to the latter as *'transport gluttony'*. Mattioli (2016) suggests that targeting excess travel, or "wants" such as air travel and long distance travel, are the best targets for reducing the environmental impacts of excess travel while reducing equity concerns.

In our car dependent urban environments, car ownership and use *can* be the easiest and most stress-free way to travel for some individuals, as well as widening access to opportunities (Mullen et al. 2020), leading to a paradox whereby car ownership can be seen as beneficial to health and wellbeing at the individual level; indeed there is often a strong relationship between car ownership, income and deprivation whereby those with higher incomes and higher rates of car ownership have better health outcomes. However, the relationships are more complicated than to assume that car ownership and use can therefore improve health outcomes. The benefits of car use are both because of spatial planning that assumes car use, making access through other travel modes difficult, costly, and/or time-consuming, combined with the confounding effect of income/wealth: the more affluent generally have better health and are more likely to be able to afford to buy and run a car. Thus better health outcomes can be achieved by reducing car reliance and ensuing that access is improved for all. This would also help those, especially in rural areas, who can struggle to afford car but have limted travel options.

In many instances, poor accessibility has resulted from urban sprawl as a result of shifts in travel behaviour over time, accelerated by spatial planning decisions. As societies have become more car dependent, cities have been built to meet the needs of those travelling by car, perpetuating car dependence as it becomes impossible, difficult, unsafe, expensive, time-consuming or undesirable to travel by other transport modes. As more people acquire personal vehicles in order to meet their access needs, health problems associated with travel behaviour patterns dominated by private car use escalate, leading to a vicious cycle of car dependence and associated health impacts (Baum 2015).

Redesigning environments to facilitate active travel (walking, cycling and public transport) can both result in immediate direct health benefits to those who can travel by these modes and reduce inequalities in health, but can also have longer term population health benefits by reducing societal dependence on cars.

The system level change to urban environments that can facilitate a shift towards healthier travel behaviours would require changes in the ways in which transport investments are funded and appraised to better account for health impacts and costs. Tools such as the World Health Organization's Health economic assessment tool (HEAT) (World Health Organization 2008; Götschi et al. 2020) can be helpful.

We have discussed how current patterns of travel behaviour impact health but it is also important to think about how changes in travel behaviour over time can influence health outcomes. Policies designed to impact on travel behaviour can have wide-ranging impacts for health but transport policy still often takes place with limited consideration of the health impacts. An example is in current debates around autonomous vehicles which, if they materialise, are likely to have considerable impacts upon travel behaviour and subsequently on health (Fitt et al. 2019; Curl and Fitt 2019).

<A> HOW HEALTH STATUS AFFECTS TRAVEL BEHAVIOUR

Thus far, we have focussed on how travel behaviour impacts health outcomes for individuals and populations. Also important to consider are the ways in which travel behaviour patterns differ because of physical and mental health conditions. We have outlined above that travel is important for access, including to healthcare, employment and social connections. However, often those with health conditions face greater challenges in travelling, meaning their travel behaviour patterns are different from that of the wider population. Furthermore, if health conditions mean that people cannot travel or it is more difficult for them to do so, these impacts can further perpetuate ill health. This highlights the complex and reciprocal nature of the relationships between travel behaviour and health, whereby travel behaviour impacts on health outcomes, but is also impacted by our health status, resulting in complex feedback loops in the relationships between travel behaviour and health.

<b> General physical impairments

The most common physical causes of non-fatal but chronic poor physical health in high income countries are musculoskeletal conditions, affecting 1.7 billion people worldwide (WHO 2021b). These can lead to marked impairments in the ability to travel, for example through an inability to walk far or quickly enough, or to climb steps, making some train stations and buses inaccessible.

As people age, their ability to be mobile and thus their mobility options change. This means that travel behaviour can change, affecting the range of destinations people are able to reach, which can in turn impact health outcomes. Declining function in older people affects their travel behaviour through reducing their mobility options (Silverstein et al. 2017) as people may be unable to drive, and walk shorter distances or more slowly. The impacts of ageing on travel behaviour is covered in more detail in chapter XX of this volume.

Signalised pedestrian crossings in many countries use an assumed walking speed of 1.2m/s [2.7mph; 4.3kph]. Several studies have shown that the normal walking speed of most older people is well below this, for example in England (Asher et al. 2012; Webb et al. 2017), South Africa (Amosun et al. 2007) and Brazil (Duim et al. 2017). Therefore, models of travel behaviour which assume an average speed of travel are likely to over-estimate access for those with reduced mobility (Curl 2018).

Trip frequency, mode or distances can be influenced by a concern about falling. Although we previously discussed injury as a health outcome related to travel behaviour, injury risk can also influence travel behaviour. Trips and slips when walking along the street are well-recognised issues for older people, whose injury and fatality rates are an order of magnitude greater than among younger people (Feleke et al. 2018) due to both increased risk of falling and increased severity of the resulting injuries because of frailty or pre-existing conditions. The risk of falling, even among those who have not fallen, can lead to fear of falling and activity avoidance (Wijhuizen et al. 2007)..

Concerns about falling, or barriers such as a poor walking environment and inadequate crossing times can deter people from going out, especially where they need to cross a busy road REF. This can include not using public transport as reaching the station or bus stop will often require a major road to be crossed. This is particularly a problem for people with mobility impairments (whether musculoskeletal or sensory) and those using walking aids or a wheelchair. It includes those with temporary impairments, such as a broken leg, as well as chronic conditions.

In addition to physical impairments that impact bodily mobility as summarised above, physical impairments includes sensory impairments. Visual and/or hearing impairments can have considerable impact on the journeys that people are able to make and the experience of travel. For example, the availability of information in different formats, changes to streets and the attitudes of public transport staff can make it unpleasant or difficult to travel. People with sensory impairments may develop strategies to travel particular routes or at particular times of day.

<b> Specific physical illnesses

This sections outlines some ways in which specific physical illnesses can impact travel behaviour.

People who experience a heart attack or stroke will usually have legal constraints on being allowed to drive; this can be permanent for those operating a heavy good vehicle or public service vehicle. For a stroke, the ability to drive safely will vary according to the nature of the residual problems. For example, while adaptations to vehicles can be made for arm or leg weakness or loss of function, this cannot be done for visual problems (whether affecting the eye or the brain) (Mindell et al. 2014). People with neurological diseases may have the same problems as those who have had a stroke and may also cause difficulties with balance. Occupational therapists are trained to conduct driving assessments – and can also contribute evidence where older people are being urged by relatives to stop driving. Unfortunately, the problems that affect the ability to drive can also make walking, cycling, or using public transport problematic.

Musculoskeletal disease can interfere with the ability to travel, whether through pain, an inability to stand for long or to walk more than a short distance. Climbing stairs, including at train stations, or on and off buses may be impossible or take longer than bus drivers, operators, or other passengers may tolerate – or the affected individual may perceive they are being a nuisance and so avoid such trips. There can also be problems in getting in or out of a car. Cycling can be a successful travel mode for people whose ability to walk is limited and some anecdotal evidence suggests that e-scooters have extended the range of travel for those with respiratory conditions.

One problem with travel is the need for toilets, experienced by most people at some time and particularly by those with young children out of nappies, and by older people with urgency. This can be a major problem affecting the ability to travel and the choice of travel mode for those with gastro-intestinal disease, urinary tract disease, some neurological diseases, or pregnant people with frequent and/or urgent needs for a toilet. For longer journeys, trains can provide the necessary facilities, although reaching the station can be a problem, given the lack of public toilets in most places.

<b> Mental illness

Poor mental health is very common. 'Common mental disorders' include anxiety and depression, affecting one-quarter to one-third of the population at some time, although rates vary by country income level and geographical region (Steel et al. 2014).

Little work has been conducted on the impacts of mental illness on travel behaviour. To travel, a wide range of skills are required, including the ability and confidence to concentrate; access, remember, process and interpret information; interact with strangers; and make decisions.

A survey by Mackett (2021) found a wide range of difficulties among people with poor mental health, most of whom had anxiety and/or depression. Interacting with other people was the commonest problem reported, with difficulties coping with other people's behaviour and concerns over how other people perceived them. Problems were reported with interactions both with staff and with other passengers. A lack of support was the second most commonly cited problem, both because of feeling a lack of control and needing other people's help. Unfamiliar environments were another cause of anxiety, as were wayfinding and buying tickets. Problems of wayfinding included feeling disorientated, being lost, and needing to find the route. Other problems included worries about what to do if/when the travel mode failed and alternative arrangements were required: this could be beyond some people's tolerance levels. In many cases, travel that needs advance planning could not be undertaken if an individual's condition varies considerably day-to-day; a rail ticket booked in advance could be wasted if the individual felt unable to travel that day, while booking on the day of travel, or buying a flexible ticket that is not at a set day/time, are too expensive. Because of these problems, poor mental health can lead to people not leaving home, resulting in loss of access and social interaction and the benefits of these (Mackett 2021). This problem is exacerbated in people with agoraphobia or obsessive compulsive disorder, who may feel unable to travel at all or need a companion and support. There are also specific phobias related to certain travel modes, including fear of flying (aerophobia) and of trains

(siderophobia) (Mindell et al. 2014). People with mental health challenges can find travel by taxi reduces the mental complexity of trips, but there is relatively little research or understanding of taxi as a mode of transport (Mackett 2021).

Motor vehicle crashes are higher among drivers with severe mental illness and those using psychotropic medications such as benzodiazepines, which cause drowsiness (Mindell et al. 2014).

<b> Cognitive impairment

Those experiencing cognitive decline, up to and including dementia can face difficulties with travel. For example, short-term memory loss can lead to major difficulties with way-finding, whether remembering one's home address or where to catch which bus, or how to obtain a ticket. Cognitive decline and particularly dementia also affect the ability to drive, and increases the mismatch between ability and self-rated safety as a driver (Freund et al. 2005). Policies for 'dementia-friendly cities' that can prolong independence are important not only for the wellbeing of people with dementia but also for their carers. Stress levels increase and wellbeing decreases for family members and others who support people with dementia if they need to act as chauffeurs at frequent intervals in addition to providing other practical or emotional support.

Those with learning difficulties often have similar problems, but without the ongoing decline in cognitive function, With sufficient support, those with milder disability can learn to travel specific routes independently.

<b> Considering a broader range of needs in travel behaviour studies

Travel behaviour modelling tends to focus on the average traveller, in particular when considering travel speeds. The examples above show ways in which physical and mental health status mean that the travel behaviour of those with such conditions can differ significantly from the "average" person upon which travel behaviour is typically modelled. Moreover, the 'average' traveller is usually assumed to be a commuting man. This is problematic from a health equity perspective, because those people that are already marginalised in terms of participation in society can be further excluded as transport systems are designed based on an understanding of the travel needs of the general (able white male) population, and ignoring the needs of those who already face significant challenges accessing everyday destinations. Design of cities and transport systems that further exclude those who already experience health challenges can further exacerbate health challenges and increase isolation.

Although there is an increasing evidence base around the travel behaviours and challenges of those with different health statuses, needs are often not well understood by transport planners and modellers. For example, measures of spatial accessibility, which are designed to draw attention to inequalities in access still build in assumptions that are "gendered, ableist, racialised, classed and aged" (Middleton & Spinney (2019)), as they are based largely on an average travel time and fail to account for other barriers impacting the ability to travel.

<a> COVID-19 AND TRAVEL BEHAVIOUR

Changes to travel behaviour as a result of COVID-19 lockdowns and restrictions have drawn sharp attention to the reciprocal relationships between health and travel behaviour. The virus spread rapidly partly because of our hyper-mobile society, and subsequently travel has been restricted by efforts to contain the spread, with subsequent implications for health. This section summarises the impacts of travel behaviour on the spread of disease changes in travel behaviour and the health implications of the changes in travel behaviour associated with restrictions.

<b> Impacts of travel behaviour on spread of communicable diseases

Research in recent decades had predominantly focussed on the importance travel behaviour for of non-communicable diseases. However, from early 2020, the impacts of international travel behaviour on the spread of COVID-19 were obvious. The virus spread rapidly, partly because of our hyper-mobile society, and subsequently travel was restricted, globally and locally, in efforts to contain the spread. Concerns about COVID-19 also resulted in changes to local travel behaviours, with many commuters avoiding public transport where they had other options.

The pandemic has highlighted the privilege of immobility, or the ability to choose whether or not, and when and how to travel in order to minimise exposure to disease. Those who had the least choice, and have to travel for work, often using public transport, are also those most likely to have pre-existing disease or risk exposures ('co-morbidity') particularly diabetes, smoking rates, ethnicity, low paid jobs, overcrowding) exposing them to infection and more severe consequences of infection.

<b> Health impacts of travel changes associated with pandemic restrictions

In the section above we focussed on how individual health impairment might impact upon travel behaviour. However, the pandemic has shown that concerns about exposure to disease can also affect travel behaviours (Lyons 2021). The COVID-19 pandemic – and government responses – demonstrate clearly the importance of travel behaviours on health-related behaviours and exposures. Travel fell dramatically during lockdowns with both positive and negative health impacts. The number of steps people took fell markedly, with a geographical and time pattern reflecting the timing and nature of local regulations (Tison et al. 2020). There has also been increased reluctance to use public or shared transport in many countries (Lee et al. 2021) but not all (Nguyen and Pojani 2021).

These changes have had immediate impacts on some short-term health impacts associated with travel behaviour including injury, local air pollution and greenhouse gas emissions. In the UK there was a decrease of 14% in road casualties during 2020 compared with the previous year (Christie, 2021). In April 2020 there were nine deaths on the road in New Zealand, compared with 45 in April 2019 and 26 in April 2018 (Ministry of Transport 2022). April 2020 covered the period of the strictest lockdown in New Zealand, which has a notoriously high road death rate over the Easter holiday period. Road traffic noise also fell markedly, as was noticed across the world as traffic levels plummeted during lockdowns to control the COVID-19 pandemic (Basu et al. 2021). Changes in travel behaviour were also

accompanied by falls in ambient air pollution in many countries, particularly particulate matter (Albayati et al. 2021; Polednik 2021; Rahman et al. 2021) although these have been cases where car use, or industrial emissions, have returned to pre-pandemic levels (Albayati et al. 2021). In the UK, reductions in travel during the COVID-19 pandemic restrictions in 2020 were associated with a step-change fall in greenhouse gas emissions (GOV.UK 2021). However, ozone levels rose in some areas during lockdowns, for example, in Brazil (Siciliano et al. 2020). Restrictions on mobility and social interactions have had negative impacts on loneliness and mental health (partly due to anxiety about employment, education, income and risk of disease, but also through lack of social contact), with widespread increases in NCD risk factors such as smoking, alcohol consumption and obesity. However, many people have also had positive experiences of low cars, low noise and air pollution; hearing bird song, for example (Wild 2020). Although these changes are unlikely to have longer term impacts on health, given the relatively short term nature of restrictions they do draw attention to the ways in which changes in travel behaviour have the potential for significant health impacts.

In addition to these short term changes in travel behaviour and immediate obvious health impacts there are likely to be long term changes in travel behaviour due to the COVID-19 pandemic (van Wee and Witlox 2021). Such changes may have both positive and negative implications. This includes some people travelling less frequently by working from home more often. However, over the longer term this might mean travelling longer distances less frequently so that while frequency of travel may change, distances may not, as people offset less frequent travel by moving further away from work. Fear of infection has been shown to influence the use of public transport, although use of public transport reduced this fear, showing complex and cyclical relationships (Kroesen et al. 2023).

With easing of restrictions, people in wealthier areas, many of whom could work from home, reduced the number of trips more than those in less affluent neighbourhoods, who were more likely to have more precarious employment or jobs that required their physical presence (Kim et al. 2021). Avoiding using public transport sometimes resulted in deferring medical care. In Canada, this was more common among those from a minority ethnic group, those with a disability, with no access to a vehicle, and/or a low income (Palm et al. 2021). Worldwide, walking and cycling remained increased above usual levels; car use gradually rose toward pre-pandemic levels, as people who could do so chose to avoid public transport (Linares-Rendón and Garrido-Cumbrera 2021). ‘Essential workers’ were particularly likely to use active travel as a preferred behaviour (Cusack 2021). Urban mobility fell worldwide, particularly use of public transport, but less so in LMICs where most people have no other options for trips too long to walk or cycle and where in-person work is required. Indeed, lower-income workers are those least likely to be able to work from home and therefore need to continue to travel (Linares-Rendón and Garrido-Cumbrera 2021). In many respects the pandemic and associated restrictions acted as a multiplier of existing transport poverty issues -those who faced difficulties with access, found that these were compounded (Cochran 2020), especially for those without a car.

<A> SUMMARY AND CONCLUSION

Our societal reliance on private motor vehicles as a mode of transport imposes health risks on others by generating air and noise pollution; making large contributions to greenhouse gas

emissions and thus climate change; deterring use of the streets for health-enhancing active travel and social contacts; and causing serious, or fatal, injuries. Active travel, primarily walking or cycling, can provide sufficient physical activity to meet health-based recommended activity levels, in some instances even from active travel to and/or from public transport. Physical activity reduces ill-health and deaths from obesity, high blood pressure, respiratory and circulatory diseases, and some cancers. It also reduces depression and osteoporosis and improves mental wellbeing. Individuals' mental and physical health status and socio-economic and demographic characteristics, alongside the built environment and the availability of shared transport, are important in determining what travel choices people have, and the impacts of these on their own and other people's health. There are also health consequences of choosing or being forced not to travel, resulting in social isolation and/or lack of access to health-improving destinations.

There are many inequalities associated with travel behaviour. Most of these are imposed by motor vehicle users on others. Air pollution causes and exacerbates respiratory and circulatory diseases but also diabetes and dementia. Noise pollution interferes with sleep and concentration, resulting in high blood pressure and lower educational attainment, with long-term health implications. Most serious injuries result from collisions with a motor vehicle, although the major health consequences for older people of a fall while walking should not be overlooked.

Transport policy has considerable impacts on travel behaviour, which is a key determinant of health and health inequalities. Travel behaviour change is potentially a powerful tool for population health improvement but health consequences and impacts on inequalities need to be explicitly considered in transport policy. Efforts to change travel behaviour often focus on changing individuals' attitudes towards certain modes of transport, but in order to see the change required to improve population health outcomes, efforts need to be focussed on built environment interventions. These can reduce the amount of travel required, through spatial planning for mixed developments, such as the 15 or 20 minute city., and can facilitate healthier modes of travel by improving the environment in which people make their travel decisions. Examples include improved walking and cycling infrastructure and (enforced) slower speed limits for motor vehicles. However, it is important that such concepts don't perpetuate existing inequities by focussing average journey times and recognising that a "15 minute" city may look very different when considering current disparities in travel behaviour according to age, gender, ethnicity, socio-economic factors, and health status. Doing so may limit options available and perpetuating existing inequities and often poorer health among some groups.

Although we have predominantly described reasonably straightforward and direct implications of travel behaviour on health and vice versa in this chapter, it is also important to acknowledge the more indirect and complex causal pathways, and the political economic context that can make travel behaviour change difficult.

As briefly discussed in the injury section, relationships can be complex and paradoxical. Often perceived safety has a larger influence on travel behaviour than actual levels of safety of different modes. Perceived safety can be influenced by societal norms, media and politicians, making change to perceptions and therefore travel behaviour a complex issue.

While we have focussed predominantly on the impact of the ways in which people *do* travel on health outcomes, it is also important to consider desired trips not made due to barriers to travel (for example availability, affordability, accessibility, community severance, and fear of injury). Other people's travel behaviour, as well as the nature of transport infrastructure and individuals' existing health, also affect whether people travel. In particular, motor vehicles deter active travel, particularly among children and older adults, due to noise, air pollution, and the real and perceived risks of injury (Jacobsen et al. 2009).

If people cannot travel, they can become isolated and unable to reach employment or education opportunities, health appointments, or meet others. People with physical or mental health conditions are more likely to face a wider range of barriers, and therefore avoid trips, perpetuating health conditions and increasing risk of co-morbidities.

It is important to distinguish between choosing to travel less and not being able to travel. It is beneficial to self and to the general population to travel less (particularly by motorised modes), releasing time e.g. spent commuting, where people can work outside the home on fewer days than previously while still accessing the goods, services, destinations, and social contacts needed for a healthy life. However, not being able to travel, or travelling only with others' help due to mobility impairments, financial constraints, or lack of realistic travel options, particularly in rural areas, can have the adverse health and wellbeing consequences listed above, not only from isolation and loneliness but through lack of access to desired destinations.

Many countries and cities are introducing policies to change travel behaviour to achieve mode shift, in recognition of the harmful effects of car use on population health. However, policies which seek to restrict travel by car where adequate alternatives do not exist can lead to equity concerns (Mattioli 2016; Curl et al. 2020). Instead, efforts should be focussed on reducing the need to travel through changes to the built environment, allowing people to access essential goods, services and social connections without having to travel large distances. New Zealand's Emission Reduction Plan has outlined the need to reduce overall vehicle kilometres travelled in order to meet emissions reductions targets (Ministry for Primary Industries). This marks a step-change in transport policy that has traditionally sought to meet growing demand for travel as a result of population growth.

The built environments in which we live are key determinants of health and wellbeing (Baum 2015; Giles-Corti et al. 2016). The influence of the built environment on travel behaviour and therefore health outcomes is one key mechanism by which the built environment influences health and wellbeing. Over the long term, travel behaviour can also influence urban form and the built environment (as noted in other chapters in this volume), including distances travelled and opportunities for travel by different modes, meaning that there are complex causal pathways and feedback loops between the built environment, travel behaviour, population health, and inequalities.

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