12 Travel behaviour and health

Bert van Wee and Dick Ettema[1]

12.1 INTRODUCTION

The health impacts of the transport system are a topic of growing importance in both research and policy making. These impacts first of all apply to people in their role of travellers, but in addition the health of non-travellers is influenced by the travel behaviour of other people, an important reason being the exposure to pollutants and noise. The growing interest in the links between travel behaviour and health are partly the result of the increasing focus on cycling (and also walking) in research and policy. This interest is due to the simple reason that cycling (and walking) are forms of exercise, and they are thus healthy. Several cities worldwide have implemented cycling policies, examples being New York, Portland, London, and Paris. In addition, the increased interest in the relationship between travel and health is due to the growing concerns about the effects of urban air pollution on public health.

This chapter aims to give an overview of the health impacts of the transport system. We start by discussing the links between travel behaviour and health of travellers (Section 12.2), followed by the links between travel behaviour and health of non-travellers (Section 12.3). Section 12.4 summarizes the most important conclusions. Because some of the health effects depend on environmental pressure and safety, we refer to Chapters 10 (environment) and 11 (safety) for factors influencing environmental pressure and safety levels, and in this chapter, we only pay limited attention to these factors. Because health and well-being effects are strongly related, as we will explain below, we also discuss the dominant well-being effects of the transport system.

12.2 A CONCEPTUAL MODEL FOR THE LINKS BETWEEN TRAVEL BEHAVIOUR AND HEALTH

The WHO defines health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO, 2020). We adopt this definition but apply a demarcation: we exclude the social dimension, the reason being that the social dimension is only indirectly related to the links between travel behaviour and health. Next, we distinguish between a mental and physical component of health. Both are interrelated, but distinguishing both allows us to better conceptualize the links between travel behaviour and well-being on the one hand, and physical health on the other hand. In line with generally used terminology, we use the term 'health' to denote physical health, and 'subjective well-being' to denote mental well-being. Subjective well-being and mental health are related. However, whereas mental health studies focus on symptoms of mental illness, such as anxiety or depression, well-being studies focus on a wider spectrum of mental states, which also differentiate between people without symptoms of mental illness.

We conceptualize that the following travel-related components impact the health of travellers:

1. Level of physical activity
2. Air pollution intake
3. Casualties/injuries
4. Subjective well-being

These factors are interrelated; for instance, walking and cycling may result in increased subjective well-being (Olsson et al., 2013), but may also lead to crashes/falls. Incident risks could be a reason for people to reduce or eliminate their walk or cycle trips (see Lee et al., 2015). In addition, high concentrations of pollutants may deter people from cycling or walking.

Figure 12.1 presents a conceptual model for the dominant links between travel behaviour and health of the traveller. It relates to the conceptual model explaining the structure for a large part of this book, Figure 2.1 ('A conceptual framework for the book: How the transport system shapes travel behaviour and impacts accessibility, the environment, safety, health, and well-being'), but contrary to that figure, Figure 12.1 is a figure at the individual level. 'Travel behaviour' is the individualized factor of the 'volume' factor in the core of Figure 2.1. 'Residential choice' is a subcategory of the 'locations' factor, and 'personal characteristics' are major drivers for the 'needs and desires' of people. Figure 12.1 shows that the health effects of travel result from physical activity (component A in Figure 12.1), exposure to and intake of air pollutants (B), and involvement in casualties/collisions/falls (C). These health effects are well documented, see for example, Handy (2014) or Cohen et al. (2014). In addition, we assume that health and subjective well-being (D) are related, but the causality is debatable. Subjective well-being is commonly defined as a combination of a person's assessment of his/her quality of life and satisfaction with life, and his/her affective state, as the net effect of positive and negative emotions (Ettema et al., 2010). Studies of subjective well-being show health to be the most important determinant of life satisfaction (e.g., Walasek et al., 2019). On the other hand, we argue that a sufficient level of satisfaction with life and a good mood are beneficial to one's physical health. Diener and Chan (2011) and Diener et al. (2017) extensively review empirical longitudinal studies in this area, concluding that an individual's current affective state influences physiological health indicators measured afterwards such as blood pressure, inflammatory activity or immune functioning. In addition, they report many long-term longitudinal studies showing the impact of subjective well-being on longevity and developing diseases several years to decades later.

The conceptual model includes the dominant, but not all, relationships between factors important for the relationships between travel behaviour and health. Three examples highlight other factors that are excluded from the conceptual model. First, health also depends on genetics and other behaviours, like smoking and drinking. Second, high levels of accessibility may positively influence well-being, whereas social exclusion (the fact that people cannot adequately participate in society because of too low levels of access to destinations) could negatively influence well-being. For the links between health, transport, and social exclusion we refer to Mackett and Thoreau (2015). Third, the final impact of casualties and the health impacts of exposure to pollutants also depends on access to (Bauer et al., 2020) and the quality of the health care system. Because of the scope of this chapter and to reduce complexity such factors are not included in our conceptual model, nor discussed further in this chapter.

The conceptual model includes numbered lines for the direct relationships between (factors influencing) travel behaviour and health. In addition, dashed lines represent relationships relevant for the understanding of causalities, but these lines do not represent direct relationships between travel behaviour and health – we do not further discuss these in this chapter. It is good to realize that the conceptual model we present is not the only conceptual model available in this area. For another model see, for example, Glazener et al. (2021).

12.2.1 Dominant First Order Relationship

We next discuss the dominant direct relationships between travel behaviour and health (bold lines in Figure 12.1), in other words:

1. From travel behaviour to physical activity (arrow 1)
2. From travel behaviour to pollution intake (arrow 2)
3. From travel behaviour to casualties (arrow 3)
4. From travel behaviour to subjective well-being (arrow 4)

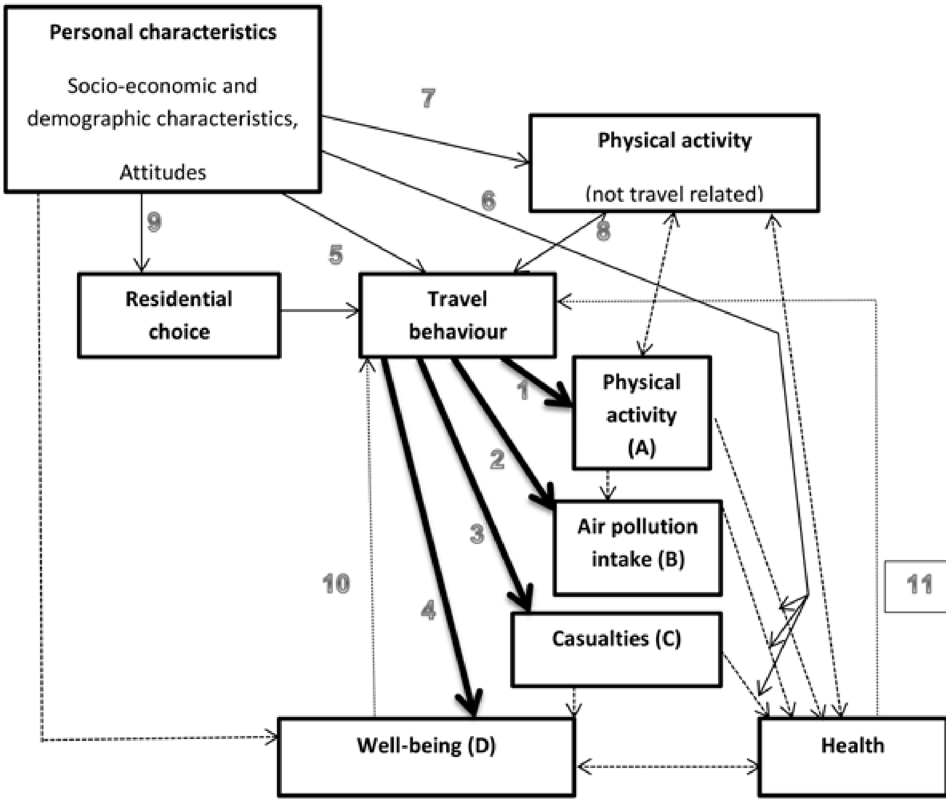
These relationships are ‘first order’ relationships because travel behaviour influences health via these routes. We call all other relationships in Figure 12.1 ‘second order’ relationships. There is much more research on first order effects than on the second order effects.

Travel behaviour and physical activity (arrow 1)

For health reasons, adults should be moderately physically active (MPA) for 150 minutes or vigorously physically active (VPA) for 75 minutes every week. They can also combine the two pro rata (US Department of Health and Human Services, 2019; UK Department of Health and Social Care, 2019). Walking and cycling can contribute to meeting these requirements (Handy, 2014), especially when it is part of people’s daily routines. The time and intensity of walking and cycling depends on the chosen destinations (distances) and routes and the frequency of walking and cycling trips.

Travel behaviour and air pollution intake (arrow 2)

The exposure to air pollution applies to all categories of travellers, ranging from drivers and passengers of cars and other motorized vehicles, people cycling and walking, and people



Note: bold lines represent dominant impacts of travel behaviour on health aspects. Numbered lines represent the direct relationships between (factors influencing) travel behaviour and health. Dashed lines represent other relationships between boxes in the model.
Source: adapted from van Wee and Ettema (2016)

Figure 12.1 Conceptual model for the relationships between travel behaviour and health

travelling by underground. Concentrations of pollutants are highest on the roads, and they decrease as distance from the road increases (Janssen et al., 2002), so drivers and passengers of motorized vehicles are exposed to relatively high concentrations. Based on an overview of literature, van Wee (2007) concluded that concentrations of pollutants in vehicles are between 1.5 and over 10 times higher than in the ambient air. Concentrations of pollutants depend on the density of traffic and technical characteristics of vehicles (strongly related to year of manufacturing vehicles and engine/fuel type) and the distance between the recipient and these sources. For the importance of this distance for cyclists we refer to Schepers et al. (2015). In addition, ambient factors such as the morphology of the built environment, trees, and weather (temperature, wind speed) influence the dispersion of pollutants and consequently concentrations and exposure. Although cyclists are exposed to lower concentrations than drivers, because of the larger distance between cyclists and polluting vehicles (Mitsakou et al., 2021), cyclists inhale more air than car drivers, because they are physical active (van Wee, 2007). In Figure 12.1 this effect is conceptualized via the arrow from 'physical activity' to 'air pollution intake'. In addition, the exposure to pollutants of cyclists and pedestrians depends on travel speed. The higher the speed, the higher the breathing rates, and the higher the pollution inhaled per unit of time (Nyhan et al., 2014). However, for a given trip higher speeds also imply shorter travel times, and thus a shorter duration of exposure. The latter effect generally prevails, leading to less exposure when cycling or walking faster (McNabola et al., 2007).

People travelling by underground are often exposed to high concentrations of PM originating from mechanical friction process (wheel on rail, brakes); see Şahin et al. (2012) for a study on particles containing Fe (iron) and Cu (copper) in six subway stations in Istanbul, and Cheng and Yan (2011) for a study on particulate matter (PM) concentrations in underground environments in Tampei.

Negative health effects due to the exposure of pollutants include cardiovascular diseases, eye and throat irritation, respiratory health problems (asthma, lung damage), high blood pressure, neurological disorders and cancer, and brain and kidney damage, amongst others *see* Handy (2014) for a detailed overview of health effects of pollution. The extent to which these effects occur depends not only on the duration and accumulation of exposure, but also on personal characteristics. For instance, infants, the elderly, and pregnant women are more sensitive to certain pollutants (Lee et al., 2021). In addition, one's health status, resulting from certain behaviours such as smoking, obesity, and diabetes has an impact on the health effects resulting from exposure.

Travel behaviour and casualties (arrow 3)

Travelling goes together with incident risk. Risks relate to fatalities and injuries. No mode is 100% risk free. Risk factors are mode-specific and for road-related modes they vary between road types (see Chapter 11 of this book). It is important to realize that risk factors are highly context specific, and probably even more so for cycling than for driving, because cycling is very common in some countries (such as Denmark and the Netherlands) but not in others (such as the USA), resulting in large differences in cycling infrastructure, experience of cyclists, and the behaviour of drivers of motorized vehicles. In addition, it is not at all straightforward to estimate the risks and incident rates of *additional* cycling (and probably also walking), for several reasons. Firstly, higher cycling levels result in lower risk factors (the so-called 'safety in numbers' effect – see Elvik and Goel (2019) for a meta-analysis of many quantitative studies exploring this phenomenon). Secondly, for decisions on policy options competing trips should be compared. In other words, comparisons should not be based on aggregate average risk factors. People do not substitute a long interurban car trip of, for example, 75 kilometres for a cycling trip. But they might be inclined to substitute a 3-kilometre urban trip. In that latter case the comparison should be based on risk factors for urban roads only. Thirdly, in many countries there is a lack of data on cycling behaviour (Handy et al., 2014). Fourthly, cycling is poorly included in mainstream transport models, even in countries with a strong cycling tradition like Denmark and the Netherlands, limiting the usability of models for *ex ante* evaluations of candidate policy options. Finally, the mode specific risk factors are influenced by different risk-taking behaviours dependent on gender and age, and the different gender and age characteristics of users of different travel modes (Mindell et al., 2012).

Travel behaviour and subjective well-being (arrow 4)

The effect of travel on subjective well-being may materialize in different ways. Firstly, the experience of travel itself and the interaction with the physical and social environment during travel may influence one's mood and well-being. Secondly, access to travel facilitates participation in meaningful activities that foster subjective well-being (Ettema et al., 2010; Churchill and Smyth, 2019). Both effects will be discussed here.

The travel environment to which one is exposed has an impact on one's mood, as a result of direct emotional responses. In case of repeated trips (such as commuting) the aggregation of these responses has an impact on one's overall subjective well-being (e.g., Stutzer and Frey, 2008). These effects have been shown first and foremost in relation to different travel modes (e.g., Olsson et al., 2013; Abenoza et al., 2017; Friman et al., 2017). A consistent finding across different geographies is that active travel modes (walking, cycling) are associated with higher levels of satisfaction and well-being than car and public transport, and that public transport is associated with the lowest level of well-being (Ye and Titheridge, 2017; Olsson et al., 2013; St-Louis et al., 2014). The effect of different public transport modes is not consistent, and it appears to depend on the context and the quality of local public transport. For instance, Lunke (2020) found in Oslo that subway users had the highest travel satisfaction, followed by tram, then train and bus scored lowest. Abenoza et al. (2017) found for Stockholm that bus users had the highest satisfaction, followed by train, metro, and tram. Potential explanations for the positive effect of using active modes on well-being include the involved physical activity (Ekkekakis et al., 2008), the higher level of interaction with the environment (Gatersleben and Uzzell, 2007), the experience of autonomy and mastery (Ettema and Smajic, 2015; Ziegler and Schwanen, 2011), and the options active modes offer for social interactions in one's neighbourhood (Ziegler and Schwanen, 2011).

The effect of car driving on well-being via one's mood depends on driving circumstances. Longer duration (e.g., long commutes) and congestion lead to more stress and lower levels of subjective well-being (Novaco et al., 1990). In addition, road characteristics have an impact on the well-being effects of driving (Ettema et al., 2013). The use of public transport is consistently associated with lower satisfaction and lower subjective well-being across geographies (Olsson et al., 2013; St-Louis et al., 2014). Factors that lead to lower satisfaction and well-being while using public transport include critical incidents, such as delays or unpleasant interaction with co-travellers or staff (Friman and Gärling, 2001). More general factors that influence travel satisfaction and well-being across modes include longer trip durations, crowding and congestion.

Travel may also influence well-being in an indirect way, by facilitating participation in meaningful or pleasant activities that contribute to life goals (Pychyl and Little, 1998; Oishi et al., 1999). Levels of access to important destinations for a person and the potential to travel ('motility') therefore influence well-being (not conceptualized in Figure 12.1, but explicitly conceptualized in Figure 2.1) (Mokhtarian, 2019). Lack of transport options may lead to reduced participation in activities and access to relevant activities (Lucas, 2012). Various studies indicate that insufficient transport options are associated with less involvement in social, cultural, and economic activities and lower subjective well-being (Lucas, 2012; Delbosc and Currie, 2011). Well-being also depends on characteristics of the environment, as explained above (arrow 4) and as conceptualized and explained in Chapter 2, for example, because of the attractiveness of the environment, or noise levels.

12.2.2 Second Order Relationships

In addition to these first order relationships between travel behaviour and health, Figure 12.1 show that several second order relationships exist:

1. Socio-economic and demographic characteristics and travel behaviour (arrows 5, 6, 7)
2. Physical activity: walking and cycling versus physical activity that is not related to travel (arrow 8)
3. Subjective well-being and the use of active modes (arrow 10)
4. Health and travel behaviour (arrow 11)
5. Self-selection effects (arrows 5 and 9)

Socio-economic and demographic variables (arrows 5, 6, 7)

The importance of socio-economic and demographic variables for travel behaviour (arrow 5) is generally recognized, examples being age, education level, gender, and household characteristics (see Chapter 16). In addition, as conceptualized via arrow 6, demographic variables can also influence the impact of physical activity, crashes/falls and pollution on health. In other words, health impacts may be moderated by personal characteristics, and these effects are studied much less than the direct health effects of travel behaviour. For example, a fall from a bicycle may have more impact on someone who is 85 years old than on a 14-year old. As another example, individuals who are overweight or have diabetes profit more from being physically active than other groups (Bauman, 2004).

The effects of socio-demographic characteristics on travel-related health outcomes may be contradictory, depending on the four mechanisms as conceptualized by arrows 1–4. For instance, whereas the elderly may benefit the most from physical activities such as walking and cycling, they are also more vulnerable to crashes/falls (and will be more seriously injured) and more sensitive to pollution. Note that personal characteristics such as age and gender can also influence non-travel related physical activity (arrow 7) and its impact on health, as well as the impact of well-being on health.

Interaction of travel-related physical activity and other physical activity (arrow 8)

Walking and cycling are not the only two forms of physical activity (Figure 12.1), and therefore people may substitute other physical activities, such as going to the gym, with walking or cycling. This will reduce the additional health benefits of walking and cycling. On the other hand, it is also possible that because people who walk or cycle may feel fitter, they engage more in other forms of physical activity. We hypothesize that both effects occur, probably for different (groups of) people. The scarce studies in this area differ with respect to their results. Forsyth et al. (2008) and Troped et al. (2010) conclude that differences in spatial setting influence the amount of transport and leisure walking, but overall physical activity is not affected. Brown et al. (2015) found that the introduction of a light rail system in Salt Lake City resulted in an increase of physical activity in access and egress travel, and that also the total level of physical activity (PA) increased. Saelens et al. (2014: 854) found that 'transit users had more daily overall physical activity and more total walking than did non-transit users but did not differ on either non-transit-related walking or non-walking physical activity'. Clearly, more research is needed to better understand the relationships between travel related and other forms of physical activity. From a policy point of view, it is very important to know to what extent transport policies that result in more walking and cycling have *additional* health benefits.

Causality of subjective well-being and the use of active modes (arrow 10)

While the use of active travel is mostly assumed to lead to higher travel satisfaction and higher subjective well-being, it can also be argued that people with a higher subjective well-being are more likely to use active modes (arrow 10). While this has, to the authors' knowledge, not been investigated in the context of travel, some studies have addressed the relationship between subjective well-being and physical activity in general. Although most studies focus on the effect of physical activity on mood and mental health (e.g., Wood et al., 2013; Paluska and Schwenk 2000), only a few have investigated the reversed causality. Baruth et al. (2011) investigated the impact of subjective well-being on the effect of a physical activity intervention programme, and found that those with higher subjective well-being were more likely to increase their levels of physical activity. Other studies (e.g., Standage et al., 2012) suggest that the causality might work both ways. The effect of active travel on subjective well-being should therefore be treated carefully, since ignoring the bi-directional causality would lead to an overestimation of the well-being effects of active travel.

Health and travel behaviour (arrow 11)

Travel behaviour not only influences health via the multiple routes conceptualized in Figure 12.1, but health also influences travel behaviour. For example, people with a lower health level might walk and cycle more to improve their health, but it is also possible that their lower health level results in lower levels of walking and cycling. De Haas et al. (2021) found that the latter effect dominates, at least for cycling: people with a higher body mass index (BMI) cycle less than average.

Self-selection effects (arrows 5 and 9)

Related to the causality discussion above, we next address self-selection effects (which are also covered in Chapter 5). People often self-select in several respects. We limit ourselves to self-selection that is related to attitudes, and therefore first generally discuss the importance of attitudes in travel behaviour modelling. Above we already discussed that socio-economic and demographic variables influence travel behaviour (arrow 5). In addition, people's attitudes influence their travel behaviour. Regardless of age, gender, income etc., some people have a preference to travel by car, public transport or bike, or they prefer to walk. From the perspective of health, it is important to realize that attitudes not only influence mode choice (e.g., Lyu and Forsyth, 2021), but also the way people make use of modes, an example being the question if people use information and communication (ICT) devices while driving (increasing risk factors) (Buhler et al., 2021).

We now limit ourselves to the role of attitudes for self-selection. Arrow 9 conceptualizes that people may self-select with respect to residential location, a phenomenon called ‘residential self-selection’ (RSS) – see Chapter 5. For example, people who like travelling by active modes (because of a pro-environmental attitude, or for health reasons), may self-select residential areas that support the use of these modes. Ettema and Nieuwenhuis (2015) conclude that differences in the cycling frequency of people living in different neighbourhoods were partly explained by cycling preferences of people, and these cycling preferences influenced RSS. On the other hand, Van Dyck et al. (2011) conclude that walking behaviour of people living in different neighbourhoods in Ghent was primarily the result of neighbourhood walkability, not so much of walking preferences related RSS. Finally, Handy et al. (2006) found that walking related RSS only limitedly explains differences in walking frequency across neighbourhoods in Northern California. They also noted a substantial independent effect of the built environment on walking frequency. For a review of the literature on the effect of the built environment on walking, cycling and physical activity, we refer to Smith et al. (2017).

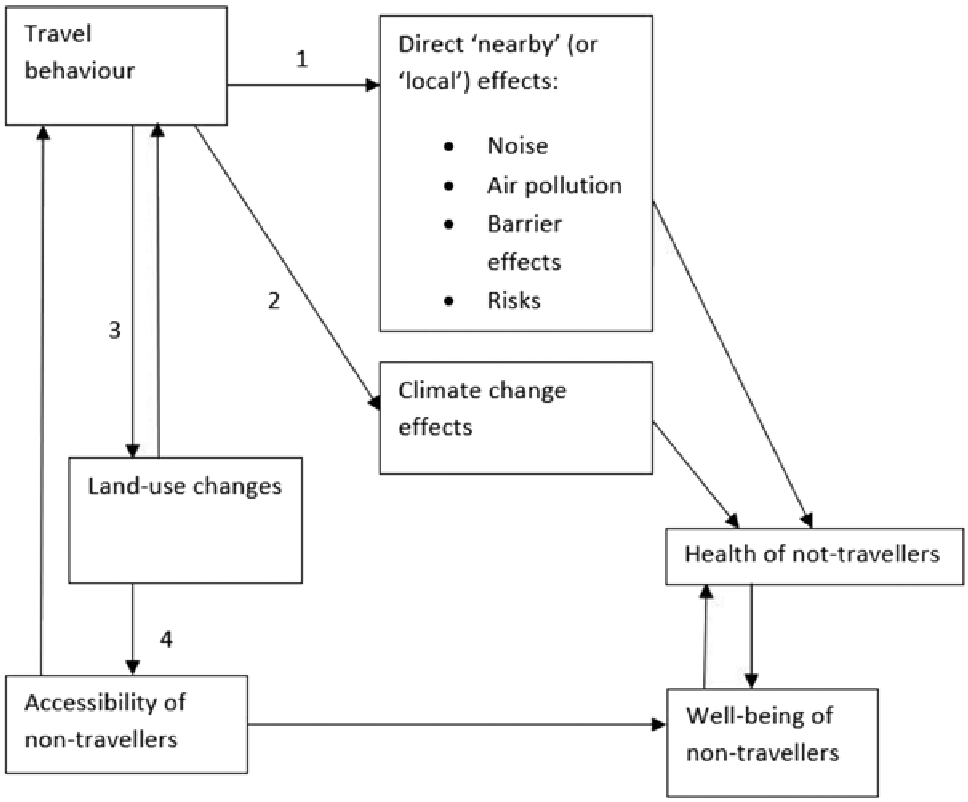
It could also be that (perceived) health of people influences their residential choice (this is not explicitly conceptualized in Figure 12.1). For instance, a person with lung disease may choose a residential location so that they are not exposed to high concentrations of pollutants of traffic (or other sources) (Anselin and Le Gallo, 2006). Or people who are sensitive to noise might select a dwelling in a quiet area. Research in this area is scarce and inconclusive (see, for example, Wardman and Bristow, 2004; Van Praag and Baarsma, 2001; Nijland et al., 2007).

To conclude, it is important to realize that self-selection effects should be better understood for assessing the relationships between travel behaviour and health.

12.3 TRAVEL BEHAVIOUR AND THE HEALTH OF NON-TRAVELLERS

We now broaden our scope to address the health of non-travellers. Travel behaviour of people does not only influence the health of the traveller, but also others, both other travellers and non-travellers. These are called ‘external effects’ or ‘externalities’ in economic literature (see Chapter 13). Because we discussed the relationships of all travellers in Section 12.2, we here limit ourselves to the non-traveller. Figure 12.2 conceptualizes health impacts of non-travellers.

Figure 12.2 shows that travel behaviour of people has an impact on the health of others first of all via nearby or ‘local’ effects (noise, air pollution, risks, and ‘barrier effects’ (e.g., crossing ability) are the dominant effects) (arrow 1). Risks of non-travellers, such as the risks of being affected by a crashed aeroplane or exploding lorry carrying fuels, are relatively rare events. People living or having daily activities (office, school) near trafficked roads are exposed to noise and pollution, as well as experience the consequences of lower levels of liveability (see also Figure 2.1). Traffic also contributes to larger scale air pollution in the form of smog (not explicitly included in Figure 12.2, to keep it simple), but in Organisation for Economic



Source: van Wee (2018).

Figure 12.2 A conceptual model for the dominant relationships between travel behaviour and health of others than the non-travellers

Co-operation and Development (OECD) countries smog is less of a problem than a few decades ago. In addition, people travelling and infrastructure in general result in barrier effects: the more traffic, the more difficult it is to cross streets. And major infrastructures like motorways, other main roads, or railways have limited options to cross at all. Secondly transport contributes to climate change, mainly due to CO_2 emissions (see Chapter 10) and climate change will have a range of health-related effects (e.g., Patz et al., 2005), such as extremely hot temperatures, exposure to flood risks, and the spread of diseases (arrow 2). Next, the transport system and travel behaviour of people in the long run induces land-use changes – see the literature on land-use and transport interaction (e.g., Wegener and Fürst, 1999, and Chapter 5 of this book). For example, if more people travel by car (as opposed to other modes), then shops, companies, and services value car accessibility higher and next might prefer to be placed at locations that are accessible by car (arrow 3). For example, a shift of activities (employment, schools, shops, etc.) to locations accessible by car might result in social exclusion of those not having access to a car, decreasing the well-being of those people, and their health. Land use changes also influence the proximity of green space and reduce the potential health benefits from being close to green space (arrow 4).

To conclude, travel behaviour influences health of non-travellers via many complex mechanisms. Although the conceptual model is not as complex as the model for health of travellers, it is difficult to include all mechanisms in empirical research, possibly resulting in biased results.

12.4 CONCLUSIONS

The main conclusions from this chapter are:

1. Health is a topic of growing importance in transport research and in policy making.
2. Superficially, the impact of travel behaviour on health of travellers seems straightforward, and the argument is related to the level of physical activity (walking and cycling), air pollution intake, casualties, and subjective well-being. However, the relationships between travel behaviour and health are complex. Travel behaviour influences health via multiple direct and indirect routes, and feedbacks and self-selection effects are all evident. In addition, travel behaviour not only influences the health of the traveller, but also of non-travellers, such as people exposed to pollution and noise. The complex nature of the links between travel behaviour and health suggest that researchers should consider advanced research methods.

The second conclusion raises three further recommendations for future research:

3. Because of these complex relationships it is difficult to assess the quantitative impacts of travel behaviour on health. It is not impossible to include all mechanisms included in our conceptual models, and therefore research can easily draw ‘wrong’ conclusions. Research into the area of health and travel should preferably make the conceptual structure of variables (not) included explicit, and it should also discuss the importance of not including important relationships.
4. Because it is difficult to quantify the effects of travel behaviour on health, it is problematic to include health effects in *ex ante* assessments of candidate policies, such as cost–benefit analyses (CBAs) and multi-criteria analyses (MCAs), especially if quantitative effects are needed, such as in case of CBA (see Chapter 15).
5. Several relationships between travel behaviour and health are still poorly understood, and consequently much additional research is needed before health effects can be included in *ex ante* evaluations of candidate transport policy options. Important topics include the interactions between travel behaviour and other physical activity, the complex relationship between cycling and health, and self-selection effects.

NOTE

1. This chapter is partly based on van Wee and Ettema (2016) and van Wee (2018).

REFERENCES

Abenoza, R. F., O. Cats and Y.O. Susilo (2017), 'Travel satisfaction with public transport: Determinants, user classes, regional disparities and their evolution', *Transportation Research Part A: Policy and Practice*, 95, 64–84.

Abenoza, R.F., D. Ettema and Y.O. Susilo (2018), 'Do accessibility, vulnerability, opportunity, and travel characteristics have uniform impacts on traveler experience?', *Transportation Research Part A: Policy and Practice*, 114, 38–51.

Anselin, L. and J. Le Gallo (2006), 'Interpolation of air quality measures in hedonic house price models: Spatial aspects' ['Interpolation des mesures de la qualité de l'air dans les modèles hédoniste de l'estimation immobilière: Aspects spatiaux'], *Spatial Economic Analysis*, 1(1), 31–52.

Baruth, M., D. Lee, X. Sui, T.S. Church, B.H. Marcus, S. Wilcox and S.N. Blair (2011), 'Emotional outlook on life predicts increases in physical activity among initially inactive men', *Health Education and Behavior*, 38(2), 150–58.

Bauer, J., D. Klingelhöfer, W. Maier, L. Schwettmann and D.A. Groneberg (2020), 'Prediction of hospital visits for the general inpatient care using floating catchment area methods: A reconceptualization of spatial accessibility', *International Journal of Health Geographics*, 19(1), Article 29.

Bauman, A.E. (2004), 'Updating the evidence that physical activity is good for health: an epidemiological review 2000–2003', *Journal of Science and Medicine in Sport*, 7(1), 6–19.

Brown, B.B., C.M. Werner, C.P. Tribby, H.J. Miller and K.R. Smith (2015), 'Transit Use, Physical Activity, and Body Mass Index Changes: Objective Measures Associated With Complete Street Light-Rail Construction', *American Journal of Public Health*, 105(7), 1468–74.

Buhler, T., E. Comby, L. Vaudor, L. and T. von Pape (2021), 'Beyond "good" and "bad" cyclists. On compensation effects between risk taking, safety equipment and secondary tasks', *Journal of Transport and Health*, 22, 101131.

Cheng, Y.-H. and J.-W. Yan (2011), 'Comparisons of particulate matter, CO, and CO_2 levels in underground and ground-level stations in the Taipei mass rapid transit system', *Atmospheric Environment*, 45(28), 4882–91.

Churchill, S.A. and R. Smyth (2019), 'Transport poverty and subjective wellbeing', *Transportation Research Part A: Policy and Practice*, 124, 40–54.

Cohen, J.M., S. Boniface and S. Watkins (2014), 'Health implications of transport planning, development and operations', *Journal of Transport and Health,* 1(1), 63–72.

De Haas, M., M. Kroesen, C. Chorus, S. Hoogendoorn-Lanser and S. Hoogendoorn (2021), 'Causal relations between body-mass index, self-rated health and active travel: An empirical study based on longitudinal data', *Journal of Transport and Health*, 22, 101113.

Delbosc, A. and G. Currie (2011), 'Exploring the relative influences of transport disadvantage and social exclusion on well-being', *Transport Policy*, 18(4), 555–62.

Diener, E. and M.Y. Chan (2011), 'Happy people live longer: Subjective well-being contributes to health and longevity', *Applied Psychology: Health and Well-being*, 3(1), 1–43.

Diener, E., S.D. Pressman, J. Hunter and D. Delgadillo-Chase (2017), 'If, why, and when subjective well-being influences health, and future needed research', *Applied Psychology: Health and Well-Being*, 9(2), 133–67.

Ekkekakis, P., E.E. Hall and S.J. Petruzzello (2008), 'The relationship between exercise intensity and affective responses demystified: To crack the 40-year-old nut, replace the 40-year-old nutcracker!' *Annals of Behavioral Medicine*, 35(2), 136–49.

Elvik, R. and R. Goel (2019), 'Safety-in-numbers: An updated meta-analysis of estimates', *Accident Analysis and Prevention*, 129, 136–47.

Ettema, D., T. Gärling, L.E. Olsson and M. Friman (2010), 'Out-of-home activities, daily travel, and subjective well-being', *Transportation Research Part A*, 44(9), 723–32.

Ettema, D., T. Gärling, L.E. Olsson, M. Friman and S. Moerdijk (2013), 'The road to happiness: Measuring Dutch car drivers' satisfaction with travel', *Transport Policy*, 27, 171–78.

Ettema, D. and R. Nieuwenhuis (2015), 'Residential self-selection effects and TOD development: How does relocation motivation influence the effect of built environment?', Paper presented at 2015 TRB Annual Meeting.

Ettema, D. and I. Smajic (2015), 'Walking, places and wellbeing', *Geographical Journal*, 181(2), 102–09.

Forsyth, A., M. Hearst, J. Oakes and K.H. Schmitz (2008), 'Design and destinations: Factors influencing walking and total physical activity', *Urban Studies*, 45(9), 1973–96.
Friman, M. and T. Gärling (2001), 'Frequency of negative critical incidents and satisfaction with public transport services. II', *Journal of Retailing and Consumer Services*, 8(2), 105–114.
Friman, M., T. Gärling, D. Ettema and L.E. Olsson (2017), 'How does travel affect emotional well-being and life satisfaction?', *Transportation Research Part A: Policy and Practice*, 106, 170–80.
Gatersleben, B. and D. Uzzell (2007), 'Affective appraisals of the daily commute: comparing perceptions of drivers, cyclists, walkers and users of public transport', *Environment and Behavior*, 39(3), 416–31.
Glazener, A., K. Sanchez, T. Ramani, J. Zietsma, M.J. Nieuwenhuijsen, J.S. Mindell, M. Fox and H. Khreis (2021), 'Fourteen pathways between urban transportation and health: A conceptual model and literature review', *Journal of Transport and Health*, 21, 101070.
Handy, S. (2014). 'Health and travel', in T. Gärling, D. Ettema and M. Friman (eds), *Handbook of Sustainable Travel*, Dordrecht/Heidelberg/New York/London: Springer, 199–214.
Handy, S., X. Cao and P.L. Mokhtarian (2006), 'Self-selection in the relationship between the built environment and walking: Empirical evidence from Northern California', *Journal of the American Planning Association*, 72(1), 55–74.
Handy, S., B. van Wee and M. Kroesen (2014), 'Promoting Cycling for Transport: Research Needs and Challenges', *Transport Reviews*, 34(1), 4–24.
Janssen, N.A.H., B. Brunekreef, G. Hoek and P. Keuken (2002), *Traffic-related air pollution and health*. Utrecht/Apeldoorn: Utrecht University, Institute for Risk Assessment Sciences, Environmental and Occupational Health Division / TNO Milieu, Energie en Procesinnovatie.
Lee, A.E., S. Underwood and S. Handy (2015), 'Crashes and other safety-related incidents in the formation of attitudes toward bicycling', *Transportation Research Part F*, 28, 14–24.
Lee, J.-E., H.J. Lim and Y.-Y. Kim (2021), 'Publication trends in research on particulate matter and health impact over a 10-year period: 2009–2018', *Environmental Health and Toxicology*, 36(1), e2021005.
Lucas, K. (2012), 'Transport and social exclusion: Where are we now?', *Transport Policy*, 20, 115–13.
Lunke, E.B. (2020). 'Commuters' satisfaction with public transport', *Journal of Transport & Health*, 16, 100842.
Lyu, Y. and A. Forsyth (2021), 'Attitudes, perceptions, and walking behavior in a Chinese city', *Journal of Transport and Health*, 21, 101047.
Mackett, R.L. and Thoreau, R. (2015). 'Transport, social exclusion and health', *Journal of Transport and Health*, 2(4), 610–17.
McNabola, A., B. Broderick and L.W. Gill (2007), 'Optimal cycling and walking speed for minimum absorption of traffic emissions in the lungs', *Journal of Environmental Science and Health - Part A Toxic/Hazardous Substances and Environmental Engineering*, 42(13), 1999–2007.
Mindell, J.S., D. Leslie and M. Wardlaw (2012), 'Exposure-Based, 'Like-for-Like' Assessment of Road Safety by Travel Mode Using Routine Health Data', *Plos One*, 4 December.
Mitsakou, C., J.P. Adamson, A. Doutsi, H. Brunt, S.J. Jones, A.M. Gowers and K.S. Exley (2021), 'Assessing the exposure to air pollution during transport in urban areas – Evidence review', *Journal of Transport and Health*, 21, 101064.
Mokhtarian, P.L. (2019), 'Subjective well-being and travel: retrospect and prospect', *Transportation*, 46, 493–513.
Nijland, H.A., S. Hartemink, I. Van Kamp and B. Van Wee (2007), 'The influence of sensitivity for road traffic noise on residential location: Does it trigger a process of spatial selection?', *Journal of the Acoustical Society of America*, 122(3), 1595–601.
Novaco, R.W., D. Stokols and L. Milanesi (1990), 'Objective and subjective dimensions of travel impedance as determinants of commuting stress', *American Journal of Community Psychology*, 18(2), 231–57.
Nyhan, M., A. McNabola and B Misstear (2014), 'Evaluating artificial neural networks for predicting minute ventilation and lung deposited dose in commuting cyclists', *Journal of Transport and Health*, 1(4), 305–15.
Oishi, S., E.F. Diener, R.E. Lucas and E.M. Suh (1999), 'Cross-cultural variations in predictors of life satisfaction: Perspectives from needs and values', *Personality and Social Psychology Bulletin*, 25(8), 980–90.
Olsson, L.E., T. Gärling, D. Ettema, M. Friman and S. Fujii (2013), 'Happiness and satisfaction with work commute', *Social Indicators Research*, 111(1), 255–63.

Paluska, S.A. and T.L. Schwenk (2000), 'Physical activity and mental health: Current concepts', *Sports Medicine*, 29(3), 167–80.
Patz, J.A., Campbell-Lendrum, D., Holloway, T. and Foley, J. A. (2005), Impact of regional climate change on human health. Nature, 438, 310–317.
Pychyl, T.A., and B.R. Little (1998), 'Dimensional specificity in the prediction of subjective well-being: Personal projects in pursuit of the PhD', *Social Indicators Research*, 45(1–3), 423–73.
Saelens, B.E., A. Vernez Moudon, B. Kang, P.M. Hurvitz and C. Zhou (2014), 'Relation between higher physical activity and public transit use', *American Journal of Public Health* 104(5), 854–59.
Şahin, Ü.A., B. Onat, B. Stakeeva, T. Ceran and P. Karim (2012), 'PM10 concentrations and the size distribution of Cu and Fe-containing particles in Istanbul's subway system', *Transportation Research Part D*, 17(1), 48–53.
Schepers, P., E. Fishman, R. Beelen, E. Heinen, W. Wijnen and J. Parkin (2015), 'The mortality impact of bicycle paths and lanes related to physical activity, air pollution exposure and road safety', *Journal of Transport and Health*, 2(4), 460–73.
Smith, M., J. Hosking, A. Woodward, K. Witten, A. MacMillan, A. Field, P. Baas and H. Mackie (2017), 'Systematic literature review of built environment effects on physical activity and active transport – an update and new findings on health equity', *International Journal of Behavioral Nutrition and Physical Activity*, 14(1), Paper 158.
Standage, M., F.B. Gillison, N. Ntoumanis and D.C. Treasure (2012), 'Predicting students' physical activity and health-related well-being: A prospective cross-domain investigation of motivation across school physical education and exercise settings', *Journal of Sport and Exercise Psychology*, 34(1), 37–60.
St-Louis, E., K. Manaugh, D. Van Lierop and A. El-Geneidy (2014), 'The happy commuter: A comparison of commuter satisfaction across modes', *Transportation Research Part F*, 26, 160–70.
Stutzer, A. and S.B.S. Frey (2008). 'Stress That Doesn't Pay: The Commuting Paradox', *The Scandinavian Journal of Economics*, 110(2), 339–66.
Troped, P.J., J.S. Wilson, C.E. Matthews, E.K. Cromley and S.J. Melly (2010), 'The built environment and location-based physical activity', *American Journal of Preventive Medicine*, 38(4), 429–38.
UK Department of Health and Social Care (2019), 'Physical activity for adults and older adults'. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1054541/physical-activity-for-adults-and-older-adults.pdf (Accessed 23/05/2023)
US Department of Health and Human Services (2019), 'Physical Activity Guidelines for Americans, 2nd edn'. https://health.gov/sites/default/files/2019–09/Physical_Activity_Guidelines_2nd_edition.pdf. (Accessed 23/05/2023)
Van Dyck, D., G. Cardon, B. Deforche, N. Owen and I. De Bourdeaudhuij (2011), 'Relationships between neighborhood walkability and adults' physical activity: How important is residential self-selection?' *Health & Place*, 17(4), 1011–14.
Van Praag, B.M.S. and B.E. Baarsma (2001), 'The Shadow Price of Aircraft Noise Nuisance', Tinbergen Institute Discussion Paper, No. 01–010/3.
van Wee, B. (2007), 'Environmental effects of urban traffic', in T. Garling and L. Steg (eds), *Threats from Car Traffic to the Quality of Urban Life. Problems, Causes, and Solutions*, Amsterdam: Elsevier, 9-32.
van Wee, B. (2018), 'Land use policy, travel behavior and health', in M. Nieuwenhuijsen and H. Khreis (eds), *Integrating Human Health into Urban and Transport Planning*, Dordrecht/Heidelberg/New York/London: Springer, 253–269.
van Wee, B. and D. Ettema (2016), 'Travel behaviour and health: A conceptual model and research agenda', *Journal of Transport and Health*, 3(3), 240–48.
Wardman, M. and A.L. Bristow (2004), 'Traffic related noise and air quality valuations: Evidence from stated preference residential choice models', *Transportation Research Part D*, 9(1), 1–27.
Walasek, L., G.D. Brown and G.D. Ovens (2019), 'Subjective well-being and valuation of future health states: Discrepancies between anticipated and experienced life satisfaction', *Journal of Applied Social Psychology*, 49(12), 746–54.
Wegener, M. and Fürst, F. (1999), Land-Use Transport Interaction: State of the Art. Transland. Integration of Transport and Land Use Planning. Work Package 2, Deliverable D2a. Institute of Spatial Planning, University of Dortmund, Dortmund.
WHO (2020) (World Health Organization), 'Basis documents, forty-ninth edition. https://apps.who.int/gb/bd/pdf_files/BD_49th-en.pdf, assessed 22-5-2023, page 1. (Accessed 23/05/2023)

Wood, C., C. Angus, J. Pretty, G. Sandercock and J. Barton (2013), 'A randomised control trial of physical activity in a perceived environment on self-esteem and mood in UK adolescents', *International Journal of Environmental Health Research*, 23(4), 311–20.
Ye, R. and H. Titheridge (2017), 'Satisfaction with the commute: The role of travel mode choice, built environment and attitudes', *Transportation Research Part D: Transport and Environment*, 52, 535–47.
Ziegler, F. and T. Schwanen (2011), '"I like to go out to be energised by different people": An exploratory analysis of mobility and wellbeing in later life', *Ageing and Society*, 31(5), 758–81.