

Land-Use and Transport: a Review and Discussion of Dutch Research

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1. Introduction

Numerous studies of the interaction between land use and transport have been carried out in the past. In this paper we evaluate a selection of Dutch studies. Before reviewing the studies, we present a conceptual model for passenger transport (section 2), give an overview of the way in which land-use influences travel behaviour (section 3). We also give an overview of transport in Dutch land-use policy plans (section 4) and a categorisation of research (section 5). We then review empirical studies (section 6) and model-simulation studies (section 7) of the impact of land-use on transport. This is followed by a synthesis of the results and look at the transferability of results to other countries (section 8), a discussion of the policy implications of our findings (section 9) and some suggestions for further research (section 10).

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2. A conceptual model for passenger transport²

Given the overall population size and demographic characteristics, the total volume of passenger transport and the split between transport modes depends on the locations of human activities, the needs and desires of people and the transport resistances (generalised transport costs). Locations are related to such activities as living, working, shopping, recreation and education. The needs and desires of people are related to socio-economic and cultural factors. Income is an important determinant, but not the only one. Availability of cultural facilities such as museums within travel distance might stimulate people to think about wanting to visit them. Transport resistances are dependent on monetary factors, travel times, comfort and reliability of all alternatives. Figure 2.1 illustrates the relationships between these determinant categories.

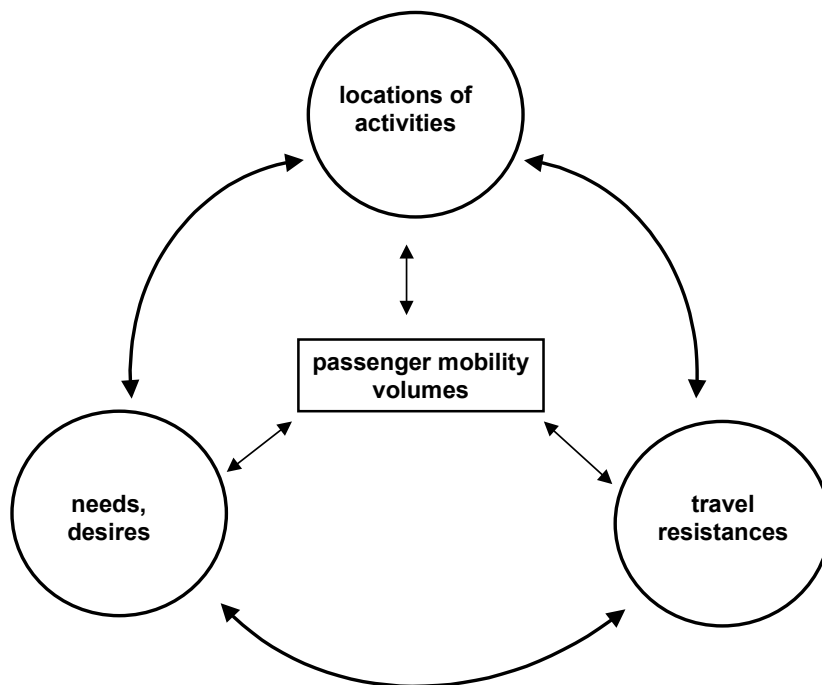


Figure 2.1 Relationships between activity locations, needs and desires, transport resistances and passenger transport.

Source: Van Wee (1997)

Figure 2.1 shows that all three categories are influential in all directions. Changes occurring in one of the three categories of determinants could have an impact on the system as a whole. Changes in land-use patterns might change transport resistance between certain locations. For example, the suburbanisation of offices in the Netherlands in the eighties resulted in longer travel times by public transport and more congestion on motorways. It also increased the

²This section is mainly based on Van Wee and Van Der Hoorn (2000).

benefits of car ownership because of the poor public transport accessibility of the new office locations. More air connections and decreasing airfares made it possible to equip remote locations with recreational facilities. This development stimulated people's interest in holidays at such locations. Growing car ownership levels decreased travel times by car and encouraged suburbanisation. Partly because of growing car ownership levels and car use, most Western countries expanded the motorway network, resulting in shorter travel times, a higher level of car usage and dispersed land-use patterns.

The current situation can be considered a kind of continuously changing equilibrium (or maybe better: disequilibrium). This is because changes occur long before the long-term equilibrium becomes a fact.

Travel demand has been defined as the sum total of realised needs of travel, expressed as the actual number of trips or trip kilometres. The theoretical foundation for the relation between travel and spatial structure 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. Rather, it comes from the need to reach the locations where activities take place, such as the dwelling, the work place, and services and facilities. So, from this perspective of utility, travel is seen as *derived demand*. The demand for travel depends on the utility of the activity, on the one hand, and on the (aggregate) costs to reach that destination, on the other hand. These aggregate costs (the individual's valuation of the time, money, and effort needed to cover the distance) are not only determined by the quality of the transport system but also by the characteristics of the spatial structure surrounding the sites where the activities take place. The spatial structure determines the generalised costs between the activities, as well as the ease of access to the various traffic modes. Figure 2.1 reflects these theoretical foundations.

3. Impact of land use on travel behaviour

3.1 Indicators for land- use effects of travel behaviour

Most research and policy documents on the impact of land use on travel behaviour use as indicators (1) kilometres (vehicles, passengers), mostly by mode, often by motive; and (2) number of trips, mostly by mode, often by trip. Some studies also pay attention to travel distances and give a breakdown by population category. Some studies give environmental indicators, such as CO₂ and NO_x emissions. Very few studies give accessibility indicators, such as congestion levels or lost vehicle hours. We think that these indicators are relevant, but many studies do not use indicators that express the quality of the land use and infrastructure system. Therefore we think that additional accessibility indicators as used in geography (potential accessibility; time-space related accessibility indicators) are also needed.

3.2 Determinants for the indicators

The value of the indicators of section 3.1 can be influenced by several determinants: (1) the number of out-house activities, (2) modal choice, (3) travelling distance by mode, and (4) the extent to which chain trips / a chain of activities are made. A clarification of the fourth determinant: people may combine more activities in a chain of trips. For instance, a person may first bring a child to school, then go to work and do shopping after work, before turning

home. Given the total number of activities, such a chain might lead to fewer trips, and even to fewer kilometres travelled, than if single home-based trips to all activities were made. On the other hand, such complex trips induce people to use individual transport, which is in many cases the car.

3.3 Impact of land use on the determinants

The literature quotes several land-use variables that may influence the determinants of section 3.2. The most frequently mentioned variables are:

- The location of houses, jobs, shops and other opportunities in combination with infrastructure networks
- Densities of houses, employment and other categories of land use
- The level of the mix in land-use categories
- Other factors related to the land-use structures (orientation to a single town or centre versus multi- towns/centres orientation, concentration versus a sprawl of urbanisation)
See for example Handy (1997); Verroen (1994).

The locations of jobs related to infrastructure networks may significantly influence modal choice of commuters: the share of train is much higher if jobs are located near railway stations than if they are located at the edge of the city, far away from a station ñ see section 6.2.

Among the spatial factors, density in particular is assumed to exert an influence on travel behaviour. Some authors even consider density to be a valid proxy for the other spatial characteristics (Steiner, 1994). Density may influence the aggregate cost of travel in several ways. As densities increase, distances become shorter. This results in fewer travel kilometres, but it may increase the frequency of trips. The effect on the choice of the travel mode is less ambiguous. Shorter distances through areas with high densities induce people to use slow modes of transport. Moreover, areas with higher densities offer more support for public transit. Finally, congestion discourages the use of the private automobile as an alternative travel mode.

One form of spatial structure that significantly affects the distance between activities is known as mixed use development. If dwellings and shops are highly intermingled, it becomes more likely that the shopping needs can be satisfied in the immediate vicinity of the home. This may encourage shorter trip distances and a higher share of slow modes.

3.4 What to influence by land-use policies?

Most research and policy questions with respect to the impact of land use on transport are related to overall travel behaviour impacts that can be expressed using the indicators of section 3.1 (kilometres; number of trips). Although the Dutch government has a target for car use (between 1986 and 2010 a maximum growth in car use of 35%) the car use level can be seen as an intermediate target, having a major impact on congestion and environmental indicators.

Land use may not only influence the indicators as mentioned before (such as the overall level of car use), but also the *spatial patterns* of travel and so congestion levels, environmental and safety impacts. E.g. accident risks vary strongly, depending on the road type; the concentration of traffic on fewer main roads results in a decrease in noise nuisance. Finally

land use may influence the locations of the places where people face the 'output' of traffic. E.g. the distance between houses or schools and the road influences noise levels and the concentrations of pollutants. We suggest that further research into the spatial distribution of traffic should be carried on, in order to be able to show the impact on accessibility, liveability and the environment.

4. Traffic and transport in the National Spatial Planning Plans

In the Netherlands there is a tradition of policy reports for land use at the National level. The first report on land-use planning (spatial planning) dates from 1960, the current report, the fourth, is from 1988-1991 with an update in 1996. Later this year the fifth report is expected. Van Wee (1995) gives a review of transport in the plans. He concludes that in the first two reports (1960 and 1966) the government expects a strong growth in road traffic that should be facilitated. Many new roads had to be built. The interaction between land use and transport was first noticed in the second report. The third report dates from 1976-1985 and was written after the oil crisis of 1973 and after the report of the Club of Rome (1972). Environmental aspects played an important role in the third report. The government considered a shift to public transport and to slow modes as desirable. Land use should contribute to transport goals. E.g. new offices should be built near public-transport nodes. Many of the policy intentions were not carried out due to a specific lack of land-use instruments. The Fourth report gives quantitative targets for the maximum growth in car use. Land use has to contribute to the reduction in the target growth in car use. As in the third report the policy is that new offices should be located near public transport nodes (mainly railway stations). Big new residential areas can only be built at locations with good public transport facilities, mainly railway stations. The compact city concept is leading to the development of residential areas. Contrary to the period before the fourth report, there are *maximum* numbers of parking places (relative to the number of people working) near office locations, located near public transport nodes. Unlike the previous reports the fourth report gives specific instruments for putting policy into practice. At the time of writing (2000) it can be concluded that the fourth report certainly has had an impact on the development of new residential areas and of new industrial areas (especially: office areas). But not all urbanisation is in line with land-use policy. And in practice most (if not: all) new office areas have more parking places than the guidelines.

The goals of Dutch land-use policy in the fourth report were specified as follows: first, to boost the economic base of the cities; second, to reduce the increase of mobility; third, to be able to site dwellings, jobs, and services and facilities relatively close to each other, and to design the layout of development sites in such a way that access by bicycle and public transport is optimised; and fourth, to slow down the encroachment of urbanisation on rural areas (MVRM, 1991, 1996). The emphasis on control of mobility is remarkably strong. That is because the shoring up of the economic base of cities, as well as the imposition of limits on residential construction in rural areas, are also meant to contribute to the attainment of the mobility goals.

To help reach the policy goals, a serious attempt has been made in recent years to densify the existing built-up areas (by developing 'brownfield sites'), while 'greenfield sites' are developed as close to the existing built-up areas as possible. There are serious attempts to

create overall densities of at least 30 dwellings per hectare (12 dwellings per acre) in new developments, with even higher densities being aimed for near public transport stops. At the same time, the so-called ABC policy for the siting of employment is used to promote the location of labour-intensive activities near public transport stops—this principle should also result in densification. Because it became clear that indiscriminate densification could impede the attractiveness of the city, national government has recently attempted to promote increased spatial variation in densities. The outcome of this policy is invariably that intensive and multiple land use is sited in specially designated locations, which leaves room for low-density development, parks, and open space elsewhere. The overall result is that the overall density standard can be maintained.

Evaluating transport in the land-use plans leads to the conclusion that there is a focus on the higher spatial scales. Apart from the location policy that links types of firms with types of locations, greatest attention was paid to general urbanisation concepts such as the compact city and the location of residential areas in relationship with infrastructure. Besides the focus has always been on changes in land-use categories (e.g. from agricultural land to residential areas) and not on the link between individual households and houses, and individual firms and buildings.

5. A categorisation of research

The studies reviewed differ by research method and type, aim, scale and variables used. Table 1 gives an overview of possible research categories.

Table 1: Categorisations of research into land-use impact on transport

Number	Categorisation with respect to	Categories
1	Method	Empirical research versus model simulations
2	Scale	Neighbourhood, town/city, region, higher-than-region
3	Aggregation level / research subject	Individuals/households versus neighbourhoods or cities
4	Position of infrastructure	Only land use varies, or both land use and infrastructure varies
5	Model type	Long-term equilibrium versus dynamic models
6	Model type	“Traditional” models versus other model types (e.g. micro-simulations, activity models)
7	Model type	Only impact of land use on travel behaviour or interaction between land use and travel behaviour
8	Dependent variables	Kilometres/trips per mode; activity patterns, use of infrastructure, financial variables
9	Independent variables	With or without control for other variables, including socio-economic variables
10	Method	Only land use differs or (also) origin-destination patterns
11	Independent variables	Focus on policy variables, or also non-policy variables
12	Bias within homogeneous groups	With or without correction for bias within homogeneous groups
13	Aim of the study	E.g. forecasting environmental impacts or congestion levels; estimating intensity ñ capacity relationships

Some explanation:

Number 9: suppose an empirical study shows a relationship between density and car ownership: areas with higher densities have lower car ownership levels. This relationship might be caused by differences in incomes. People with lower incomes have lower car ownership levels. These people might live more than average in higher density areas. So the impact of densities on car ownership levels might be explained by differences in incomes. The relationship between densities and car ownership levels therefore should be controlled for the variable 'income'.

Number 10: most research and policy documents pay attention to changes in land use, e.g. the conversion of agricultural land to urban land use. Besides it is possible to change the locations of actors within existing land-use patterns, e.g. the division of households within the given houses.

Number 12: most studies use homogeneous population categories, using variables such as income, age, sex and education level. It is assumed that within these homogeneous groups people have the same behaviour in given circumstances. However, within these groups there may be people with specific preferences, for example some people might prefer the car, others might prefer to travel by public transport. Pickup and Town (1983) found that people with a preference for travelling by public transport do not consider a residential location remote from a station.

For empirical studies we think that numbers 2 (scale), 9 (with or without control for other variables) and 12 (with or without correction for bias within homogeneous groups) are the most important. For model simulations we think that 6 (traditional or other models), 10 (only land use differs or also origin-destination patterns) and 12 are the most relevant. We use these numbers to review the literature. However, we exclude 10 and 12 because we did not find a study that looked at this subject.

6. Review of literature: empirical studies of land-use impact on transport

6.1 Studies of residential areas and their travel behaviour impact

In the Netherlands, new construction is to be guided by the so-called Vinex locations (named after the acronym for the Fourth Report on Physical Planning Extra). According to the compact city policy contained within Vinex, new housing development areas have to be sited in accordance with the urban concentration principle. Den Hollander et al. (1996) have evaluated the impact of the proximity principle on the commuting rate, by comparing the behaviour before and after a move to a Vinex-like residential location. The research showed that with a usage rate of 60 percent, the car was and remained the preferred mode of transport. Furthermore, the use of the car showed hardly any tendency to decrease. The journey to work has become slightly shorter. However, any reductions were entirely accounted for by a small number of households who had moved over a very long distance and had reduced their commuting substantially. The other households proved to have increased the distances they covered. The study is limited in that it does not compare locations (rather than the unknown previous location).

Konings et al. (1996; see also Maat 2001) investigated 25 new residential locations in the province of Noord-Brabant. The locations were distinguished according to urbanisation type

(intra-urban, urban extensions, and rural) and housing density (low, intermediate and high). Urbanisation and density are combined to location types; a few of these seldom occur, however, five types are actually used here. Location types as well as socio-economic variables were put into regression analyses.

The study reveals no significant differences between the location types with regard to the number of kilometres driven weekly per household. At infill development areas within the urban regions, where densities are high, many households (25%) do not drive to work. But their contribution to reduced mobility is virtually wiped out by a group with a long commuting by car at infill locations. The differences in number of car kilometres are chiefly explained by the variables of car ownership and household composition. Car ownership is lower at infill locations, especially double car ownership. A two-car family will drive at least twice as many kilometres as a one-car household. Dual-income families drive more kilometres than single-income households do. Single-income households with children drive more than households without children; however, the opposite applies to dual-income households: with children: they drive less than without children.

There is a slight but significant correlation with housing density: driving decreases somewhat at higher densities. A respectable share of commuting (25%) is by cycling or walking, however. Interestingly, precisely in rural areas, the bicycle plays a specific role. Public transport usage is scarce though its use rises in tandem with higher densities.

The move to a new residential location has had virtually no effect on the choice of mode of transport for the journey to work. On average, there has been a slight reduction in the number of kilometres travelled to work. However, that decline may be explained by one member of the household ceasing to work. As found in the Randstad study, most of the reduction in kilometres may be attributed to the households that have moved over a long distance; the rest of the newcomers actually travel more kilometres than previously.

Dijst and Van Vossen (1996) carried out research into residents of Vinex-locations. They conclude that in the Netherlands urban form and land have some impact on car use. However, the level of car use is not primarily determined by land-use variables but by household income. But even for income, land use has some impact on modal choice.

Snellen (1999) assessed the relationship between mode choice and characteristics of urban form on frequently made trips, by using a multinomial logit model. Therefore, travel data was collected by using travel diaries, as well as data about the physical structure of the neighbourhoods studied. The models included not only trips and urban form features, but also socio-economic characteristics of households and individuals including income, household type, dwelling type, age, gender and car availability.

From her study it can be concluded that distance and availability of motorised transport are the main, and most consistent, factors influencing mode choice. It was found that shorter distances favour non-motorised transport modes, while car availability yields the opposite effect. It is important to notice that both these factors are difficult to influence. Results show, for instance, that nearby available facilities are often not chosen as a destination by neighbourhood inhabitants.

Another main conclusion is that road network types on especially the neighbourhood and local street level are important spatial variables with regard to mode choice. Results show that grid type networks favour non-motorised modes, as opposed to loop type structures, which favour motorised modes. The influence of other spatial factors proved to be absent or limited, while a number of socio-economic factors do play a (modest) role.

Hilbers *et al.* (1999) also carried out research into travel behaviour effects of Vinex locations. They controlled for other relevant variables. They conclude that the differences in travel behaviour between the location types are significant. People in Vinex locations in the Randstad, outside the existing urban area on average travel 44 km per day, people in Vinex locations within the existing urban area 33. Differences in car use are even bigger: car use of people living in Vinex locations within the existing urban area is about one third lower than of people living in the Vinex locations outside the existing urban area.

Dieleman *et al.*, (2002) carried out research into the relationships between the residential environment and travel behaviour. They conclude that the type of residential environment is clearly related to distances travelled with the different modes of transportation. The number of kilometres travelled by private car is much lower in the three largest cities than in suburban and rural environments. Medium-sized cities hold the middle ground in this respect. Relatively long distances are travelled by public transport by persons living in large and medium-sized cities and new towns, where this service is more readily available than elsewhere. The distances one walks or bikes does not seem to differ substantially between the various residential environments, although the medium-sized cities seem to be the environment most suitable for biking also over somewhat larger distances. They controlled for person and household variables.

Meurs and Haaijer (2001) carried out research into the impact of land use at the neighbourhood level (the immediate vicinity of the dwelling, including the dwelling itself, and the street) on travel behaviour. The study controlled for personal variables and location of the neighbourhood on an aggregate level. They found that the environment affects the number of shopping trips by 30%, while the effect on commuting trips is negligible (1%). The effects proved to be higher on walking and cycling than on car use. The most influencing design characteristics in favour of the bicycle are a *éwoonerfi* (priority for slow modes; maximum speed 5 km/h) and a garden with privacy. It is concluded that people who have shops for daily needs and schools within short distance, and live in neighbourhoods with higher densities and cyclists and pedestrian friendly infrastructure use the car less than others.

Utrecht University carried out research into the impact of the residential area on travel behaviour, using data of the National Travel Survey. Some of the results were reported in Schwanen *et al.* (2001, 2002), and Schwanen and Dijst (2002; forthcoming); for an overview of all results we refer to Schwanen (2003). The analyses have indicated that the spatial configuration of land use and transport systems influences many aspects of travel/activity behaviour. Mode choice appears to be most sensitive to this spatial configuration, followed by distance travelled. For car drivers the variation between spatial contexts in commuting distance is larger than in commuting time. Though significant, the impact on commuting time is limited. The research is interesting because of the subject of research: it is one of the few examples focusing on travel time as a dependent variable. Besides, the research is interesting because of the methodology: the researchers used multi-level regression models. The only other example of the use of multi-level regression models for the impact of land use characteristics on travel behaviour is the research of Snellen (2001) who carried out research of the impact of land use at the local level on travel behaviour. She hardly found any significant impacts, even not for densities.

Maat and Arentze (2003) reported on the effects of the spatial context on activity participation and in particular the assumption that higher accessibility to activity locations encourages greater activity participation, and thus more trips. Detailed activity data and

spatial information was collected from households in an area including the cities of Amsterdam and Utrecht. Activity patterns were reported as separate frequencies and duration of work, school, daily and non-daily shopping. Six comprehensive and clearly distinguishable patterns were derived from the data. The patterns were largely explained by their sociodemographic variables, but little evidence was found that activity patterns vary across spatial characteristics. There was some indication that people living further on from daily shops have a longer shopping duration, and there is some influence of the availability of shops and services on activity patterns. Significant parameters were mainly associated with part-time patterns, indicating that some groups are more sensitive to the spatial context than others.

Maat and De Vries (2003) investigated whether the amount of green space close to the dwelling and in the residential environment influences the use of green space amenities elsewhere. Behavioural patterns in respect of trip frequency and modal choice are analyzed in connection with detailed spatial data, controlled for sociodemographic variables. The greater the availability of gardens and public green space in the vicinity, the more residents will use them. Whilst the availability of green space in the vicinity leads to using green space amenities, it appears that a more urban residential environment does not lead to compensation behaviour. It is only very attractive parks which draw people from a wider catchment area. This makes trips to green space amenities more distance-sensitive than other leisure activities, shopping and work. It also appears that the greater the distance to a park or natural area, the less people walk to it and the more they go by bicycle and, particularly, by car. Proximity to green space amenities therefore encourages people to visit them and to choose a sustainable means of travel. However, this suggests that since people are primarily distance-sensitive when it comes to green space, it is obvious that many households will continue to choose to live in a green residential environment, even if it means that this is a remote neighbourhood, with longer journeys to work and amenities.

As already mentioned in section 5, within homogeneous groups of people there might be people who prefer to travel by certain modes. Only few authors have addressed the impact of life styles, attitudes or preferences for modes on travel behaviour, the link with residential location and land use, and self-selection. The few examples mainly come from the USA (Kitamura *et al.*, 1997; Bagley and Mokhtarian (2003). The only Dutch example we know is the research of Van Wee *et al.* (2003), who conclude that a variable expressing the preference for modes adds significant additional explanatory power to regression models for travel behaviour, which include person and household characteristics as well as land use variables.

6.2 Studies on the location of work places on travel behaviour

This section presents some Dutch case studies showing the effects of accessibility by public transport, car and bicycle upon modal split. The section is largely based on Van Wee and Van der Hoorn (1996).

Two comprehensive studies were carried out around 1980 into modal split in inter-local commuting (Van der Hoorn *et al.*, 1984). The objective of the first was to investigate means of furthering Park and Ride. The second study is on the occasion of the opening of a second bridge over the Lek river is a before-and-after study into the effects of the removal of a major congestion point for car traffic. An important aspect of both studies was a segmentation into 'choice travellers' and 'captives'. Even in a best case scenario, large part of the population will not be sensitive to policy measures, because of the presence of constraints on

mode choice (e.g. no driving licence, or the necessity to use the car for business trips during the day). About half of the total group of commuters were found to be choice travellers and within this group the train had a substantial market share (50-60%). At the Lek bridges this continued to be the case even after the disappearance of car traffic congestion. A conclusion from both studies is that the ease of egress transport from the station to the work address is much more important as an incentive to use public transport than that of access from home to the station. This is because at the home end (in addition to local public transport) the car and bicycle are available for the trip to the station whereas at the workplace end only public transport and walking are available. Van Wee and Van Der Hoorn (1996) therefore conclude that areas near railway stations should be used for labour-intensive activities and office development as far as possible, maybe at the cost of housing developments.

AGV (1985) finds similar results. Mode choice of people working in The Hague (1981-1983) was studied in relation to the distance to the Dutch Railways Stations. For a distance of less than 200 metres the share of the car is less than 20% and that of public transport 57%. Over greater distances the share of public transport reduces rapidly. This report also quotes results from a 1979 survey on the occasion of the relocation of a department of the Province of South Holland. The department moved a distance of just a couple of hundred metres to a location very close to the Central Station in The Hague. Car use was found to be halved: from 37% to 19%, while public transport use doubled: from 34% to 70%. Bicycle use went down from 27% to 9%.

Van Dinteren *et al.* (1991) investigated mode choice and location of firms in several cities and towns. Directors of firms were interviewed. Therefore the results give only an indication of the mode choice. They conclude that car use of people working near railway stations is about 12% lower than at other locations.

One of the few studies into the modal choice of visitors of establishments was carried out by the Geographic Institute of Utrecht University (1990). The Academic Hospital (AZU) relocated from the centre of Utrecht, within walking distance of Utrecht central station, to University area, near the A28 motorway, kilometres away from Utrecht central station. The research focuses on visitors (patients, visitors of patients and other visitors) who visited the hospital both before and after the relocation. The car share increased from 58 to 72%. The train share dropped from 10% to 0%. Cycling and walking also diminished.

A special category of research into the impact of the location of the work place on travel behaviour is research into relocations of firms. Van Wee (1993b) gives an overview of several of such studies. Most of the relocations are from locations with relatively good to locations with relatively poor public transport access. In general after the relocation car use increased. An example of a relocation study, but in the opposite direction is a study executed by the Ministry of Housing, Spatial Planning and the Environment. As a result of the ABC policy, in 1992 this Ministry located its new offices beside the Central Station in The Hague, which is highly accessible by public transport, and clearly an A-type location. The switch in travel destination induced a modal shift for commuting in favour of public transport (from 34 to 77 percent of all trips), whereas the car's share dropped from 41 to 4 per cent, with a corresponding decrease in distance travelled by car of 69 percent. However the average commuting distance (all modes) increased by 8 percent to 20.6 km, whilst the share of cycle and walking trips decreased from 25 to 19 percent, as good public transport encouraged a modal switch. These effects are changing over time as employees change the location of their

homes. In addition to the move to the new location, the Ministry implemented various other measures such as transportation demand management and parking policy.

6.3 Studies of accessibility potential of land-use configurations

Almost all studies we found focus on the relationship between locations and travel behaviour. The impact on accessibility has hardly been investigated. In this section we evaluate studies that focus on accessibility. We first evaluate studies focusing on potential accessibility indicators. Then we briefly pay attention to studies focusing on time-space indicators showing possibilities for people to carry out activities at different locations.

Potential accessibility

Verroen and Hilbers (1995) carried out a model simulation study for the Randstad area and connection areas. It focuses on land-use alternatives for the period of 2005 to 2015 (see section 7). The study not only gives kilometres per mode but also an accessibility indicator, the so-called potential accessibility (the average number of activities that can be reached within a certain time). The study shows that mixed land-use results in 1% less car use and 3% less public transport passenger kilometres. However, potential accessibility is better (3%). Concentrating future urbanisation in relatively few locations (areas with more than 25,000 to 40,000 homes and jobs) leads to slightly less car use but a significantly better accessibility.

Van Wee *et al.* (2001) evaluated the potential accessibility of jobs for the labour force in the Netherlands for each zone of the National Model System (about 1300 zones). They used a more or less traditional potential accessibility indicator, but also an extension of that indicator, correcting for the competition of employees for jobs. They conclude that the potential accessibility of jobs is highest for people living in the Randstad area (the highly urbanised western part of the country). After introducing the so-called competition factor the difference between the Randstad and the rest of the country increases.

Geurs and Ritsema Van Eck (2000) evaluated potential accessibility by car and public transport of 1995 as well as for a scenario for 2020, assuming more or less current practice. They conclude that between 1995 and 2020 the potential accessibility by car of jobs for employees and of the labour force for employers will increase significantly, despite the expected increase in congestion in that period.

Time-space studies

Several studies have been carried out into the scope for activities within time and space limits. They are founded in the time-space geography (see, for example, Høgerstrand, 1970; Dijst, 1995; 1998; Arentze and Timmermans, 2000). The studies we found generally focus on specific situations (e.g. time-space prisms of people living in a specific neighbourhood) and do try to find general conclusions on the impact of land use and land-use policies on possibilities to fulfil activities. We therefore do not review these studies in this article.

6.4 Conclusions

In the Netherlands (as in most countries) more research has been carried out focusing on residential areas than on the work location. This is striking because commuting causes most congestion and network capacity problems.

Most studies of residential areas investigated individual behaviour, and controlled for socio-economic variables such as income, gender, household type and age. The samples were stratified in different neighbourhood types (except for Muconsult, who used a national random sample). The spatial characteristics vary per neighbourhood, per street or postcode and per dwelling; however, most data used on a lower spatial level than the neighbourhood was not included in uniform spatial data files, but were reported by the respondents themselves (Muconsult asked the questioner to report some characteristics). The study of Dieleman et al. is an exception, as they did not use individuals but cities as research units.

The studies on residential areas differ with respect to the effects found. Although most studies conclude that land-use variables influence travel behaviour, the strength of the relationship differs. Moreover, the influencing variables differ, e.g. Konings et al. found a tiny relationship with density, Snellen found effects from distance, and Muconsult found effects of a *öwoonerfi* and a garden.

The results of studies focusing on work locations seem less diffuse: all studies that we found conclude that the location of work places matters: near public transport nodes (mainly: railway stations) the share of public transport in commuting is (much) higher than for locations near motorways, far away from public transport.

Unlike the research into residential areas, in several of the cross-section data based empirical research on work locations researchers did not control for other variables. For the studies of firm relocations this is not or hardly a problem, because travel behaviour of the same employees are compared. Even if such studies compare travel behaviour of all people working at the old location with all people working at the new location this is hardly a problem because only few people change jobs and relatively few people started working for the firm shortly after the relocation.

7. Review of literature: model simulations of land-use impacts on transport

In the Netherlands several model simulation studies of the impact of land use on transport have been carried out. For a review of these studies we refer to Van Wee and Van Der Hoorn (2001). The studies focus on the Netherlands as a whole or at least a large part of it. Most of the studies were carried out to be used in discussions for concepts of future urbanisation.

Without any exception the studies conclude that land use has a relatively strong impact on transport. For example, the differences in car use can be as high as twenty percent or even more of the travel to, from and within the areas which locations were varied geographically. An example: in the study of Verroen *et al.* (1995) 6% of all dwellings were varied geographically in 2015 and 12% of the jobs. The differences in car use are 2%. The locations of houses being the dominant factor, the relative impact of land-use differences is high: 2% of car use, related to 6% of houses. It should be noted that in the study, as in most other scenario studies, land-use variants that encourage car use beforehand, such as variants with very low densities, far away from public transport and existing cities and towns, were not considered at all. Therefore the range in mobility may be even higher. On the other hand, for several reasons Van Wee and Van Der Hoorn (2001) conclude that the models used overestimate the impact of land use on transportation. Some of the reasons are: (1) time budgets are not incorporated in the models, making potential variations in average travelling time per person possibly bigger than in practice; (2) the models are based on cross-section data; such models

generally overestimate impacts of changes (contrary to most panel data based models), (3) bias *within* homogeneous groups of people is not incorporated. This is important because people that prefer travelling by public transport generally do not live at places with poor access to the public transport system (Pickup and Town, 1983); such preferences explain part of the relatively high use of public transport of people living near stations.

In short, according to the model simulation studies the relative impact of land use on transport is important. One has to notice that the *absolute* impact varies strongly and depends on the percentage of all houses and other land-use categories that are varied geographically. This percentage is very much related to the time horizon of studies: locations for future urbanisation are fixed for some 10 to 15 years in future. Therefore the importance of land use for a period of 10 to 15 years or shorter is limited. The longer the period, the more important land-use policies are, in absolute terms as well as relative to other policies.

All model simulation studies that we found used more or less traditional *state-of-the-art* models. We did not find studies using micro-simulations or dynamic models.

Apart from these model simulation studies a method was developed to allow planners at the local level to develop plans that result in less energy use for travel: Local Traffic Performance (LTP). LTP can be used for the design of new neighbourhoods as well as for the redesign of existing neighbourhoods. The method also includes a model to estimate effects of the designs. Twelve concrete plans developed using the LTP method were recently evaluated (Hilbers *et al.*, 2002). The evaluation shows that the plans differ substantially in the possibilities to reduce energy use in transport. Local characteristics like site and size were less important for success than timing and local support. Crucial was the support of the project leader. Model simulations were available for eleven cases. The alternatives resulting in the lowest energy use for each case show energy use reductions of up to 10 % in seven cases, 10-20% in three cases and 29% in one case for which a quite extreme car-free zoning system was assumed.

8. Synthesis and transferability of results to other countries

Looking at Dutch studies of the impact of land use on transport, several conclusions can be drawn. Firstly, as in many other countries, the number of empirical studies related to urbanisation in general or locations for new residential areas is limited. This is remarkable as since the mid-seventies the Dutch government, more than in most other countries, has been seeking to influence travel behaviour by land-use policies. Moreover, it is striking that Dutch research has been no more able to support the supposed relationship by convincing evidence: the Dutch situation ought to show a clearer relationship than the American one. Secondly, hardly any empirical research at the level of the direct vicinity of the dwelling has been carried out. The explanation for this may be the policy focus on urbanisation in relationship with infrastructure. Planning within neighbourhoods is generally seen as a local community task. Thirdly: in contrast to many other countries the number of scenario studies covering the Netherlands as a whole, or at least a large part of it, relatively high. Since the mid-eighties at least 6 of such studies have been carried out. Several of such studies do not only vary locations for future urbanisation but also quantity and quality of infrastructure networks. Fourthly, several studies on the relationship between the location of employment in relationship with infrastructure and commuting have been carried out. This may be explained

by the fact that since the third report on physical planning (1976) the location of employment in relationship to infrastructure is mentioned in the official governmental policy.

Can the results of Dutch research be used for policy making in other countries? The answer varies. Although many similarities between the Netherlands and many other western countries exist, there are some differences. Firstly: the bicycle is a relatively important means of transport, probably making it a more attractive alternative in land-use configurations that promote short distance trips. With respect to the bicycle it should also be emphasised that in urban transport the bike is the main competitor local public transport, and not the car, making policies to promote the use of local public transport less attractive in the Netherlands than in most other countries. Finally, the bike is available as a means of transport to and from railway stations. This is important especially at the home-end of a trip, since most people in the Netherlands have at least one bicycle. At the work end of commuting trips (or other frequently made trips) some people still have a bike, parked at the railway station, but much less that at the home end. The availability of the bike as a means of transport to and from railway stations probably increases the attractiveness of the train for longer distance trips.

Another difference between the Netherlands and other countries is the urbanisation structure. Densities are very high in the Netherlands, resulting in relatively short distances between cities and towns. Therefore inter-urban and even inter-regional travel is relatively more important than in cities/regions such as many US cities, London, Paris, or Berlin. Instead, the whole western part of the country is highly urbanised (the Randstad), with a low-density area, mainly agricultural land (the Green Heart), between the major cities and towns. Therefore travel *between* cities and towns probably is relatively high compared to many regions in the USA and some other countries. It is not clear yet what the importance of such differences are for the relationship between land use and transport. Probably the car is more often an attractive alternative than in regions with one major big city, other relevant factors remaining constant.

Another noticeable difference between the Netherlands and for example the USA is the interpretation of the compact-city concept. In the Netherlands densities of urban areas are relatively high and much higher than for example in the USA. What is a compact city in the USA might therefore be a low-density area in the Netherlands. 'Compact' therefore is a relative term. This makes conclusions on the impact of compact city difficult to translate to other countries.

The assumption that travel behaviour can be influenced by changing the spatial structure has subsequently been incorporated into various planning models. In the Netherlands, such hypotheses became part of urbanisation models on the regional scale, such as the concentrated decentralisation, compact city, and network cities. In the United States and Australia, the debate there is mostly concerned with the design of neighbourhoods, using such models as neo-traditional design, transit-oriented development (dense), and new urbanism (less dense, more attention to design) (Maat, 1999).

Generally speaking, we think that the *sign* of the relationship between land-use variables and travel as found in the Netherlands will be the same as in other countries, but that the *strength* of the relationships might differ.

9. Policy implications

Should land use play a major role in mobility policy? The results of the studies reviewed seem to tend towards a *yes*. However, the question is more complicated, for several reasons. Firstly, there is the issue of efficiency (see Van Wee, 1993a; Martens, 2000): as far as we know no cost-benefit analysis of land-use policies has ever been made. If land-use options reduce car use and so congestion and environmental impact, it does not mean it is an efficient, a cost-effective way to reduce congestion and environmental pressure. One has to notice that it is much more difficult to perform a cost-effective analysis for land use than it is for technical measures. One reason for this difference is the fact that it is very difficult to estimate the costs (compared to other alternatives). Another reason is that land-use policies (as infrastructure policies) have an impact for at least 100 years. It is very complicated to estimate long-term impacts and to discount future effects. Secondly, for land-use policies the question always is: what is the alternative? Which land-use strategies are compared? Houses and offices have to be built anyway, so the question should be focused on alternative land-use strategies and the differences in the costs and benefits.

Generally speaking we think that alternative land-use strategies should be evaluated, taking into consideration:

- The way people value their living and working area. A differentiation between different groups of people should be made
- Financial aspects, both for the (national, regional and local) government as well as for the households and firms
- Environmental impact of mobility, both at a local (e.g. noise nuisance) and the supra-local level (e.g. CO₂).
- Accessibility impacts, not only focusing on congestion at the main road network, but also in a geographical way: to what extent does the land-use ñ transportation system enable us to travel between locations that we want to visit and so to do activities we want to participate in). Possibly also the value option is important: people may value the *possibility* of performing an activity at an other location (and thus make the related trip) even if they do not carry out the activity.
- Safety impacts, not only in terms of (expected) injured and deaths but also subjective safety and possibilities / limitations due to unsafety, such as the possibilities for children to play on the streets and to go to school independently.
- Land coverage, both direct and indirect. Open space conservation is part of it.

One other issue that we want to discuss is the robustness of the land-use ñ transport system. In other words: how vulnerable are we for (for example) an expected or unexpected limitation in energy availability for transport? Such limitations may be the result of political instability in oil producing countries, the depletion of fossil fuels, and much higher prices for fuels or stringent environmental policies. The question then will change from *how can land use contribute to reducing transport problems* to *how can land use enable us to do activities at different places?* This changing role not only is important for land use but also for the role of public transport and slow modes, and for telematics. We assume that land-use ñ transport strategies that are positively valued with respect to travel behaviour impacts will be robust. Such strategies include compact building, mixed land use and good public transport availability.

10. Recommendations for further research

Based on the review, many recommendations can be made. The categorisation of studies as presented in table 1 allows for many recommendations. However, in this section we only focus on what we consider the most important recommendations.

Firstly we think that more research into characteristics of the direct vicinity of the dwelling should be carried out; we only know one example of such a study in the Netherlands, showing a relatively high potential of land-use impact on that scale (Muconsult, 2000). Unfortunately the study focuses on number of trips per mode and not on travelling distances. Therefore further research is needed.

Secondly the dynamics in land use and transport deserve more attention of research as well as policy making. Empirical research including the changes in land use and transportation is very scarce. The models use to forecast impacts of land use on transport are long-term equilibrium models. However, the dynamics in changes may be of great importance. For example, Van Wee (1997) shows that medium-term effects of office relocations (5 years after the relocation) on car use are only one third of the long-term equilibrium effects as estimated by models.

Thirdly more research into the impact of the land use and transport system on accessibility is needed. Accessibility should be defined in a geographical way and not or not only in terms of congestion on the main road network, the focus of current policy in the Netherlands. As far as time-space geography is concerned we think that much more research has to be carried out that enables to draw general conclusions on the impact of land-use (and transport) policy on accessibility.

Fourthly we think that more research on the spatial distribution of traffic should be carried on, in order to be able to show the impact on accessibility, liveability and the environment.

Fifthly, the available outcomes of research show that there are significant differences in the travel patterns of people living in different types of dwellings and neighbourhoods. The 'explanation' is generally limited to the presentation of correlations between neighbourhood features (such as density, a 'woonerf' or a garden) and observed travel behaviour, corrected for socio-economic factors. Such statistical outcomes, however, fall short of a causal explanation of travel behaviour on the basis of determinants of the spatial structure (see also Handy, 1997; Crane, 1998). What we need is a conceptual model to explain what they mean for travellers, and how they affect travellers in the choice they made concerning travel.

Finally we think that more attention should be paid to bias within homogeneous population groups.

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