5
Land use and transport

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5.1 INTRODUCTION

As explained in Chapter 2 people travel because they want to carry out activities such as living, working, shopping and visiting friends and relatives at different locations. Land-use patterns therefore would seem to have a potentially large impact on transport. After decades of scientific and policy debate, there is still no consensus about the impact of land use on travel behaviour, but the meta-analyses of the quantitative impacts of land-use variables of Ewing and Cervero (2010) is generally accepted to summarize the state of knowledge. Still, important debates remain, a first topic being the role of residential self-selection, and another topic being the possible change in attitudes of people, due to the exposure to the built environment (see below).

Note that land use (and infrastructure) has a long-term impact on travel behaviour. Once a residential area is designed and built, it will be very hard to change, for example, densities (e.g. dwellings per square kilometre), or locations of shops and services. So, if 'wrong' choices are made, these will be difficult to 'repair', and the impacts on travel behaviour will be long-lasting. On the other hand, it will take several years before the impacts of land use on travel behaviour are fully materialized. A mismatch between preferences of households and the characteristics of their residential areas may be long-lasting, and may only disappear after households relocate.

The purpose of this chapter is:

1. to discuss the theory explaining the potential impacts of land use on travel behaviour;
2. to give an overview of research findings; and
3. to discuss the pros and cons of the effectiveness of land-use policies.

The chapter is limited to passenger transport, because much more is known about the impact of land use on passenger transport than on goods transport.

Section 5.2 examines the impact of land use on travel behaviour from the perspective of Chapter 2 (especially Figure 2.1). Section 5.3 explains from a theoretical perspective why land use, at least theoretically, affects travel behaviour. Section 5.4 gives examples of studies of land-use impacts on transport. Section 5.5 discusses reasons for the differences in conclusions

between the studies. Section 5.6 discusses the evaluation of the impact of land use on travel behaviour in general, and is followed by section 5.7, which goes into the trade-off between environmental versus accessibility benefits of land-use concepts in more depth. Finally, section 5.8 summarizes the most important conclusions.[1]

5.2 A CONCEPTUAL MODEL FOR TRENDS IN PASSENGER TRANSPORT – THE LINK WITH CHAPTER 2

As expressed in Chapter 2, given the overall population size and demographic characteristics, the total volume of passenger transport and the split between transport modes depend on the locations of human activities, the needs, wants, desires and preferences of people and the transport resistance (generalized transport costs). Locations include activities such as living, working, shopping, recreation and education. The needs and desires of people are related to socio-economic, cultural and personal factors. Income, age, education level and household characteristics are important socio-economic variables (see Chapter 3). Cultural factors, for example, (partly) explain why in some cultures cycling is 'uncool', whereas in others it is very common. Personal factors relate to attitudes and people's preferences (regardless of variables such as age and income; see Chapter 3). Transport resistance depends on monetary factors, travel times, comfort and the reliability of all the options (see Chapter 6). The top of Figure 2.1 illustrates the relationships between these determinant categories. The current situation reflects a kind of continuously changing equilibrium (or maybe a better term is 'disequilibrium'). This is because new changes occur in advance of the long-term equilibrium actually coming about.

5.3 WHY SHOULD AND HOW CAN LAND USE AFFECT TRAVEL BEHAVIOUR?

This section explains why theoretically land-use related determinants can affect travel behaviour. The general theoretical underpinnings are discussed, and this is followed by a summary of the most often mentioned land-use determinants: density, mixed land use (also labelled as 'diversity'), neighbourhood design and distance of origins and destinations to public transport modes, such as railway stations. Subsection 5.3.3 explores the relationships between land-use variables, other variables and travel behaviour. An overview of the literature on empirical findings related to the theoretical underpinnings is given in section 5.4.

5.3.1 The Potential Impacts of Land Use on Travel Behaviour: The Theory of Utilitarian Travel Demand

The theoretical foundation for the impact of land use on travel behaviour can be found in the theory of utilitarian travel demand (see handbooks on transport economics, e.g., Button, 2010; see also Chapter 3). This theory postulates that the demand for travel does not derive its utility

from the trip itself, but originates rather from the need to reach the locations where activities take place, such as the dwelling, the workplace, and services and facilities. So, from this perspective of utility, travel is seen as 'derived demand'.[2] The demand for travel depends, on the one hand, on the utility of the activity and, on the other, on the (aggregate) costs to reach that destination. These aggregate costs, often labelled as the generalized transport costs (GTC) (the individual's valuation of the time, money and effort needed to cover the distance; see Chapter 6), are determined by characteristics of the transport system and by the spatial structure, such as the distribution of activities over space (see Chapter 2). So according to this theory the locations of activity, in combination with the utility of the activities at those locations and the characteristics of the transport system, have a strong impact on people's travel behaviour. The importance of location of origins and potential destinations for travel behaviour is reflected in the so-called traditional four-step model (see Chapter 16) and was recognized more than half a century ago (Mitchell and Rapkin, 1954).

5.3.2 Key Land-Use Variables and Their Impact on Travel Behaviour

The key land-use variables influencing travel behaviour are often labelled by 5 Ds (Density, Diversity, Design, Destination accessibility, Distance to transit), as proposed by (amongst others) Cervero in many publications. Below I discuss these. One can debate if the best approach to discuss the impact of land use on travel behaviour is the common 5Ds approach. Handy (2018) argues that it is better to depart from accessibility and its impact on travel behaviour, for several reasons. Some important reasons are first that all Ds influence accessibility, that the terminology is confusing, and that several of the Ds mutually interact so that synergy effects can occur, and that the stand-alone impact of the Ds on travel behaviour becomes less relevant. We nevertheless depart from the 5 Ds firstly because this is common practice in almost all research in the area, and secondly because departing from accessibility would not allow us to disentangle the impact of the land-use system on travel behaviour from that of the transport system (and maybe even the needs and desires of people). Such an approach would conflict our conceptual model of Chapter 2.

Density

Densities refer to the number of opportunities per square kilometre (or acre or any other surface indicator), such as dwellings, households, people and jobs. Gross densities relate to overall available space, net densities to the space that is (or can be) developed (excluding roads, open space, water, etc.). A fundamental question here is: why should density influence travel behaviour? Let us assume two equal land-use scenarios, but with densities in scenario A higher than those in scenario B. Other factors such as average travel speeds for all modes and the type of dwellings, households, jobs, shops and so on are equal. Travel for almost all modes costs money. Other factors being equal, people will prefer to travel less to save money. And travel also costs time. Many studies have shown that people value travel time negatively (see, for example, Wardman, 1998; Gunn, 2001; see also Chapter 6). Other factors being constant, people in scenario A, where density is greater, will travel less than in scenario B: people can

reach the same locations for their activities while travelling fewer kilometres and so save time and money. In addition, because of the shorter distances more destinations can be reached through active modes (walking, cycling), theoretically resulting in a shift from car to active modes of transport.

Of course, other factors do not remain constant. For example, owing to the higher densities people can get to more activities at the same time. At least part of the potentially saved travel time can be compensated if people choose a more remote destination: the additional utility for reaching a more remote destination may be greater than the disutility of additional travel (see also section 5.7). Nevertheless, higher densities offer the possibility of travelling less. In order to obtain the benefits from higher densities, housing, offices and other locations should be built in higher densities.

It is important to notice that the spatial scale at which densities occur matters. If, for example, a new residential area of 1000 inhabitants with high densities is built in a region with low densities outside the new residential area, travel behaviour will hardly be affected because almost all destinations will be outside the neighbourhood. And people in that residential area will still have only a few opportunities within reach for a given time (or GTC) budget.

Mixed land use

This factor focuses on the level of mixing of several categories of land use, such as dwellings, workplaces (firms), shops, schools and medical services.

Let us again assume two scenarios for a town. In scenario A all shops, schools and other services are located in the centre of town. In scenario B some of the shops, schools and other services are spread across town throughout all the neighbourhoods. The average distance from all dwellings to the nearest services is much smaller in scenario B than in scenario A. Keeping mode choice constant, the smaller distances will result in fewer passenger and vehicle kilometres. There is also an effect on modal choice, as active modes will be relatively more attractive because of the shorter distances.

Again, part of the initial effect might be lost. In the centre, for instance, there might be relatively fewer parking places, the distances from these parking places to the shops and services might be greater, and, unlike in the neighbourhoods, there might be paid parking. So, although distances from dwellings to the services are greater, the share of the car might be lower in scenario A than in scenario B. Nevertheless, potentially mixed land use can influence travel behaviour.

Neighbourhood design

Neighbourhood design is related to land use at the lowest scale, starting from the dwellings or buildings and linked to the direct vicinity of the dwellings. Design quality might be important for travel behaviour (Marshall and Banister, 2000; Boddy, 2007; Liu et al., 2021). For example, if at the dwelling the place where bicycles are stored is near the road, the bicycles' share might be larger compared to dwellings where the bicycle storage facilities are at the back. If the car can be parked near the dwelling, on one's own property or in a public parking place near the dwelling, car use will be more attractive than where there are central parking places further away from dwellings. An attractive environment might stimulate people to walk or cycle. This

attractiveness relates to allocation of space for several land-use categories, the architecture of the built environment and the presence of features such as parks and trees. Road infrastructure design may also be of relevance. For example, if there are attractive pavements and cycle lanes the share of active modes may be larger than if there are no or less attractive facilities for active modes.

Distance to public transport connections

The distance to railway stations may have an impact on modal choice as (differences in) travel times by car and train are very important. For public transport, total travel time contains both the 'in vehicle' (in train) time and the access and egress time (e.g. from home to the station by bus or bike or walking, and from the station to the office by walking or taking local public transport). If more dwellings and opportunities (e.g. jobs) are located near railway stations, access and egress times are shorter for a larger number of trips, resulting in a higher share for the train as compared to the car. In this way, distance and connections to railway stations may result in a higher share for public transport.

Destination access

The variables discussed so far focus on the origin of the trips, more specifically on the residential area. But, of course also the destination matters. If the destination is close to a railway station, the likelihood that people travel by train is higher compared to if it is not. And if parking near the destination is not easy or even impossible, such as in many inner cities, people are less inclined to travel by car.

Interactions between determinants

The determinants (5 Ds) can interact. For example, the effect of building in higher densities may have an additional impact on mode choice if the areas are located near railway stations. Then there is an additional effect on modal choice which was not mentioned in the section above on densities. And if the area around a railway station is attractive it can encourage more people to take the train, increasing the modal shift potential of building in higher densities.

5.3.3 Relationships Between Land-Use Variables, Other Variables and Travel Behaviour

Very old studies sometimes directly investigated correlations between land-use variables and travel behaviour variables, ignoring other variables (see Figure 5.1). Since the late 1980s, studies into the impact of land use on travel behaviour have included socio-economic and demographic variables, as visualized in Figure 5.2 (see Chapter 3 for the general impact of socio-economic and demographic variables). Figure 5.2 shows that travel behaviour is influenced not only by land-use variables but also by socio-economic and demographic variables, such as income, age, education level and household variables. The studies find lower impacts of land-use variables on travel behaviour variables, as part of the impact is accounted for by the socio-economic and demographic variables. For example, people with higher incomes can afford to live in relatively expensive houses in lower-density residential areas. The impact of

densities on travel behaviour would be overestimated if the difference in income levels was ignored.

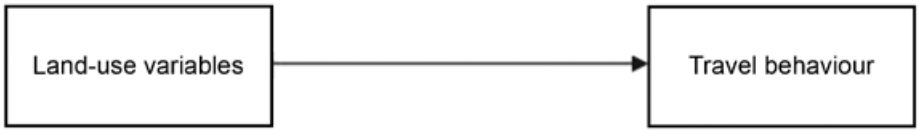

Figure 5.1 Relationships between land-use variables and demographic variables and travel behaviour – the traditional approach

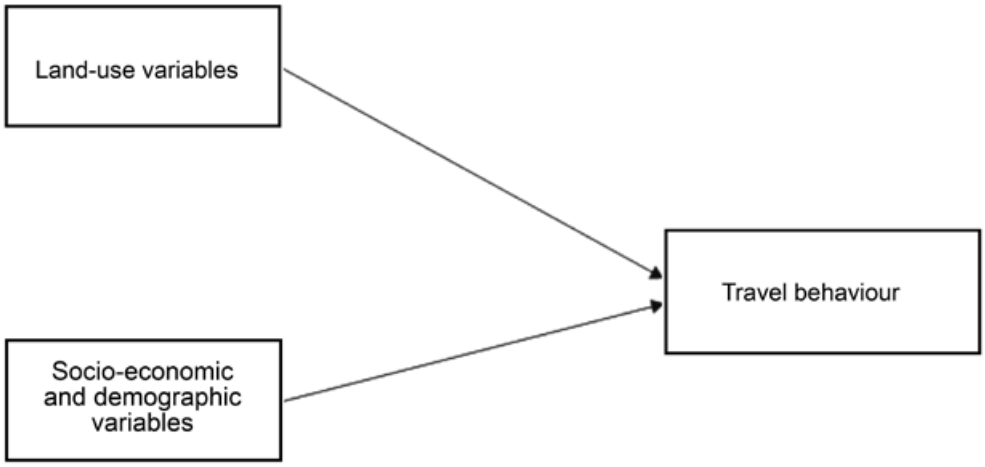

Figure 5.2 Relationships between land-use variables, socio-economic and demographic variables, and travel behaviour

Most recently, three more (often interrelated) changes have been made that are not included in Figure 5.2. Firstly, researchers have added more people and household variables not covered by socio-economic and demographic variables. These variables relate to attitudes, lifestyles and preferences for modes. Such variables express the possibility that people with the same socio-economic and demographic variables can still differ. Such attitudes, lifestyles and preferences relate to the needs of people, as explained in Chapter 3. For example, some people may have a more pro-environmental attitude and lifestyle, or a more culture-oriented lifestyle as opposed to a more material lifestyle, or people might simply prefer, more than others, to travel by car ('car lovers'), public transport ('public transport lovers') or in some countries by active modes. Studies that include such variables generally find a decrease in the impact of land-use variables compared to studies that do not include such variables. The second change is that researchers have recognized that people self-select themselves to locate in specific residential areas. Mokhtarian and Cao (2008: 205), based on Litman (2005), state that self-selection

refers to 'the tendency of people to choose locations based on their travel abilities, needs and preferences'. Self-selection can then result from 'traditional' variables such as income but also from attitudes and lifestyles or preferences for modes. Thirdly, and partly related to the phenomenon of residential self-selection, researchers have changed the model structure of variable categories by explicitly adding that socio-economic and demographic variables, and variables related to attitudes, lifestyles and preferences for modes have an impact on residential choice. The more complex relationships between the categories of variables that result can be estimated by so-called structural equation models (SEM models). Figure 5.3 conceptualizes the three changes that result from including additional variables and the more complex model structure.

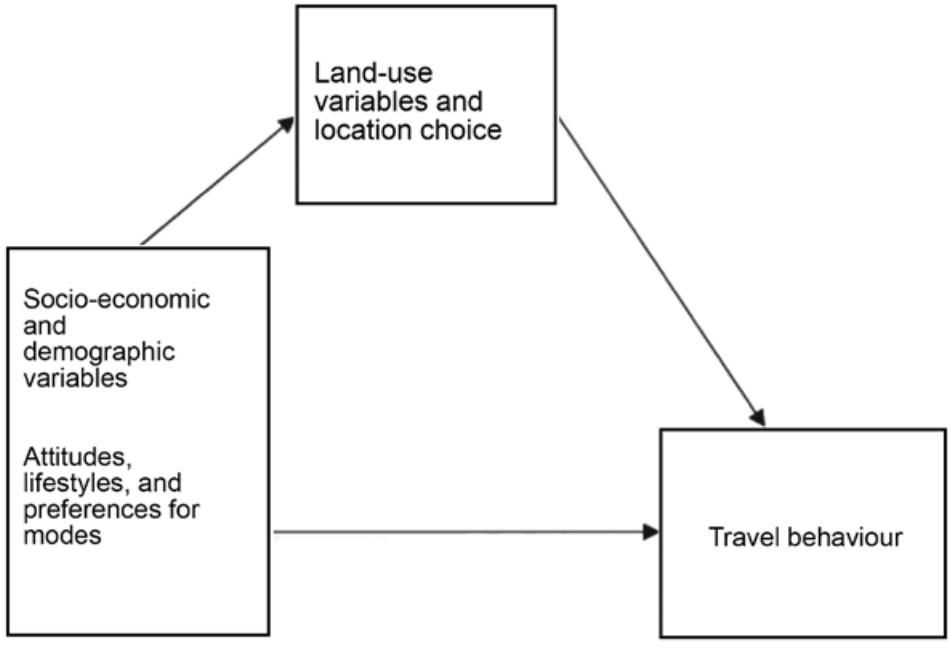

Figure 5.3 Relationships between land-use variables and location choice, socio-economic and demographic variables, attitude variables and travel behaviour – the current approach

The debates about the causal structure of (clusters of) variables still continues, and more advanced models are proposed (see, for example Cao et al., 2009 and Heinen et al., 2018). A topic that has been discussed frequently is the question about whether attitudes are stable or not *see* for example Kroesen et al. (2017), who show that the built environment can indeed change attitudes, or see van Wee et al. (2019) explaining the complex mechanisms via which attitudes can change in general. Another discussion relates to the question if the impact of land-use variables on travel behaviour is linear or not and if threshold values for such variables exist (e.g., Tu et al., 2021). At the time of writing this chapter, 2022, the debates were not at all finished.

5.4 THE IMPACT OF LAND USE ON TRANSPORT – A SHORT OVERVIEW OF THE LITERATURE

The aim of this section is not to give an extensive review but to summarize some empirical examples of the theory as discussed in section 5.3. I first give examples of studies into the impact of densities, mixed use, neighbourhood design and distance to public transport connections, followed by studies that add attitude, lifestyle and preference of modes variables and the use of SEM models.

5.4.1 Densities

One of the most frequently cited studies on the impact of densities are the study by Newman and Kenworthy (1988, 1999; see also Kenworthy and Laube, 1999), who concluded that energy use for travel per inhabitant is negatively related to urban density. Ewing and Cervero (2010) give an overview on the quantitative impacts of densities on vehicle miles travelled, concluding that the elasticity of local density for vehicle miles travelled and vehicle trips is around -0.05. In other words: a 1 per cent in increase of local densities results in a 0.05 per cent decrease in vehicle miles travelled and vehicle trips.

Most studies in the area of land use (or the built environment) on travel behaviour in general, and also with respect to the impact of densities, focus on OECD countries, but increasingly studies from other countries have been published. For example, Ahmadipour et al. (2021) present results from Tehran, Iran, confirming the impact of densities and mixed use on travel behaviour of earlier studies.

5.4.2 Mixed Use

The impact of mixed use on travel behaviour is often studied together with other land-use characteristics. Ewing and Cervero (2010) conclude that a 1 per cent increase in diversity (mixing uses) results in a decrease of -0.03 per cent in vehicle trips, and a 0.05 per cent decrease in vehicle miles travelled.

5.4.3 Neighbourhood Design

Manaugh and El-Geneidy (2011) show for Montreal that, if walkability of a neighbourhood is high, people make significantly more walking trips for most non-work purposes. Pan et al. (2009) found that, in the pedestrian- and cyclist-friendly neighbourhoods in Shanghai, residents travel shorter distances than in other neighbourhoods, and that pedestrian- and cyclist-friendly urban form makes the non-motorized modes feasible options. Recent studies sometimes also include bike sharing infrastructure. For example, Shaer et al. (2021) show that local bike sharing infrastructure influences cycling levels in Tehran.

5.4.4 Distance to Public Transport Connections, Destination Accessibility

Distances to public transport connections relate to both the origin and the destination of trips. An important category of destinations is work locations, including offices. Brons et al. (2009) show that access to railway stations contributes to travel by train. They conclude that expanding access services to the railway station can increase the mode share of rail. Cervero (2006: 53) emphasizes the importance of both ends of a trip: concentrating 'housing near rail stops will do little to lure commuters to trains and buses unless the other end of the trip – the workplace – is similarly convenient to and conducive to using transit'.

5.4.5 Attitudes, Lifestyles and Preferences for Modes, Residential Self-Selection and SEM Models

One of the first studies that included attitude variables was the study by Kitamura et al. (1997). They studied travel behaviour of people living in five neighbourhoods in the San Francisco Bay area, including socio-economic and demographic variables, land-use variables and 39 attitudinal variables. They found that attitudinal variables explained the highest proportion of the variation in the data *see* Cao et al. (2009) for an overview of empirical studies in the area of residential self-selection; see Mokhtarian and Cao (2008) for an overview of methodologies of studies in the area of residential self-selection, in both bases up to around 2007–08. Since then numerous studies have been published. For example, Faber et al. (2021) show that travel-related reasons (defined as 'the extent to which a travel preference actually affected the final decision to live in a certain neighbourhood', p.121), more than general travel mode attitudes, influence location choices of households. In addition, and in line with the study of Kroesen et al. (2017) referred to above, they conclude that attitudes and travel-related reasons influence residential choice and travel behaviour, but also vice versa.

Note that self-selection is not limited to residential self-selection but may also occur with respect to work location choice or the choice of other destinations (van Wee, 2009). Studies that include land-use variables and socio-economic and demographic variables, together with variables related to attitudes, lifestyles and preferences for modes, residential self-selection and travel behaviour, generally use SEM models to disentangle the relationships between variables.

An overall conclusion of such studies is that travel behaviour results from a complex interplay of all these variables, as conceptualized by Figure 5.3. The impact of land-use variables on travel behaviour can easily be overestimated if such complex relationships are overlooked. An important question then becomes what the impact of overestimation would be. Should the conclusion be that land-use policies that encourage people to travel by public transport or active modes or over shorter distances do not make sense, or at least make less sense than often assumed? Some people do not agree with this conclusion. For example, Næss (2014) even speaks about 'tempest in a teapot': he argues that, even if attitudes of people explain residential choice as well as travel preferences, people will only act according to their preferences if their residential area allows them to do so. Secondly, he argues that car ownership, and to some extent also transport attitudes, is influenced by the characteristics of the residential locations.

A third reason is provided by Schwanen and Mokhtarian (2005), namely that some people face a lack of congruence between physical neighbourhood structure and their preferences. One could argue that, for quality-of-life reasons, reducing such a lack of congruence matters.

5.5 WHY ARE THE CONCLUSIONS DIFFERENT?

Why do researchers find different results with respect to the possible impact of land use on transport? There are several reasons for this and some of them will be presented in this section.

5.5.1 The Research Method

A major source of differences as found between studies relates to research methods. Section 5.4 has already explained the importance of including other variables that have an impact on travel behaviour, including the importance of phenomena such as residential self-selection and ensuring an adequate structure between variables. Generally speaking, Handy (1996) concludes that more advanced research methods have generally found smaller and less significant effects of land use on travel behaviour.

Next, I discuss more reasons why study results differ, some of them also being methodological reasons.

5.5.2 The Level of Difference in Crucial Factors

One of the causes for different results from research is that the study areas sometimes do not really differ with respect to the most important land-use factors that influence transport, such as densities and the level of mixed land use. Small differences between areas with respect to important land-use factors of course result in small differences in travel behaviour.

5.5.3 The Geographical Scale

An often-neglected aspect in the discussion is the geographical scale. Firstly, the definitions or indicators for densities differ between studies (see subsection 5.3.2, the remark on gross versus net densities). Secondly, the size of the area at which forms of mixed use or densities occur matters (see subsection 5.3.2). Thirdly, several scales can be distinguished, including the direct surroundings of the dwellings, the neighbourhood, the town or city, the region, the part of a country, the whole country and even the international scale. The scale of research may affect the results. For example, Newman and Kenworthy (1988, 1999) focus on large cities. In several countries such as Denmark or Belgium, such cities do not exist. Therefore, it is not possible to conclude beforehand that building in high-density locations in such countries will result in lower energy use for transportation equivalent to the results found by Newman and Kenworthy.

5.5.4 The Time Horizon

Another reason may be the time horizon included. It is generally recognized in academic literature that, after changes in determinants for travel behaviour, people will not change their behaviour instantaneously. This comment relates not only to changes in land use but also to changes in infrastructure and prices. The relevance of how much time has passed since changes took place and when the empirical research is undertaken has implications for the findings. Suppose a new railway station is built in or near a residential area or office park. Many people might not immediately change their travel behaviour (in this example, their mode choice) but people might move from the residential area and new households that move to the dwellings that become available might be more inclined to travel by train. As explained above, people self-select themselves into residential areas based on their attitudes toward travel and preferences for modes. As a result, the impact of the new railway station will probably increase over time.

5.5.5 Differences Between Countries

Differences between countries (and even within countries, regions) complicate the transferability of results. Firstly, concepts play an important role in the discussion on the impact of land use on transport. Let us assume the compact city. What is considered to be a low-density residential area in many European regions and countries may be an example of compact building in the USA. In other words, what people consider as compact will differ between regions and countries.

There are other reasons that make the translation of land-use effects from one country to another risky. Examples relate to the role of different modes in the transport system but also to cultural differences. In Denmark and the Netherlands, and since recently also in several other cities and regions worldwide, the bicycle plays an important role in the transport system. For short distances, the bike may compete with the car or local public transport. But in many other countries, cities and regions the role of the bike is limited or absent. The role of the public transport system also varies from country to country. Such differences may result in other effects of the same land-use concepts. For example, as rail transport is a minor form of passenger travel in the US, results from empirical research there on the impacts of distances to and from stations would have little relevance to Europe, where levels of rail use are much higher, and vice versa.

Cultural differences may also be of importance, not only between, but even within, countries. As already explained in section 5.2, in some cultures cycling is not at all 'sexy', whereas in others such cultural barriers do not exist.

5.5.6 Indirect Effects

Figure 2.1 shows that land use may have a direct impact on passenger travel, but it also shows the existence of several indirect effects. These effects may be very complex – see all the arrows

in Figure 2.1. It is very complicated to distinguish all the kinds of direct and indirect effects quantitatively.

5.5.7 The Impact of Policy

Policy can also affect land-use patterns. The travel behaviour of people living in a high-density, public-transport-oriented city such as Tokyo may differ strongly from the travel behaviour of people living in a low-density, car-oriented city such as Los Angeles. But this does not mean that it will be easy to implement Tokyo's urbanization patterns and infrastructure systems in the USA. So, even if land use has an impact on travel behaviour, it does not mean that it is easy to use land-use policy as an instrument to influence travel behaviour. The effect of land-use policies may therefore be limited compared to the effect of land use in general. Generally speaking, researchers who assume relatively strong impacts of policy on land use are more optimistic about possibilities to influence travel behaviour by land-use planning than those who have not made this assumption (Anderson et al., 1996).

To summarize, there are many reasons for different researchers and policy-makers to draw different conclusions with respect to the impact of land use on travel behaviour. Probably methodological reasons dominate. A systematic analysis of possible causes for differences will be needed to discover these reasons.

5.6 EVALUATING THE IMPACT OF LAND USE ON TRAVEL BEHAVIOUR: INDICATORS AND EVALUATION METHODS

Several of the more advanced studies have found significant impacts of land-use variables on travel behaviour, even though there is no consensus on this impact (Cao et al., 2009). Here, and in line with for example Ewing and Cervero (2010), it is assumed that there is enough empirical evidence to conclude that land-use characteristics as discussed above have an impact on travel behaviour. And several options for policy-making exist, such as building in higher densities, mixing land use, building in high densities near railway stations, and design options for walking- and cycling-friendly neighbourhoods. Would the conclusion then be that policy-makers should be advised to base land-use planning only on impacts on travel behaviour, or even only on impacts on car use? Probably not, as choices with respect to land-use policies should be made considering all relevant aspects, including travel behaviour but also impacts. This section will first discuss these impacts, followed by a discussion on how to evaluate land-use alternatives using these criteria.

5.6.1 Indicators

Most research (and policy documents) on the impact of land use on travel behaviour places the topic in an environmental context: land use could improve the environment by reducing car use and its negative impacts. Research generally uses the following indicators to express this impact: (1) kilometres (vehicles, passengers), mostly by mode, often by trip purpose; and (2)

the number of trips, mostly by mode, often by trip purpose. Furthermore, some studies also focus on trip distances. Only a small minority of studies provide environmental indicators, such as CO_2 and NO_x emissions. These indicators are relevant but very often are not produced on a comprehensive scale. Additional (categories of) indicators are now discussed. It should be noted that some of the suggestions are related or even overlap. The first three suggestions are related to the positive aspects of travel, aspects that are very often neglected in transport discussions in general and in discussions on the impact of land use on transport.

Accessibility

Many studies do not use indicators that express the quality of the land-use and infrastructure system: to what extent does this system enable us to travel between locations we want to visit and thereby participate in the activities desired? Therefore additional accessibility indicators could be used, including those used in geography (potential accessibility, time–space related accessibility indicators), utility-based indicators (see Geurs and van Wee, 2004, for a literature review of accessibility indicators) and travel time indicators (e.g. Schwanen et al., 2002). So far the use of such indicators has been limited, but Handy (2020) hypothesises that this might change in the future *see* section 5.7 for further discussion.

The option value

Current evaluations focus on user benefits only, but if non-user benefits are relevant, then the option value may be important. The option value in the context of land use and transport can be described as an individual's valuation of the opportunity to be able to use a particular transport mode or piece of infrastructure in the future that is not being used in the present, or the option to have access to a specific destination that is currently not visited. For example, car owners may value the ability to use a public transport service when they cannot make use of the car, for example owing to unavailability or a breakdown, bad weather, increases in fuel prices or other car costs, or the loss of the ability to operate a car. Or a person may value having access to shops she does not currently visit (see Geurs et al., 2006 and Bondemark et al., 2021) for empirical studies of option values).

The consumer surplus

The consumer surplus plays an important role in evaluations (including cost–benefit analyses – CBAs) of infrastructure projects. The consumer surplus is the difference between the market price of a product or service and the value for a consumer. For example, if a consumer is willing to pay 50 euros for a book but the price is 20 euros, the consumer's surplus is 30 euros. Some trips probably have a very high consumer surplus. For example, if one wants to visit a relative in hospital, the visit may be worth much more than the costs of travel. Let us assume two scenarios: scenario A with the current pattern of hospitals and scenario B with many fewer hospitals (e.g. in order to profit from scale effects). In scenario A, visiting a relative in the hospital is possible after a ten-minute cycling trip, whereas in scenario B a car trip of half an hour is needed. Assuming the visiting frequency is the same in both scenarios, the consumer surplus of scenario A is much larger than that of scenario B. The difference is the GTC of the car trip in

scenario B minus the GTC of the bicycle trip in scenario A (costs include both monetary and non-monetary costs such as travel time).

Safety

Safety impacts of land-use and transport alternatives may differ. If they do, such impacts should be included in the *ex ante* evaluation of these alternatives.

Health impacts due to exercise

If people travelled more by active modes, this would have not only environmental and safety advantages but also health advantages (see Chapter 12).

Environmental impacts

If environmental impacts are included, it is usually done by listing emissions levels. However, for local air pollution, exposure is very important. The same amount of kilograms of emissions may have different exposure impacts. It is highly relevant if pollutants are emitted on a road with many people (living, working, carrying out recreational activities) in its vicinity as opposed to a road in an agricultural area (see Chapter 10). Noise effects are also highly dependent on the direct vicinity of a road or railway. The literature hardly pays attention to wider liveability effects, such as the impacts resulting from moving and parked vehicles, regardless of their exhaust and noise emissions (such as the fact that in many places children cannot play on the streets anymore) (see Chapter 2), but such impacts are also relevant for the evaluation of land-use policies.

Valuation by the people

Much is known about residential choice preferences (see, for example, Huang et al., 2014). Many people prefer living in spacious homes on spacious plots. On the other hand, building in low densities results in less accessibility to opportunities and to the public transport system. Building in low densities also results in a larger space claim on residential areas and thus in less green space between cities and towns. How do people value such items? We hardly know. But people's opinions are relevant for an overall view of the pros and cons of land-use scenarios.

We probably know even less about what people think of the job location. What do people prefer – a job location on the edge of town, near a motorway or in the inner city near a railway station? Probably different groups of people have different preferences. Such valuations of people could be relevant for the *ex ante* evaluation of land-use concepts.

Financial aspects

The relevant factors here include the costs of construction, maintenance and exploitation of land-use and transport alternatives. We know more about the financial aspects of the transport system, in general, and more about infrastructure costs, in particular, than we know about costs of land-use alternatives. The impact on GDP (and unemployment) is also relevant. The (valuation of) indirect effects of land-use and transport alternatives (such as effects on the labour and housing market) are much more difficult to estimate than the direct effects (see SACTRA, 1999, or Banister and Berechman, 2000, for a discussion of the indirect effects of

infrastructure). A distinction should be made between costs for society as a whole, for the government and for the users or consumers.

Robustness

Another issue is the robustness of the land-use and transport system. Here I use the term 'robustness'; other terms often being used for more or less the same concept are 'flexibility', 'reliability', 'resilience', 'vulnerability' (about the opposite of robustness) and 'substitutability': the last concept can be defined as 'the extent to which the preferred travel alternative can be substituted by other initially less preferred alternatives' (van Wee et al., 2019: 1). Robustness plays a role at several terms, ranging from the short term of being able to change routes while travelling, for example because of a road block, to long-term robustness playing a role over several decades. For the long term questions are raised about: how vulnerable are we to, for example, an expected or unexpected limitation on energy availability for transport? Energy limitations may be the result of political instability in oil-producing countries, much higher oil prices (for example, due to 'peak oil'; see Chapter 10) or stringent environmental (climate) policies. Preferences of consumers and firms might also differ in the future. In addition, what will happen if sustainably produced energy becomes available at reasonable prices? The question then will change from 'How can land use contribute to reducing transport problems?' to 'How can land use enable us to perform activities in different places under different conditions?' This changing role is important not only for land use but also for the role of public transport and active modes, and for information and communication technology (ICT). Probably land-use transport strategies that are positively valued with respect to travel behaviour impacts will be robust. Such strategies include compact building, mixed land use and availability of good-quality public transport.

Fairness

In addition to the scores of candidate policies on the criteria discussed above, fairness is an upcoming topic in both research and policy-making (see Chapter 15). Distribution effects play an important role in fairness discussions, dominant examples being distributions across population groups by income or region.

5.6.2 Evaluation Methods

The use of a multi-criteria analysis (MCA) or a CBA for land-use scenarios is generally recommended (see Chapter 15). A lot is known about the valuations of reductions in travel time and benefits of additional travel. Much is also known about people's willingness to pay for noise reductions or risk reductions. However, choosing price tags (CBA) or weight factors (MCA) for several other output indicators is partly a political choice. This includes aspects like the value of CO_2 emissions reduction, nature conservation and 'spatial quality'. Researchers can assist policy-makers who have to weight components, and they can advise on methods, carry out research and use the results of other studies. For this reason, combining a CBA and an MCA provides an interesting basis for policy-making. For a further discussion on evaluation methods, see Chapter 15.

5.7 EVALUATING THE IMPACT OF LAND USE ON TRAVEL BEHAVIOUR: THE ENVIRONMENT VERSUS ACCESSIBILITY

As explained above, research into the area of land use and transport has generally placed itself in the context of environmental gains: land use could contribute to lower levels of car use, and an increase in the use of active modes and public transport. However, as explained above, several researchers have found only limited impacts of land use on travel behaviour. Some of them have concluded that related policies therefore make no sense. In line with insights from economics, it can be argued that land use potentially could decrease motorized mobility (including car use), but in practice people may not travel less using motorized modes. Then there must be accessibility gains that at least equal the potential gains in savings of GTC. Therefore, the general way of evaluating land-use concepts on (only) travel behaviour and environmental gains is insufficient, and accessibility benefits should be added. Van Wee (2011: 1530) expands on this proposition: 'If the potential (theoretically possible) impact of land use on travel behaviour does not occur in practice, there must be accessibility benefits for travellers, that they value at least as highly as the benefits of the potential decreases in Generalized Transport Costs.'

I define accessibility benefits as all the benefits that provide utility to travellers, related to the activities they carry out at different locations (working, shopping, visiting friends, etc.). For the net benefits these benefits should be corrected for the disutility of travel (GTC; see section 5.3 and Chapter 6).

For economists and others with a background in utility-based discrete choice theory, the proposition is not at all surprising, as it formulates the economic approach to accessibility.

Below, the proposition is explained using a simple example. Suppose we could 'shrink' a certain region to 25 per cent of its original size. I assume a closed region (no external trips). In addition, I assume that all other determinants remain constant, in particular the locations of activities. In this case, trip distances would be reduced by 50 per cent (surface area expands quadratically with an increase in radius). I assume all trips are made by car. If there were no behavioural changes other than distance reductions, people could participate in the same activities by travelling only half of the kilometres and would need only half of the original travel time. More generally, GTC would be reduced by 50 per cent. But, according to the theory of constant travel time budgets (TTB) – see Chapter 5 – because people trade-off the benefits of activities and the disutility (GTC) of travel, it can be expected that people will choose more remote destinations. They could, for example, visit another, more remote supermarket because it is cheaper or offers more products. Or they could choose another job at a greater distance from their home because it pays better, is more challenging or offers more career prospects. Note that, according to the theory of constant TTB, not all people would change their behaviour, and certainly not everyone would travel as many kilometres as before the 'shrink'; the TTB is about averages over a large group. Some people might not change jobs at all, but others might choose a job at a distance four times the commuting distance after the shrink. Now let us assume that at the level of all people who travel in the region the potential decrease in travel times and distances completely disappears because of behavioural changes.

In that case no effects of land use would be found even though there must be accessibility benefits with a value that at least equals the potential savings of GTC. If not, people would take advantage of the decrease of GTC by 50 per cent. It is also likely that there will be greater benefits from choosing the more remote destinations. Again, please note that this insight is not new for economists; it applies to all goods and services with elastic demand.

Of course, reality is more complex than our example. People can adapt their behaviour in more respects, such as a mode change or a change in trip frequencies. A shrinkage, as in our example, might lead to a decrease in average travel speeds due to higher densities on the road network and parking capacity problems. These complexities change the potential reduction of GTC due to the 'shrink' but do not change the principle that the behavioural changes after the shrink, other than simply reducing travel distance and time, must have benefits that at least equal the value of the benefits of the potential reduction of GTC.

The same line of reasoning applies for mixed use or a reduction in distances to public transport nodal points: thanks to the land-use changes a potential reduction in GTC is possible owing to distance reduction and/or mode change, and that is valued positively. If, in practice, people did not travel less (but travelled to destinations further away) there must be accessibility benefits that the travellers value at least as much as the benefits that would be possible from the reduction of GTC.

To conclude, if research showed that land-use concepts that allow for a reduction in GTC would not result in people really reducing their GTC, it is not correct to reject such concepts because then significant accessibility effects occur.

5.8 CONCLUSIONS AND DISCUSSION

These are the most important conclusions of this chapter:

1. The theoretical foundation for the impact of land use on travel behaviour can be found in the theory of utilitarian travel demand. This theory postulates that the demand for travel does not derive its utility from the trip itself, but rather it originates from the need to reach the locations of activities.
2. The land-use related determinants that have an impact on travel behaviour that are most often mentioned in the literature are density, mixed land use, neighbourhood design, distance of origins and destinations to public transport nodes such as railway stations, and destination accessibility.
3. Travel behaviour results from a complex interplay of land-use variables, socio-economic and demographic variables, variables related to attitudes, lifestyles and preferences for modes, and residential self-selection. The impact of land-use variables on travel behaviour can easily be overestimated if such complex relationships are overlooked.
4. Empirical studies into the impact of land use on travel behaviour often find different and even contradicting results, methodological reasons probably being the most important cause of these differences.
5. Land-use concepts are often promoted because of policy reasons, environmental reasons being the most mentioned. However, most studies focus only on impacts of land use on travel behaviour. To make such studies more relevant for policy, additional output

variables are relevant. These include environmental impacts, accessibility impacts, the option value, the consumers' surplus, safety and health impacts, the valuation of land-use concepts by people, financial aspects, long-term robustness of the land-use and transport system, and fairness.

6. If most effects of land-use concepts can be quantified and expressed in monetary terms, a CBA could be an attractive method to evaluate such concepts *ex ante*. If important effects are difficult to quantify or express in monetary terms, combining a CBA and an MCA provides an interesting basis for such evaluation.
7. If the potential (theoretically possible) impact of land use on travel behaviour does not occur in practice, there must be accessibility benefits for travellers that they value at least as highly as those of potential decreases in GTC.

NOTES

1. Sections 5.3 to 5.6 are partly based on van Wee (2002). Section 5.7 is based on van Wee (2011).
2. Note that not all travel is derived (see Mokhtarian and Salomon, 2001, and Chapters 2 and 3 in this volume).

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