Land Use Policy, Travel Behavior, and Health

van Wee, Bert

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Chapter 13
Land Use Policy, Travel Behavior, and Health

Bert van Wee

13.1 Introduction

The transport system, together with the land use system, allows people to participate in activities at different places and transport goods between different locations. In case of people: it allows us to travel to work, friends, and relatives, amenities, health-care services, shops, schools, and many more destinations. This results in important economic and other accessibility-related benefits for society.

But these benefits come at considerable costs for the users, and (via the tax payer), for governments (e.g., costs of infrastructure, subsidies for public transport), and for society (environmental impacts, safety impacts).

An important effect category that is largely (but not only) of a non monetary nature is health. Health effects of the transport system can be both positive and negative. This chapter's focus is on travel-related health effects. The four dominant categories of such health effects for the traveler are accidents, exposure to pollutants, exercise, and well-being, and in addition, there are health effects for others, such as exposure to air pollution and noise for people living near heavily trafficked roads. Health is an upcoming theme in the field of transport, both in policy making and in research. Since 2013 there is even a journal titled *Journal of Transport and Health*. The growing interest in transport and health is partly related to the increasing awareness of the health risks of transport policies and the health benefits of active modes (walking and cycling), and more specifically because cycling is becoming more popular in many cities and regions across the world (Pucher and Buehler 2012), and receives a lot of attention in academic research anyway. Of the ten most downloaded papers of the journal *Transport Reviews*, six were about cycling (assessed 2-12-2016), and all these papers were published recently, since 2008. Health impacts of travel for people other than the user, mainly exposure to air

B. van Wee (✉)
Transport and Logistics Group, Delft University of Technology, Delft, The Netherlands
e-mail: G.P.vanWee@tudelft.nl

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pollutants and noise, have been addressed in the literature and policy making for decades. The same applies for accident risks of travel. The *increasing* attention paid to transport and health is related to all four health-related categories of effects for the traveler as presented above: there is an increasing awareness of cycling being a form of exercise (and thus improves health), and an activity that might increase well-being, but cycling also results in an increased intake of pollutants and is often risky (at least expressed as risks per kilometer).

But the relationships between transport and health include more than those related to active modes. People traveling by car, public transport, and aircraft are also exposed to risks and often to pollutants and experience varying levels of well-being.

Several policy categories can influence the impact of the transport system on health. Regulations for new road vehicles have an impact on emission and exposure levels, and on road safety of both people using these vehicles, and people experiencing the risk of being hit by these vehicles. Pricing policies (e.g., subsidies on public transport, levies on fuels, taxes on cars) and parking policies influence mode choice and therefore exposures and health effects. Infrastructure policies influence the (un) attractiveness to travel to distinguished destinations, via influencing travel times, travel costs, and effort. Specific public transport policies (such as those having an impact on the services offered and tariffs) influence mode choice and the intensity of using public transport (number of trips, distances traveled). Land use policies influence which activities are located were, and next in multiple ways influence travel behavior and next health, but also the health impacts of the transport system in other ways (see Sects. 13.4 and 13.5).

Despite the increasing awareness of the relationships between transport and health, to the best of my knowledge, there is no systematic overview of policies to influence the impact of the transport system on health. This chapter aims to reduce this knowledge gap. It is beyond the aims of this chapter to discuss all policies but focuses on one important and less researched category: land use policies. Land use policies are the most relevant to the scope of the book (which is on urban development) in which this chapter is included. More specifically, this chapter aims to answer the question:

How can land use policies influence the impact of travel behavior on health?

This general question is answered by answering next sub-questions:

1. In which ways does travel behavior influence health?
2. How can the impact of travel behavior on health be conceptualized?
3. How does land use influence the transport system, travel behavior, and next health?
4. Which land use policies can influence the impact of land use via the transport system on health?

Note that land use policies have way more effects than those related to health only and can influence the environmental pressure of the transport system on ecosystems (e.g., by changing mode choice) or levels of accessibility. These effects are

excluded from the current chapter (see Van Wee 2011, for a discussion on the environmental and accessibility benefits of land use policies).

Before I explain the impacts of travel behavior and the wider transport system on health, it is important to make explicit how health is defined. The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (http://www.who.int/about/definition/en/print.html). Following earlier work (van Wee and Ettema 2016), in this chapter I also consider health to be broader than the absence of disease or infirmity, but I adopt a less broad approach than the WHO, by excluding the social dimension. This is because the social dimension is only indirectly related to the links between travel behavior and health.

Section 13.2 presents two conceptual models expressing the relationships between transport and health, answering the first two sub-questions. Next, Sect. 13.3 explains the relationships between land use and the transport system and travel behavior as far as relevant for the health impacts of travel, answering sub-question 3, and Sect. 13.4 answers sub-question 4 presenting options for land use policies to influence the transport system and next health. Section 13.5 discusses some key topics for the impact of land use via travel behavior and the transport system, on health. Section 13.6 finally summarizes the main conclusions of this chapter.

13.2 Transport and Health: A Conceptualization

I first discuss health impacts related to people's traveling. Van Wee and Ettema (2016) propose a conceptual model for the relationships between travel behavior and health. I take this model, in a slightly revised form, as a point of departure. Below I present the model and summarize the underpinnings. For a more elaborate discussion of the model and sources used, the reader can refer to Van Wee and Ettema (2016) (Fig. 13.1).

Figure 13.1 makes clear that health of people traveling is primarily determined by the following components:

- Level of physical activity (Block A)
- Air pollution intake (Block B)
- Casualties/accidents (Block C)
- (Subjective) well-being (Block D)

These four main factors are interrelated, a first example being that the use of active modes may result in an increase of subjective well-being (Olsson et al. 2013), but on the other hand, accidents (crashes/falls) can decrease the use of active modes because people become disabled or because they become scared to use these modes (see Lee et al. 2015). Another example: high concentrations of air pollutants are unhealthy and can also reduce the willingness of people to walk or cycling, reducing the health benefits of physical activity.

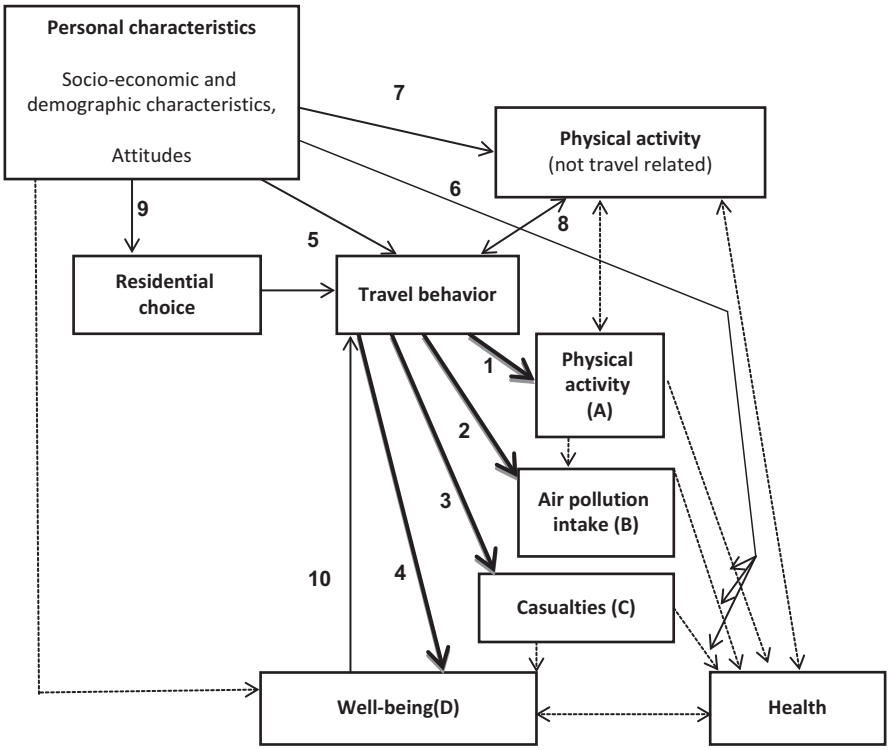

Fig. 13.1 Conceptual model for the dominant relationship between travel behavior and health of people traveling (source: Van Wee and Ettema 2016)

Arrows 1–4 express the direct impact of travel behavior on these four factors. Distances traveled influence mode choice and vice versa: the bike is not an option if a person needs to travel for 100 km, and a person preferring to cycle will chose less remote destinations. Consequently, travel behavior influences the level of travel-related physical activity of people (arrow 1—e.g., Handy 2014). If people walk or cycle, their intake of pollutants per unit of time can be higher compared to when they would drive, especially when they walk or cycle close to heavily trafficked roads (arrow 2—e.g., Nyhan et al. 2014). But if they travel in areas with lower concentrations of pollutants, the intake can also be lower compared to when they would drive. People traveling by underground are exposed to relatively high concentrations of particulate matter (PM) originating from mechanical friction processes (e.g., Şahin et al. 2012). Therefore, distance traveled and mode choice influence the levels of air pollution exposures. Other risk factors are also mode-dependent (Wegman 2013), and in case of road traffic, these vary between road types (Amoros et al. 2003) (arrow 3). In Swedish cities (momentary), well-being is highest for people who commute by active modes, followed by traveling by car and finally public transport (e.g., Olsson et al. 2013). The authors hypothesize that desirable physical exercise might explain the high level of well-being for active modes,

as well as the relatively short travel distances—long commuting distances are less appreciated. They do not explain the difference between driving and public transport. Next, travel influences (subjective) well-being because people can reach locations of activities and services (e.g., De Vos et al. 2013) (arrow 4).

In addition, several second-order relationships exist, as expressed in Fig. 13.1:

- Socioeconomic and demographic characteristics and travel behavior (arrows 5–7)
- Physical activity: walking and cycling versus wider activity patterns (arrow 8)
- Subjective well-being and the use of active modes (arrow 10)
- Self-selection effects (arrows 5 and 9)

13.2.1 Socioeconomic and Demographic Variables (Arrows 5–7)

The importance of socioeconomic and demographic variables (such as age, gender, education level, and household characteristics) for travel behavior (arrow 5) is confirmed by many studies (e.g., Stipdonk et al. 2013). In addition, these variables can mediate the impact of physical activity, air pollution intake, and crashes/falls on health (arrow 6). For example, falling from a bicycle in general will have more impact on an 80-year-old person than on a 15 years old, and obese people will benefit more from an increase of physical activity (Bauman 2004). Comparably, personal characteristics may also have an impact on non-travel-related physical activity (arrow 7), and next its impact on health, as well as on the impact of well-being on health.

13.2.2 Interaction of Travel-Related Physical Activity and Other Physical Activity (Arrow 8)

Walking and cycling levels can be related to other forms of physical activity. People may substitute these two forms. It could be that a person does not go to the gym because she already walks or cycles frequently. On the other hand, it is also possible that people who walk or cycle feel fitter and therefore also engage more in other forms of physical activity. For example, they might take the stairs and not the elevator. Such relationships are hardly studied in the literature, and the results are inconclusive.

13.2.3 Causality of Subjective Well-Being and the Use of Active Modes (Arrow 10)

It is possible that people with a high level of subjective well-being walk and cycle (arrow 10) more than average, but to the best of my knowledge, there is hardly any literature on this topic, an exception being Baruth et al. (2011) who conclude that

people with higher levels of subjective well-being achieved more than the average increase in physical activity levels during a physical activity intervention program. It could be that a higher level of subjective well-being increases the willingness to change behavior, but this is rather speculative. The literature generally studies the reverse causality: the impact of walking and cycling on mental health and mood (see above).

13.2.4 Self-Selection Effects (Arrows 5 and 9)

A potential important phenomenon relevant for the relationships between travel behavior and health is self-selection. People self-select in many ways. For example, people with higher incomes generally live in neighborhoods with more expensive houses. This form of self-selection is generally included in research by including socioeconomic and demographic variables, and therefore I do not further discuss it. But people can self-select in many other respects, the most often studied form being residential self-selection based on preferences for modes or travel attitudes more generally (e.g., Cao et al. 2009). The impact of attitudes on travel behavior is conceptualized via arrow 5 in Fig. 13.1 and the impact of attitudes on residential self-selection by arrow 9. Residential self-selection can also be influenced by health considerations (not conceptualized in Fig. 13.1). For instance, people who think exercise is important may chose a residential location that encourages walking or cycling.

As expressed by the heading of Fig. 13.1, this figure conceptualizes the dominant relationships related to travel behavior for the people traveling. In addition, there are effects on other people. Figure 13.2 conceptualizes these impacts.

Figure 13.2 shows that people traveling affect the health of others, nearby or "local" effects being a first category (noise, air pollution, risks, and "barrier effects" (e.g., crossing ability) being dominant effects). People exposed to these effects are other road users, and people staying near roads, such as residents, and children at schools located near heavily trafficked roads. Traffic also contributes to larger-scale air pollutions in the form of smog. To keep Fig. 13.2 as simple as possible, these are not explicitly included in another box but assumed to be included in the "nearby" box. In addition, people traveling and the infrastructure they use result in barrier effects: people cannot easily cross streets because of traffic, or there are no nearby physical options to cross motorways, other main roads, or railways. Secondly, transport contributes to climate change, mainly due to CO_2 emissions, and climate change will have a range of health-related effects (e.g., Patz et al. 2005), such as exposure to flood risks, extremely hot temperatures, and the spread of diseases. Next, travel behavior in the long run will induce land use changes, as often expressed in the land use and transport interaction literature (e.g., Wegener and Fürst 1999). For example, if more people travel by car, companies, shops, and services value car accessibility higher and might prefer to be located at locations well accessible by car. And such land use changes influence accessibility levels. For example, a shift of activities to locations well accessible by car might result in social exclusion of those

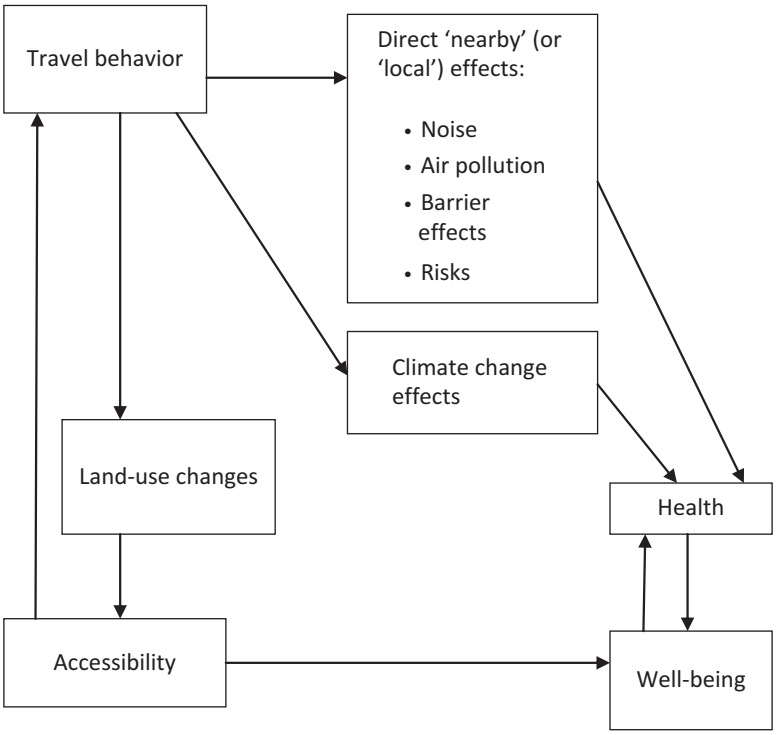

Fig. 13.2 Conceptual model for the dominant relationship between travel behavior and health of others than the traveler

not having a car available (e.g., Lucas 2004), decreasing the well-being of people and next their health. And changing land use has an impact on travel behavior. Land use changes also influence the nearness of green space and health effects due to exposure of green space.

13.3 Land Use, the Transport System, and Health

I now move to the impact of land use on the transport system and next on health.

Figure 13.3 conceptualizes the ways in which land use can influence the four blocks that influence health of people traveling (physical activity, air pollution intake, casualties/accidents, and well-being) as presented above. Note that the figure is not limited to the direct effects of travel behavior via these four blocks but takes a broader perspective also focusing on the locations of travel, which comprise both the locations of infrastructure, as well as the use of infrastructure by people traveling.

Figure 13.3 shows that land use (the locations of activities) can influence the four blocks relevant for health in multiple ways. First, land use can influence travel

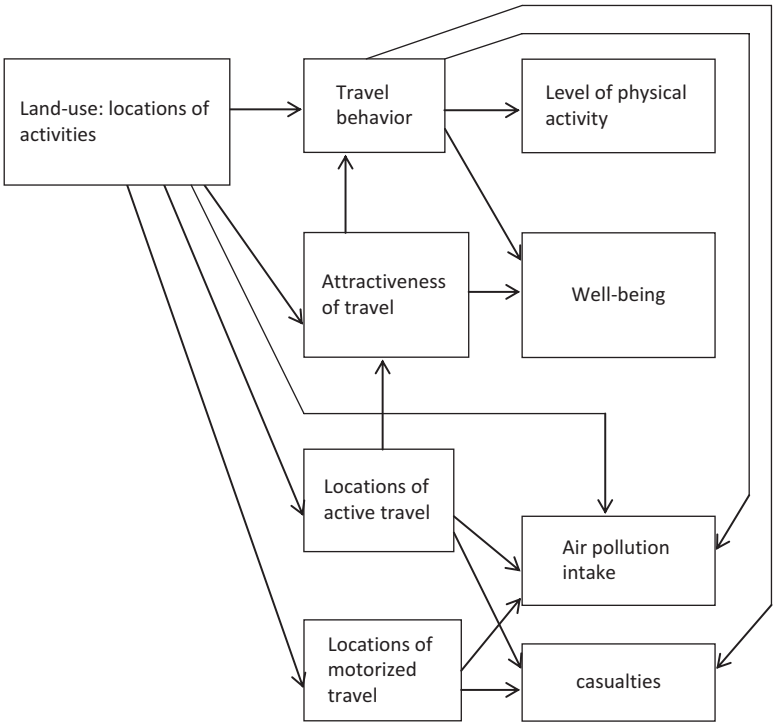

Fig. 13.3 Impacts of land use, via the transport system, on physical activity, air pollution intake, casualties, and well-being of people traveling

behavior and next the levels of physical activity and well-being (and next health—see above). The land use factors that are often found to have an impact on travel behavior are sometimes labeled as the five Ds and include density, diversity, design, destination accessibility, and distance to transit (Ewing and Cervero 2010). Density is expressed in units of a variable per unit of surface, e.g., population size, number of jobs, or houses per square kilometer. Higher densities, at least theoretically, allow for shorter trip distances because destinations are nearer. Shorter distances increase the attractiveness and convenience of walking and cycling and increases the share of these modes. And an increase in the levels of walking and cycling can increase both physical activity and well-being, as explained above. Diversity expresses the level to which different land use categories (dwellings, shops, medical services, schools, jobs, etc.) are mixed. Higher level of mixed land use can reduce travel distances. For example, if all shops and services would be concentrated in the center of a town, people on average would have to travel longer compared to when shops and services would be distributed over neighborhood centers (and the town center). Consequently, mixed land use also influences mode choice because, as explained above, active modes are relatively attractive for shorter distances. Design expresses street network characteristics and can influence travel behavior in many ways. For example,

a grit-based street pattern can reduce travel distances compared to other street patterns that force people to take longer routes. And next, as explained above, it can influence the share of active modes. Destination accessibility expresses how (un) easy it is to reach the locations of destinations. It is often expressed in travel times or distances to (potential) destinations. The nearer destinations, the shorter travel distances and the higher the share of active modes. Distance to transit expresses the shortest distance (or sometimes time) to travel to a bus stop or railway station and influences mode choice, in particular the share of transit. Results of many studies reveal that land use does influence travel behavior, after controlling for socioeconomic and demographic variables and even after controlling for (attitudes based) residential self-selection. But the influence is not very strong and limited compared to socioeconomic and demographic variables (Ewing and Cervero 2010, and see many references in that study for further underpinnings of this general conclusion). But there still is discussion about the quantitative results, the interpretation, and the desirability of related land use policies (e.g., Stevens 2017).

Note that design can also relate to the characteristics of infrastructure, not only to land use, and infrastructure characteristics also influence travel behavior. And there is a gray area, related to reduced car access, or even car-free zones. Some researchers interpret this as infrastructure planning, but one can also see this as a form of land use planning. In case of this latter interpretation, it is important to note that zones with little or no motorized traffic, often central urban areas, will have better air quality and will be more attractive for pedestrians and cyclists—see, for example, Nieuwenhuijsen and Khreis (2016) who conclude that such areas have direct and indirect health benefits, but that the size and conflicts between different effects are yet unclear.

Secondly, land use can influence the attractiveness of travel. Nice scenery and attractive infrastructure (cycle lanes, wide pavements) increase levels of walking and cycling (Meurs and Haaijer 2001) and can improve the well-being of travel directly, e.g., due to enjoying the scenery (see Gatersleben and Uzzell 2007).

Thirdly, the locations of active travel and motorized travel infrastructure matter. The locations of active travel infrastructure matter, at least because of the attractiveness of the specific route taken (see previous point) and next because the specific routes taken have an impact on risks and the intake of pollutants. This is because risk factors vary between road types (see above), and the concentrations of pollutants also vary between roads. The magnitude of these impacts to some extent not only relates to the characteristics of the infrastructure and the direct environment of infrastructure but also to the locations of motorized transport (where and when do which motorized vehicles drive), as conceptualized by the arrow from "locations of motorized travel" to "air pollution intake" and "causalities". If, for example, roads for motorized road traffic are adjacent to cycle lanes, the intake of pollutants will be higher compared to cases in which the distance to the nearest road with motorized traffic is larger. And also for people traveling by motorized modes, the intake depends on the concentrations of pollutants which vary by road, and the risks vary by road type (and even road).

The impact of land use on travel behavior also influences the health of others, as conceptualized by Fig. 13.4.

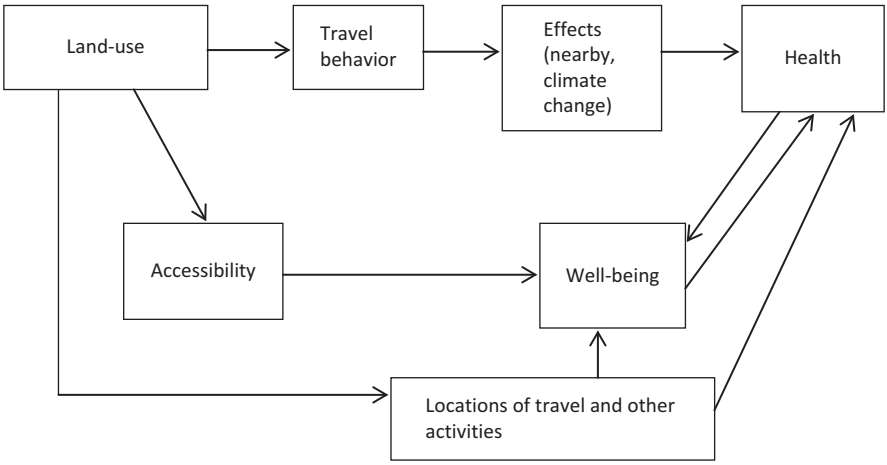

Fig. 13.4 Impacts of land use, via the transport system, on health of others than the traveler

Land use influences travel behavior and accessibility and next health in the way as conceptualized in Fig. 13.2. In addition, it has an impact on where people drive, and where other people stay (travel, live, work, shop, etc.), and therefore on their exposure to the negative impacts of people traveling (air pollution, noise, barrier effects, long-term climate change impacts). It may even influence well-being because of other negative environmental implications of travel, such as the impact of parked and driving vehicles, regardless of risks, pollution, and noise. For example, if many cars are parked in streets in residential areas, it may prevent children from playing on the street.

13.4 Land Use Policies

The next question is: How can land use policies influence travel behavior, the attractiveness of travel, the locations of active and motorized travel, and the locations of other activities (working, living, shopping, etc.)? I first discuss the determinants that land use can influence, followed by a discussion on specific policy instruments. Table 13.1 presents the main determinants for land use policies.

Firstly, land use policies can influence all Ds as presented above and next travel behavior. But the options for this influence differ across regions and countries/states, depending on the policy instruments available and the planning culture at stake. In several European countries, it is much more common for policy makers to develop land use policies than in the USA, although planning concepts like *Transit Oriented Development* and *New Urbanism* have gained popularity during the past decades (Cervero and Radisch 1996; Handy 1996, 2005).

Land use policies can, among others, include policies encouraging building in high densities and policies that stimulate mixed land use (diversity) and building

Table 13.1 Determinants influenced by land use policies and their impact on travel-related health

Determinants for land use policies	Impact on:
Density	Travel behavior, locations of active and motorized travel
Diversity	Travel behavior, locations of active and motorized travel
Design	Travel behavior, locations of active and motorized travel
Destination accessibility	Travel behavior, locations of active and motorized travel
Distance to transit	Travel behavior, locations of active and motorized travel
Attractiveness of infrastructure	Quality of the environment/attractiveness, route choice
Attractiveness of the areas near infrastructure	Quality of the environment/attractiveness, route choice
Any form of land use in general	Locations of other activities

near railway stations. Such policies often have synergetic effects. For example, not only building near stations will increase the share of the train in travel, but building in high densities near stations will further increase the potential of rail. See Van Wee (2002) for a more elaborate discussion of how land use policies can influence travel behavior.

Secondly, land use policies influence the attractiveness of travel, by improving the attractiveness of both the infrastructure and the areas adjacent to infrastructure. Infrastructure can be made attractive, for example, by constructing attractive noise barriers and using asphalt with nice colors. The area adjacent to infrastructure can be made attractive by vegetation or water areas and nice buildings near infrastructure. Infrastructure can be planned making use of already nice areas. The attractiveness of infrastructure and the adjacent areas influences the attractiveness of a given route and can also influence route choice.

Thirdly, all journeys have an origin, a destination, and a route connecting both, and land use planning can influence the locations of activities and consequently the locations of active and other forms of travel: where do people travel? The determinants influenced by land use policies are the same five Ds as discussed above. In addition, the routes that people chose between given origins and destinations can be influenced by land use planning, as explained above, by influencing the attractiveness of infrastructure and the adjacent areas.

Fourthly, land use policies can influence all activities other than travel and consequently the levels of exposure to pollution, noise, and barrier effects and well-being-related effects.

Which specific policy instruments do authorities have available as far as land use policies are concerned? The way in which land use policies are implemented varies between countries. I distinguish between direct and indirect policies. Direct policies directly determine which land use categories are (not) allowed at which locations,

zoning being a dominant instrument type. Indirect policies can be manifold. For example, several policies can influence land values and prices, and these values influence land use as expressed by bid-rent theory (e.g., Alonso 1964), examples being restrictions on urbanization and anti-speculation policies. Regulations, e.g., with respect to maximum speeds, can influence the negative impacts of motorways on the environment and indirectly the (un)attractiveness of the surroundings for specific land use categories. It is beyond the scope of this chapter to discuss all indirect policies. I limit myself to policies related to the level of service of the transport system, distinguishing infrastructure policies and public transport policies.

Infrastructure influences land use, as recognized by so-called Land Use—Transport Interaction models (LUTI models) (e.g., Wegener and Fürst 1999). Areas around railway, metro, or tram stations are attractive for some use categories (e.g., companies with many office jobs) because of the high accessibility by public transport; areas near motorway that exists may be attractive for other use categories (e.g., distribution centers for goods). On the other hand, areas close to motorways or rail infrastructure may be less attractive because of noise or air pollution.

Parking policies are a next category of infrastructure policies that may influence land use. Abundant and free parking may have a positive influence on the attractiveness for cars but is likely to negatively influence the quality of the urban environment, making some areas less attractive. Especially central urban areas suffer from driving and parked cars, and many cities have introduced restrictions on parking (see Mingardo et al. 2015 for a conceptualization of the development parking policies over time).

In addition to infrastructure policies, specific public transport policies can influence land use indirectly. Not only do the locations of stations have an impact on land use, as explained above, but so do bus stops. And for all forms of public transport, the services offered (as expressed by time tables) matter: the "better" the services, the higher the likeliness that stations and stops influence land use.

13.5 Discussion

In this section, I discuss the content of this chapter from the perspective of the relevance for research and (land use) policy making.

13.5.1 Lack of Integrative Approaches

This chapter made explicit that the relationships between travel behavior and health are manifold and complex. In the debates and research papers on land use and travel behavior, health is only seldom addressed. The framing of why land use could matter is much more related to the environmental impacts of travel behavior, due to mode choice and distanced traveled (mainly by car). But this chapter has made it clear that land use and land use policies have a much broader link with health than

related to environmental impacts only. I think the general theme of land use, travel, and health therefore is poorly studied.

A key element in this general theme is the complexity of the many relationships as presented in this paper, and this complexity is hardly addressed in the academic literature and in (land use) policy making, although there are studies addressing parts of these complex relationship (e.g., Nieuwenhuijsen 2016), and studies discussing qualitatively the complex relationships (e.g., Khreis et al. 2016). There certainly is a gap in the academic literature with respect to quantifying the complex relationships as discussed in this chapter. The relationships between land use policies and health via travel behavior are poorly addressed in policy documents in general, and to the best of my knowledge, the complex relationships are about absent. This is understandable, both in the case of research and policy making. Focusing on research, I think to fully study the complex relationships is about undoable, at least if these need to be studied simultaneously and quantitatively, with one large dataset of multiple combined datasets. Data collection then would be very complex, and respondents need to provide a lot of data, probably leading to low response rates. I think the best way forward is to split the full picture in parts and study these. Combining those parts, preferably quantitatively, probably leads to a better understanding of the complex relationships.

More specifically, I next discuss some specific topics that are poorly understood, the first one being related to Fig. 13.1: we do not know the interactions between travel as a form of physical activity and other types of physical activity. And we poorly understand the combined effect of all four blocks on health. There are a few attempts to at least include multiple effects. For example, De Hartog et al. (2010) studied the combined effect of cycling on physical activity, the intake of air pollutants, and accidents and concluded that a shift from driving to cycling increases expected life years. But the study did not include the (other) complex relationships relevant for the health benefits of the assumed substitution from driving to cycling, as conceptualized in Fig. 13.1. Note that this discussion is not only related to the impact of land use on travel and next health but is of a more general nature, though also relevant for the link with land use.

The relationships as conceptualized in Fig. 13.2 between land use, accessibility, and travel behavior are much better understood. The main challenge is to link these relationships to the right part of the figure: the impacts on health via intermediate effects ("nearby," climate change, well-being). A lot of literature focuses on the impact of land use and land use policies on travel behavior, ignoring emissions, exposure to emissions, risks, well-being, and health.

Focusing on Fig. 13.3, the impact of land use on travel behavior has been studied frequently, although there still are important debates, as addressed above. And the locations of travel are also well addressed. A more or less separate strand of literature studies the impact of emissions via dispersion to exposure, and these relationships are also relatively well known. The same applies to the impact of this spatial distribution of travel (mainly by road type) on causalities. All other relationships as conceptualized in Fig. 13.3 are poorly understood, and these are promising challenges for future research.

Most relationships conceptualized in Fig. 13.4 are addressed in the preceding figures, the exception being the impact of the spatial distribution of activities on well-being. To the best of my knowledge, this is also an understudied topic and thus an interesting topic for future research.

I now switch to Table 13.1. As mentioned above, the impact of the 5Ds on travel behavior is relatively well understood, although important debates remain. The impacts of land use on the attractiveness of infrastructure and the surrounding areas have received way less attention of literature, and this is a promising area of future research. For policy making it is even more understandable that the complexities as presented in this chapter are poorly recognized. It is about impossible to "sell" policy measures to decision makers, if the effects are communicated in a complex way. A way out could be to summarize the health effects of candidate land use policies in terms of differences in expected life years, quality-adjusted life years or comparable indicators, probably added with a brief description addressing who are affected (e.g., categories of travelers, neighborhoods) and in which way (e.g., due to changes in exercise or exposure to risk or pollutants).

13.5.2 The Evaluation of Land Use Policies

A next topic is the question of how to evaluate land use policies that aim to improve health via travel behavior. Let us assume land use policies influence health in a positive way, in any of the ways conceptualized in Fig. 13.3. Does this mean that these policies should thus be implemented? The answer to this question is not necessarily "yes". This is because such policies have many more impacts and these can all be relevant to social welfare. In Van Wee (2002), I give an overview of relevant effects:

- Accessibility effects: how (un)easy can people reach destinations, and can companies transport goods between destinations?
- The option value: how do people value options to travel, even if they do not use these (see Geurs et al. 2006)?
- The consumers' surplus of travel: of how much more value is traveling for a traveler than it costs?
- Safety effects.
- The valuations of dwellings and the residential area, regardless of travel implications.
- Financial aspects: land use policies can influence costs. For example, building within the existing urban area is generally more expensive than building adjacent to the current urban area.
- Robustness: how robust is the land use and transport system for trend breaks, like disruptions due to climate change policies, strong changes in energy prices (up or down), or trend breaks in mobility behavior? Will it fulfill its role in societies under such changing conditions?

So, for final decisions, it is important to at least take into consideration the most important effects of candidate policy options. If this is not done, policy makers and next decision makers are poorly informed about the pros and cons of these options, while the role of policy-related research is to inform decision makers.

13.6 Conclusions

This section summarizes the most important conclusions that follow from this chapter. A first conclusion is that travel behavior can influence health via (1) level of physical activity, (2) air pollution intake, (3) casualties/accidents, and (4) (subjective) well-being.

A second conclusion is that the impacts of travel on health depend on personal characteristics, other forms of physical activity, and residential choice, and the interrelationships between these factors, and the impacts of travel behavior on health, are rather complex and under researched.

Third, these complex interrelationships are only partly understood. Consequently, several research challenges remain.

Fourth, land use can influence health via the transport system in multiple ways. It influences travel behavior, the attractiveness of travel, and the locations of active and motorized modes.

Fifth, travel behavior can be influenced by land use policies via the five Ds: density, diversity, design, destination accessibility, and distance to transit.

Sixth, land use can also influence the attractiveness of travel, and the locations of origins and destinations of trips, and route choice.

Seventh, decision making with respect to land use policies should not only be based on health impacts but should include many other aspects, at least accessibility effects, the consumers' surplus of travel, safety effects, the valuations of dwellings, and the residential area, regardless of travel implications, financial aspects, and the robustness of the land use and transport system.

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