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The influence of socioeconomic characteristics, land use and travel time considerations on mode choice for medium- and longer-distance trips

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Abstract

This paper contributes to the limited number of investigations into the influence of the spatial configuration of land use and transport systems on mode choice for medium- and longer-distance travel (defined here as home-based trips of 50 km and over) in the Netherlands. We have employed data from the 1998 Netherlands National Travel Survey to address the question as to how socioeconomic factors, land use attributes, and travel time affect mode choice for medium- and longer-distance travel, and how their role varies across trip purposes: commuting, business, and leisure. The empirical analysis indicates that land use attributes and travel time considerations are important in explaining the variation in mode choice for medium- and longer-distance travel when controlling for the socioeconomic characteristics of travellers.

Keywords: Medium- and longer-distance travel; Mode choice; Land use; The Netherlands

1. Introduction

The increase in personal mobility plays an important role in the spatial transformation in advanced economies, where networks and activity patterns of individuals and organisations are increasingly stretched out in geographical terms (Frandberg and Vilhelmson, 2003). This increase in mobility has come about through technological innovations in transportation and rising levels of affluence, which have allowed people to travel farther within relatively constant travel time budgets (e.g., Schafer, 1998).

Economic and social benefits along with environmental threats can be expected from increasing mobility. Economically, it strengthens links between different regions and offers regions opportunities to profit from the mutual exchange of knowledge and creativity (Batten, 1995). Socially, the increased ability to travel greater distances enhances individuals' possibilities to access a wide range of facilities and specialised services like health care, retail outlets or social events, particularly in rural areas. These travels also make it possible to maintain social networks that are spatially extended (Urry, 2003). Moreover, it is necessary for going on vacation or most day-trips and, therefore, a precondition for tourism activities (Mallett, 1999a). Nonetheless, the increase in travel distances poses a major threat to the environment, because it involves more energy consumption and emission of pollutants. This claim is supported by US evidence showing that long-distance trips are responsible for more than 20% of all passenger-miles travelled (Bureau of Transportation Statistics, 1998).

Thus far, the importance of medium- and longer-distance travel has not been reflected in geographers' and

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transport researchers' efforts to gain insight into the determinants of travel demand. Academic research is still heavily concentrated on short-distance travel or trips conducting within daily urban systems. It is unclear whether conclusions about mode choice for short-distance trips can be transposed easily to medium- and longer-distance trips given that the latter involve more time and monetary out-of-pocket costs. A person undertaking a medium- or longer-distance trip thus faces a different decision situation than an individual making a short-distance trip, and may therefore respond differently.

In so far as medium- and longer-distance travel has been analysed, the focus has been primarily on the impact of socioeconomic factors at the individual and household levels (Algers, 1993; Georggi and Pendyala, 1999; Mallett, 1999a,b; O'Neill and Brown, 1999). The relevance of the spatial configuration of land use and transport infrastructure for these trips has rarely been documented. In addition, most previous work on the impact of urban form on mode choice decisions in general has frequently neglected to account for the influence of travel impedance factors (including travel time), which may result in erroneous conclusions about the role of land use factors in such decisions (Cervero, 2002).

As a consequence, more insight into the determinants of medium- and longer-distance travel behaviour is needed. In this study, we have concentrated on mode choice for these trips for different purposes and especially the impact of land use and transport infrastructure under travel time considerations. For this purpose, we have used the 1998 Netherlands National Travel Survey.

According to the literature, what constitutes medium- and longer-distance travel is usually defined on the basis of some minimum physical distance threshold. Unfortunately, there is no standard definition of such travel as can be seen from the current thresholds employed in National Travel Surveys in various countries to delimit long-distance trips: 100 miles (167 km) for USA (Bureau of Transportation Statistics, 1998); 50 miles (83 km) for the UK (Office for National Statistics, 1998); 100 km for Sweden (Swedish Institute for Transport and Communications Analysis, 2003), Norway (Denstadli and Hjorthol, 2002) and the European long-distance travel mobility survey.[1] We have arbitrarily defined medium- and longer-distance trips as trips that are longer than 50 km (one-way). This threshold was determined on the basis of the average extent of the daily urban system in the Netherlands permitting the focus on trips where their travelled distance exceeds the average size of individuals' daily action space.

The remainder of the paper starts with a brief review of the literature and existing empirical evidence regarding the factors that influence medium- and longer-distance mode choice. In Section 3, we proceed with a theoretical discussion of the determinants of mode choice. The data handling and research methods used for the empirical analysis are described in Section 4. We then present some descriptive results and follow with the results of logit models of mode choice in Sections 5 and 6, respectively. The paper concludes with a discussion.

2. Previous research

Among the most important factors affecting mode choice for short-distance trips, or trips conducted within daily urban systems, are travellers' socioeconomic characteristics. The limited number of studies dealing with medium- and longer-distance trips suggest that these also play a significant part in the choice of transport mode for this type of trips. Analysis of the 1995 American Travel Survey shows that 80% of trips greater than 100 miles are undertaken by private car (Georggi and Pendyala, 1999; Mallett, 1999a,b). These studies also indicate that mode choice for medium- and longer-distance trips does not differ much between men and women; however, women tend to travel by bus more often and men by aeroplane. Regarding income, low-income adults in the US are more dependent on the private car and inter-city buses and trains than are other income classes. Those in higher income classes make more use of faster transport modes in particular aeroplanes. Age also affects mode choice. As people grow older, they substitute trips by bus and aeroplane for medium- and longer-distance private car journeys. We are not aware of any study that has addressed the impact of educational level or household composition on mode choice for medium- and longer-distance trips.

It is evidenced in medium- and longer-distance travel studies that mode choice varies across types of trip. Georggi and Pendyala (1999) assert that the mode choice varies considerably with trip purpose and trip length. Personal vehicle use is higher for personal or social trips, while air travel is predominant for business. Using British data, Rickard (1988) shows that travelling alone, or owning a rail season ticket, increases the propensity to travel over greater distances by rail, since it is more economical. This is particularly true for British students for they tend to buy annual Student Railcards, which allow them a one-third discount off rail fares. Algers (1993) shows for medium- and longer-distance business trips in Sweden that employment status and the level of economic well-being of the employing firm

[1] This survey was carried out in the 15 Member States of the European Union in 2001 and Switzerland. It is part of the Fifth Framework Programme of the Competitive and Sustainable Growth Programme funded by the European Commission (EC) (Dateline Consortium, 2003).

increase the probability of choosing a more expensive mode. Car ownership also increases the propensity to travel by car for business trips. It appears that the relative importance of the factors that are relevant in the decision process seems to depend on the purpose of the medium- and longer-distance trip.

Previous studies of mode choice for medium- and longer-distance travel have rarely addressed the role of land-use factors, although a few exceptions can be quoted. Estimating a combined mode and destination choice model on Swedish data, Algers (1993) takes account of the socioeconomic characteristics of travellers, travel cost, travel time (including access and egress time) and some elements of land use attributes at the destination. He points out that the total number of trips over 100 km is sensitive to the characteristics of the destination, including the total population size and number of jobs. However, because the main focus of his study was not the influence of land use factors on mode choice, he did not analyse their impact in great detail. Bricka (1999) analysed variations in trips over 100 miles at state level using data from three US states: New York, Massachusetts, and Oklahoma. In her opinion, the variations between states in mode, trip length, and trip purpose can be accounted for by certain differences between rural and urban areas, including dissimilar demographic profiles, the availability of modes and urban form. However, her results are based only on descriptive cross-tabulation; she has not modelled the influence of these factors on mode choice.

Some studies on mode choice for inter-city travel have considered travel time elements (e.g., Sethi and Koppelman, 2000). Bel (1997) evaluates the impact of travel time changes in road travel time on the demand for inter-city rail. He reports that the addition of travel time considerations improves the explanatory power of the model for inter-city mode choice and concludes that these factors should be taken into account when studying the demand for inter-city travel.

In short, the existing literature has made it clear that mode choice for medium- and longer-distance trips depends on a traveller's socioeconomic position and varies across trip purposes, but offers few insights as to how land use factors influence mode choice. We conclude that there was a lack of empirical investigations distinguishing between trip purposes and using a comprehensive set of land use indicators together with the socioeconomic characteristics of travellers and travel time variables to explain variations in mode choice for medium- and longer-distance trips.

3. Theoretical framework

According to random utility theory (Domencich and McFadden, 1975), travellers choosing a transport mode for medium- and longer-distance trips are rational actors seeking to maximise the utility (or minimise the disutility) of travelling. In line with the existing literature discussed above, we have identified three sets of variables capable of affecting mode choice for medium- and longer-distance trips: (i) the travel costs associated with the different modes; (ii) the socioeconomic characteristics of travellers; (iii) the spatial configuration of land use and transport infrastructure at the origin and destination of medium- and longer-distance trips.

Travel time is an important constituent of travel costs. Travel time components generally consist of in-vehicle time, out-of-vehicle time, walking, and waiting time. Some travellers' socioeconomic characteristics that are expected to influence mode choice for medium- and longer-distance travel include gender, age, household structure, income, highest educational attainment, and car availability. Although the existing literature does not provide much support for any influence of household structure, its interaction with gender, or educational attainment on mode choice decisions for medium- and longer-distance travel, these factors are incorporated in the empirical analysis, because they are important determinants of mode choice for daily trips in the Netherlands (Schwanen et al., 2004).

With regard to land use, we hypothesised that density, proximity to infrastructure, and land use diversity are the three main dimensions of urban form that influence mode choice. In both the USA (e.g., Frank and Pivo, 1994; Newman and Kenworthy, 1989) and Europe (e.g., Schwanen et al., 2004; Dargay and Hanly, 2004) higher *population densities* are associated with smaller shares for the private car and larger proportions of trips by public transport and cycling/walking. This is because higher densities (and the associated higher demand for transport) facilitate well-developed public transport networks making transit a more attractive alternative, and reduce trip lengths, which stimulates cycling/walking. There is also an indirect effect of density: when densities are higher and activity locations are closer to each other, access and egress times to public transport facilities become shorter, which may further enhance the use of these transport modes.

The latter effect is captured directly by indicators of the *proximity to infrastructure networks*. Several studies of commute behaviour have indicated that travellers with good highway accessibility and travellers residing close to railway stations are more likely to commute by private car and public transport, respectively (Cervero, 2002; Kitamura et al., 1997).

A third important urban form dimension is the *level of land use diversity*, or the proximity to each other of different types of land use. Cervero and Kockelman (1997) have demonstrated that the use of transport modes other than the private car increases as the level of land use mixing rises. It is evidenced in both US

and European studies that in mixed use environments, the access and egress times from a railway station to a variety of land uses are short, making transit more attractive not only for work trips but also for leisure trips (Cervero, 1996). Recently, Cervero (2002) showed that land use diversity at the origin and destination side tends to reduce driving alone; he found that the relationship is stronger at the destination side. Frank and Pivo (1994) present similar results for commuting and shopping trips.

Furthermore, we hypothesised that the differences in the *decision situations* faced by medium- and longer-distance travellers and motivations for undertaking this type of travel would be important in decisions about mode choice. For instance, medium- and longer-distance commute trips are (frequently) undertaken on a day-to-day basis and decisions about such trips have consequences for other household members. In contrast, medium- and longer-distance leisure trips are more infrequent and often undertaken jointly with other people. Also, their destinations tend to be spatially more diffuse. In this situation, the private car may be the most convenient alternative for medium- and longer-distance leisure trips.

4. Data and definitions

The data used for the empirical analysis was the 1998 Netherlands National Travel Survey (NTS). The NTS uses two methods: telephone interviews (CATI) and a 1-day travel diary. Each year, approximately 70,000 households participate in this survey, resulting in a database of some 130,000 individuals and 500,000 trips. The travel data includes information on the purpose, self-reported distance and time, and mode (excluding airplanes[2]), as well as the geographical location of origin and destination (measured at the municipal level) of all trips for a single day; overnight trips have not been included in the data (Statistics Netherlands, 1999).

Medium- and longer-distance trips are defined in this paper as trips longer than 50 km one-way. After this threshold had been imposed, about 1.3% of the total trips remained for this analysis ($n = 6330$). The current analysis focuses on three trip purposes: commuting, business, and leisure. The latter consists of trips to visit family and friends, outdoor recreation, sport, and entertainment activities. Moreover, only home-based trips were selected, because these are most directly affected by the characteristics of a traveller's residential context. Our sample was also restricted to people over 18 years of age. Although trips abroad were available from the database, we left them out of consideration, because the information on the spatial location of origins and destinations was not detailed enough. In the descriptive analysis presented in Section 5, weight factors provided by Statistics Netherlands have been applied to correct for sampling biases in the NTS. The weights are based on a number of variables and some of their interactions: the degree of urbanisation, age, gender, household size, car ownership, fuel type, and the month in which households participated in the survey (more details in Statistics Netherlands (1999)). Bus/coach is also excluded from the analysis, because the Dutch coach network "Interliner" is only very weakly developed. Consequently the share of bus/coach travel in the medium- and longer-distance trips constitutes only 1.4%.

4.1. Socioeconomic attributes

On the basis of the information on personal and household characteristics, we defined a set of potential explanatory factors pertaining to the traveller's socioeconomic situation. The typology of households was based on the combination of three characteristics: the size of the household; the number of adults participating in the labour market; the presence of young children (less than 12 years old). Seven household types were distinguished: single worker, one-worker couple, two-worker couple, one-worker family, two-worker family, family with more than two workers, and other household types. The main difference between couple and family households is that the latter include children younger than 12 years (although their travel behaviour is not considered here). In addition to the household typology, we have used other personal and household characteristics: age, gender, education level, the annual household income, and a car availability index. The latter is the ratio of the number of cars in the household to the number of valid driving licences in the household; the ratio is set at zero if a person has no driving licence (Hanson and Hanson, 1981).

4.2. Land use attributes

Six land use variables were employed in the empirical analysis: population density, type of municipality, the availability of a railway station, indices of the specialisation of land use at the local as well as the national level, and an indicator of land use balance. Since various authors have shown these macro-level variables at the destination side to be at least as important as those on the origin side (Cervero, 2002; Newman and Kenworthy, 1989, for example), we included them for both origin and destination. 'Population density' is defined as the number of persons per hectare and is measured at the municipal level. The variable 'type of municipality'

[2] The use of airplane for long-distance domestic travel in the Netherlands is only 0.1% (own calculation using DATELINE dataset (Dateline Consortium, 2003)).

is devised to capture possible synergies among these dimensions: settlement size, population density, level of land use diversity, and the distribution of employment, services, and population across urban space. The typology is based on whether the municipality is located within or outside the Randstad (a large polycentric region in the Western part of the Netherlands) and on its urbanisation level (Fig. 1). Municipalities within the Randstad Holland were categorised into three core cities (Amsterdam, Rotterdam, The Hague), other core cities (including Utrecht), and suburban areas. Municipalities located outside the Randstad were dichotomised into a more urbanised and a less urbanised group. The variable 'availability of a railway station' indicates whether a municipality has a railway station and, if so, whether the (main) station is a feeder train or an intercity train station.

The other land use indices were constructed on the basis of data on the distribution of five land use types as defined by Harts et al. (1999): urban centre, services, residential, industrial, and park/recreation. The local specialisation indices are measures of the proportion of each land use type within the municipality relative to the total developed areas within that municipality (Eq. (1)). We expected higher scores on the indices for the urban centre and services categories to be associated with lower shares for the private car. The national specialisation indices are determined by the distribution of a single land use category across all municipalities in the Netherlands. More specifically, an index measures the

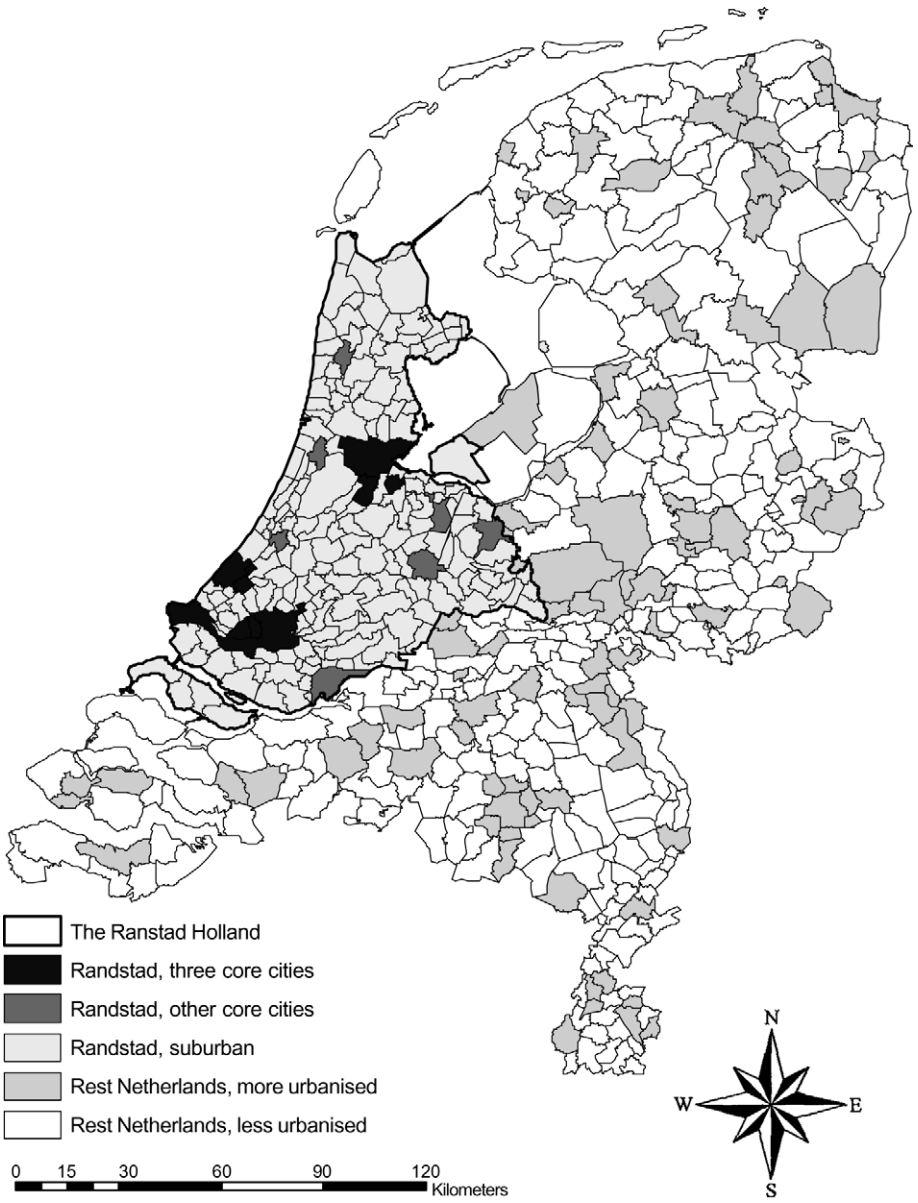

Fig. 1. Type of municipality in the Netherlands.

number of grid cells dominated by a given land use type located in a municipality relative to the total number of grid cells belonging to that land use class in the Netherlands (Eq. (2)). Our hypothesis was: areas considered highly specialised at the national level attract large numbers of visitors, which make them inconvenient for access by private car. This difficulty may be particularly true for the land use categories of urban centre and services. Drawing on Kockelman (1997), we also utilised a land use balance, or entropy index, to measure the extent to which the five land use types were equally important within a municipality. As Eq. (3) shows, the land use balance measure is normalised with respect to the natural log of the number of distinct uses considered and thus varies between 0 and 1 (with 1 signifying perfect balance of the uses considered). More balance is thought to induce public transport use. These land use indices were computed for all built-up grid cells within each municipality and a buffer of 5 km around each municipality (to reduce the effects of administrative boundaries).

$$\text{Local specialisation index} = \frac{n_{jk}}{\sum_j n_{jk}} \times 100 \tag{1}$$

$$\text{National specialisation index} = \frac{n_{jk}}{\sum_k n_{jk}} \times 100 \tag{2}$$

$$\text{Land use balance} = -\sum_j \frac{[P_{jk} \times \ln(P_{jk})]}{\ln(J)} \tag{3}$$

where j is the type of land use ($j = 1,2,\ldots,J$); k, the municipality in the Netherlands ($k = 1,2,\ldots,K$); n_{jk}, the number of 250×250 m grid cells of land use j in municipality k and a surrounding 5 km-buffer; $P_{jk} = n_{jk}/\sum_j n_{jk}$ is the proportion of 250×250 m grid cells of land use type j in all cells of built-up land in municipality k and a surrounding 5-km buffer.

4.3. Travel time computation

Travel times by car between all pairs of municipalities were calculated on the highway network with the aid of the Flowmap software (De Jong et al., 2003). All trips to and from a municipality are assumed to start/end from its centroid. If these centroids are not located at the entry or exit of the highway, travel time between these two locations is computed by using the network-based travel distance from the centroid to the nearest highway exit divided by a travel speed of 20 km/h.

A train travel time matrix for the 376 railway stations in the Netherlands was supplied by the Dutch National Railway (NS). Train travellers originating from a municipality without a railway station were assumed to travel via the nearest municipality with a railway station. If that municipality contains several railway stations, travellers were assumed to depart from the main station. The original NS data take account of the in-vehicle-time, number of transfers, and waiting time, but not the access and egress time. A study by Krygsman et al. (2004) made clear that the average access and egress time for train trips in the Netherlands is around 10 min each, and does not depend on the travel time with the primary transport mode. We therefore added 20 min to the original travel time to account for access and egress time.

Four travel time indicators were used in the logit models presented in Section 6. In addition to the absolute travel time and a measure of the absolute difference in travel time by rail and car (Eq. (4)) that are generally employed in conventional binary mode choice models (e.g., Ben-Akiva and Lerman, 1985; Cervero, 2002), we constructed an indicator of the relative difference in travel time (Eq. (5)). This is because we hypothesise that the same magnitude of travel time difference between rail and car might be valued differently according to the length of travel time (e.g., the same magnitude of travel time difference is valued less when travel time increases). This ratio is transformed into natural logarithmic to stabilise the variance and thereby improve the normality of the data.

$$\text{Absolute travel time differential} = \text{Travel time by rail} - \text{Travel time by car} \tag{4}$$

$$\text{The ratio of travel time by rail to car} = \frac{\ln(\text{Travel time by rail})}{\ln(\text{Travel time by rail})} \tag{5}$$

Although monetary out-of-pocket costs including rail fares and fuel costs are relevant to mode choice decisions, we did not take these into account, because of data limitations. Detailed information on the relevant characteristics of the cars driven, such as fuel use per kilometre or their weight, is not recorded in the NTS. If a monetary out-of-pocket cost variable had been used, it would have been based solely on travel distance and would hence be correlated strongly with (but not identical to) the travel time by car. We therefore decided only to use travel time measures.

5. Descriptive analysis

This section provides a brief overview of some of the factors that are related to mode choice for medium- and longer-distance travel, stratified by trip purpose. The results are presented in Table 1 and Fig. 2.

5.1. Medium- and longer-distance commute trips

The shares of medium- and longer-distance commute trips undertaken by private car and train are 78% and 22%, respectively. Generally speaking, men depend more heavily on the private car, whereas women

Table 1
Modal split for medium- and longer-distance travel, by trip purpose, socioeconomic, and land use factors (in %)

	Commute		Business		Leisure	
	Car	Train	Car	Train	Car	Train
Gender						
Female	62.0	38.0	79.1	20.9	79.9	20.1
Male	81.6	18.4	91.8	8.2	84.4	15.6
Household type						
Single worker	68.1	31.9	90.0	10.0	73.1	26.9
Couple one worker	74.0	26.0	90.3	9.7	86.6	13.4
Couple two workers	75.0	25.0	87.1	12.9	87.8	12.2
Family one worker	84.8	15.2	91.9	8.1	78.5	21.5
Family two workers	80.5	19.5	84.5	15.5	74.5	25.5
Family more than two workers	76.8	23.2	92.0	8.0	84.9	15.1
Other type of household	84.6	15.4	93.6	6.4	83.1	16.9
Level of education						
High education	69.3	30.7	86.5	13.5	82.2	17.8
Medium education	82.8	17.2	94.6	5.4	77.6	22.4
Low education	93.5	6.5	95.1	4.9	87.2	12.8
Household income						
High income	78.7	21.3	90.1	9.9	87.9	12.1
Medium income	76.9	23.1	91.6	8.4	81.9	18.1
Low income	0.0	0.0	0.0	0.0	56.4	43.6
Population density (origin)						
Less than 15 persons/ha	84.6	15.4	92.7	7.3	87.6	12.4
15 to 30 persons/ha	77.6	22.4	89.8	10.2	76.4	23.6
30 to 45 persons/ha	61.0	39.0	83.9	16.1	70.8	29.2
More than 45 persons/ha	51.3	48.7	78.7	21.3	73.2	26.8
Type of municipality (origin)						
The Randstad, three core cities	56.6	43.4	82.3	17.7	68.5	31.5
The Randstad, other core cities	59.0	41.0	79.5	20.5	78.8	21.2
The Randstad, suburban	85.5	14.5	93.1	6.9	86.3	13.7
Rest of the Netherlands, more urbanised	76.6	23.4	88.3	11.7	81.0	19.0
Rest of the Netherlands, less urbanised	90.5	9.5	96.1	3.9	86.9	13.1
Type of municipality (destination)						
The Randstad, three core cities	60.5	39.5	76.8	23.2	69.6	30.4
The Randstad, other core cities	62.0	38.0	79.7	20.3	62.6	37.4
The Randstad, suburban	84.9	15.1	93.8	6.2	87.1	12.9
Rest of the Netherlands, more urbanised	84.3	15.7	92.1	7.9	79.9	20.1
Rest of the Netherlands, less urbanised	95.5	4.5	99.3	0.7	91.6	8.4
Availability of train station (origin)						
No train station	91.8	8.2	95.9	4.1	88.5	11.5
Feeder train station	81.1	18.9	92.9	7.1	85.6	14.4
Inter-city train station	65.1	34.9	82.9	17.1	74.6	25.4
Availability of train station (destination)						
No train station	96.0	4.0	99.1	0.9	92.1	7.9
Feeder train station	84.3	15.7	93.8	6.2	84.6	15.4
Inter-city train station	69.0	31.0	84.7	15.3	72.4	27.6
No. of observations	2326		932		3072	

rely to a greater extent on the train. A higher level of car availability is associated with a larger share of private car trips, as Fig. 2a shows. Among one-worker and two-worker households, the presence of children increases the probability of using the car for medium- and longer-distance commute trips considerably. The underlying reason might be that the flexibility in time and space offered by the private car enables household members to cope with time pressure more efficiently. Similar results have been obtained for daily trips (Dieleman et al., 2002).

Furthermore, single workers and more highly educated people travel by train more often. One reason for this may be that they are over-represented among the employees of financial services and business firms, which in the Netherlands are frequently located in

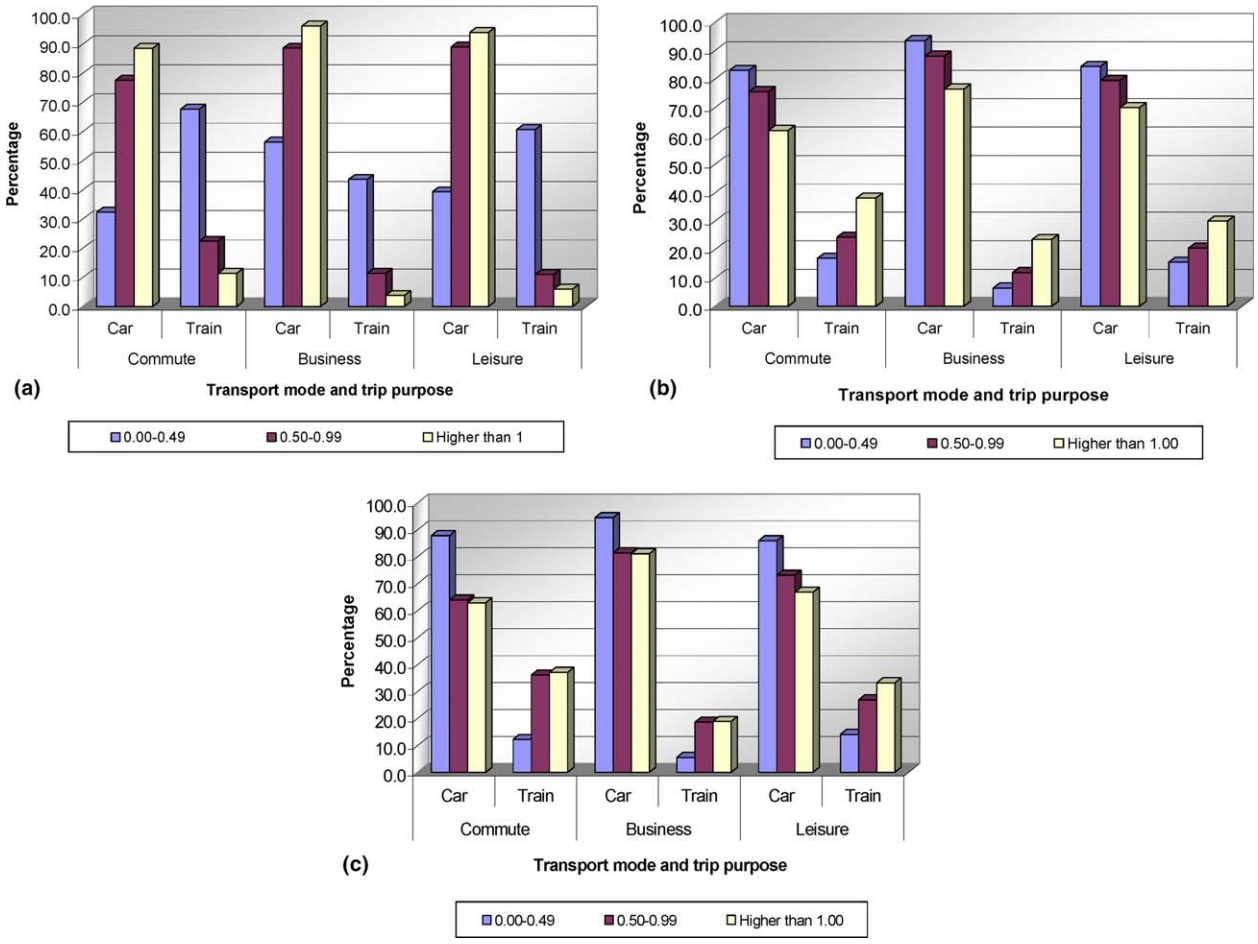

Fig. 2. Modal split for medium- and longer-distance trips, by purpose, car availability index, and land use factors: (a) car availability index, (b) local specialisation index for urban centre (destination) and (c) national specialisation index for services (destination).

high-density business parks near inter-city railway stations (Schwanen et al., 2002). This seems to lend credence to the A–B–C location policy that aims to channel new employment into nodes that are well served by public transport to restrain the use of private car (Dijst, 1997). This tendency is one indication in our data that commuters travel more frequently by train if the origins or destinations of medium- and longer-distance commute trips are situated near an inter-city railway station. This conjecture is further substantiated by the results for the urban form indicators. As Table 1 indicates, travellers residing in high-density areas tend to use the car less frequently. The local specialisation index for an urban centre (Fig. 2b) and the national specialisation index for services (Fig. 2c) variables point in the same direction: the share of train travel becomes larger as the scores for these indices increase. These variations are also reflected in the results for the spatial environment variable. As reported in Table 1, the largest differences in modal spilt are those between the core cities inside the Randstad Holland (where densities are higher and public transport networks better developed) and the rest of the Netherlands. The train is used most frequently when medium- and longer-distance commute trips start or end within these core cities in the Randstad, but the train's role is negligible in the less urbanised areas.

5.2. Medium- and longer-business trips

Private car use is very prominent for business trips: as many as 90.5% of medium- and longer-distance business trips are undertaken by this mode. As expected, men and travellers from households with a high level of car availability use the car more often than their respective counterparts (Table 1 and Fig. 2a). As far as household types are concerned, two-worker households use the train more often than any other household type; however, the presence of children does not appear to increase car dependency for business travel. Household income does not seem to affect the shares of the different modes.

Despite the fact that there is less use of public transport for business trips in comparison with commute

trips, the relationship between mode choice and land use attributes is much the same for both trip purposes. Living in a municipality with a high population density and good access to an inter-city railway station is associated with more trips by train. Car use is most common in the suburban municipalities of the Randstad and the less urbanised parts outside the Randstad, where population densities and the provision of public transport tend to be lower.

5.3. Medium- and longer-distance leisure trips

For leisure trips, the share of train travel is larger than for business trips; almost 20% of medium- and longer-distance leisure trips are undertaken by train. Table 1 demonstrates that single workers, two-worker families, and travellers with a low income and/or poor access to a private car use the train more frequently. In other cases, travel by private car is very prominent. This preference seems to result from the flexibility the private car offers in comparison with public transport, since attractive destinations of medium- and longer-distance leisure trips are more frequently located in areas with poor train accessibility, such as residential neighbourhoods and (outdoor) recreational areas. Moreover, leisure trips are more often undertaken with other people, which may make travelling by private car cheaper and also more convenient, for instance when luggage has to be carried.

Again, we see variations in modal split for the urban form factors on both the origin and destination sides. The train is used more frequently in municipalities characterised by high population densities (Table 1) and high scores on the local and national specialisation indices for urban centre and services (Fig. 2b and c). The private car is very dominant in both the suburban and less urbanised areas; the use of the train is extensive in the three core cities, other core cities, and the more urbanised areas. However, the presence of a railway station does not appear to affect train use as much as it does for other trip purposes. This difference might derive from the fact that leisure trips are not subjected to time constraints to the same degree as mandatory trips.

6. Multivariate analysis

In this section, we consider the associations between mode choice and land use attributes at the origin and destination sides on medium- and longer-distance trips, while controlling for the influence of socioeconomic characteristics of persons and households and travel time. We have estimated a series of binary logit models distinguishing between private car and train (Table 2) by using SPSS 12.0, in which the former is treated as the reference category. Decisions about the inclusion of variables in the final models presented here were made on the basis of log likelihood tests and conceptual plausibility. For each of the three trip purposes, two final models are presented. One specification corresponds to the models specified in much of the urban planning and transport geography literature (Cervero, 2002) and is called the base model; it contains only land use variables at origin and destination together with the socioeconomic characteristics of individual travellers. The other specification called the expanded model also includes travel time indicators to account for the influence of travel time. One might argue that travel costs should always be included in a mode choice model. These elements are, however, often omitted for the studies on land use and transport linkages. We have chosen to include models without travel time variables to illustrate the implications of not considering such important and well-known determinants of mode choice.

6.1. Medium- and longer-distance commute trips

Among the personal and household attributes, car availability, gender, and level of education are most strongly related to mode choice for medium- and longer-distance commuting. Car availability has a strong negative influence on the likelihood of using the train. Although it has been recognised that women's travel patterns are changing and are becoming more similar to those of men (Pazy et al., 1996), our result shows that women are still less dependent on a private car than men are. There are several factors capable of explaining this gender difference, including inequality in monetary rewards from working and the spatial distribution of jobs and household task allocation (Hanson and Pratt, 1995; Macdonald, 1999). These gender differences have also been attributed to differential access to the private car and women's weaker bargaining power for car use; in one-car households the car was, and perhaps still is, commonly allocated to the male partner to commute to his work location (Pazy et al., 1996; Pickup, 1984).

The level of education is also an important determinant of mode choice. Highly educated commuters show the highest propensity to travel by train. As argued in the previous section, this tendency may reflect the fact that many jobs for the highly educated are concentrated in the centres of urbanised areas, which are readily accessible by train. In addition, travellers aged 18–29 years travel most by private car. Somewhat unexpectedly, both household type itself and its interactions with gender are not very relevant to mode choice for medium- and longer-distance commuting. According to the model, only people from the 'other' household category are more inclined to travel by car. This finding is not in line with the many studies showing that the presence of children, the number of adults in the household, and their work status are important determinants of mode

Table 2
Binary logit model for mode choice for medium- and longer-distance travel stratified by trip purpose

	Commute				Business				Leisure			
	Base model		Expanded model		Base model		Expanded model		Base model		Expanded model	
	B	*t*-Statistic	B	*t*-Statistic	B	*t*-Statistic	B	*t*-Statistic	B	*t*-Statistic	B	*t*-Statistic
Socioeconomic attributes												
Age: 18–29 years	−0.346	−2.1							0.499	2.7		
Age: 30–49 years									−0.459	−2.6	−0.986	−6.5
Age: 50–64 years											−0.536	−3.2
Age: 65 years or more									0.588	2.9		
Female	0.982	6.0	1.027	6.2								
Low income									0.698	3.4	0.776	3.7
Low education	−1.533	−6.7	−1.499	−6.5					−0.360	−2.4	−0.332	−2.3
Medium education	−0.441	−2.9	−0.370	−2.4								
High education					0.668	2.2	0.668	2.2				
Couple one-worker									−0.884	−1.9	−0.981	−2.1
Family two-worker					1.102	2.6	1.048	2.4	0.657	2.9	0.671	2.9
Female in one-worker couple									1.561	3.1	1.628	3.2
Female in two-worker couple					1.570	2.9	1.469	2.7				
Female in one-worker family									1.203	3.5	1.233	3.5
Other type of household	−0.511	−3.5	−0.477	−3.2								
Car availability index	−2.927	−12.7	−2.906	−12.4	−3.274	−6.8	−3.312	−6.8	−3.146	−15.4	−3.112	−15.2
Land use attributes (origin)												
Randstad, suburban	−1.031	−6.4										
Rest NL, more urbanised			0.819	5.0								
Randstad, suburban: no train station									−0.474	−2.4	−0.446	−2.3
Rest NL, more urbanised: inter-city train station					0.909	2.8	0.880	2.7				
Rest NL, more urbanised: no train station											−0.753	−2.1
Rest NL, less urbanised: feeder train station			0.901	3.0								
Rest NL, less urbanised: no train station	−0.999	−4.3										
Population density			0.017	3.6								
Local specialisation index for services											0.251	4.0
National specialisation index for services					0.785	2.4	0.923	2.7	0.585	3.6		
Land use attributes (destination)												
Randstad, other core cities	0.564	3.1										
Rest NL, more urbanised			−1.135	−2.9								
Rest NL, less urbanised					−2.036	−1.9						
Randstad, other core cities: feeder train station									2.173	2.9	2.167	2.9
Randstad, suburban: no train station	−1.110	−3.0	−1.201	−3.2								
Rest NL, more urbanised: inter-city train station			0.775	2.0	0.801	2.3						
Rest NL, less urbanised: no train station	−1.956	−2.7	−2.471	−3.3					−0.578	−2.5	−0.657	−2.8
Population density	0.018	2.9	0.016	2.4	0.060	6.9	0.048	6.1	0.029	5.2	0.023	3.6

Local specialisation index for urban centre											0.619	2.6
Local specialisation index for services	0.240	2.3	0.381	3.7								
Land use balance			0.039	2.1					0.061	4.3	0.062	4.3
National specialisation index for urban centre									0.773	2.6		
National specialisation index for services			0.656	4.4					0.365	2.3	0.579	3.6
Travel times												
Travel time by car							0.018	3.4			0.008	3.1
Travel time by rail – travel time by car			−0.008	−2.0								
Ln(travel time by rail) /Ln(travel time by car)			−4.508	−3.1							−2.810	−2.2
Constant	−0.001	0.0	2.299	1.1	−3.048	−6.2	−3.685	−6.0	−5.868	−5.2	−2.716	−1.4
No. of observations	2326		2326		932		932		3072		3072	
Loglikelihood at constant	−1069.2		−1069.2		−260.9		−260.9		−1269.9		−1269.9	
Loglikelihood at convergence	−725.6		−708.9		−179.0		−173.9		−888.3		−868.4	
χ^2	687.2		720.6		163.8		173.9		763.2		803.1	
ρ^2 (Market share base)	0.321		0.337		0.314		0.333		0.300		0.316	
Adjusted ρ^2 (Market share base)	0.308		0.322		0.283		0.295		0.286		0.300	
	Private car = 0 (chosen by 82.8%); Train = 1 (chosen by 17.2%)				Private car = 0 (chosen by 92.0%); Train = 1 (chosen by 8.0%)				Private car = 0 (chosen by 85.5%); Train = 1 (chosen by 14.5%)			

choice for short-distance trips (Turner and Niemeier, 1997). It might be the case that conventional household task allocation and hence car allocation are not applicable to medium- and longer-distance commute trips. Because these trips are time-consuming, the overriding concern for households of every stature and composition will probably be to maximise efficiency and minimise the loss of time by giving the medium- and longer-distance commuter access to the fastest mode of transport as often as possible.

A number of land use variables, including population density and the provision of transport services, have a statistically significant effect on mode choice. The results suggest that the absence of a convenient railway station reduces train usage considerably, especially in the less urbanised areas. The train is more attractive when heading for jobs in high-density areas, other core cities, and municipalities with a high score on the national specialisation index for services. Destinations with such characteristics are often associated with congestion and parking problems (Schwanen et al., 2002).

The addition of the travel time variables to the base model results in a statistically significant improvement of the model fit. Because the base model is not nested in the expanded model, a test was conducted to assess whether the difference between the models in adjusted ρ^2s was statistically significant[3] (details are given in Ben-Akiva and Lerman (1985)). Since the difference was statistically significant, we can conclude that the expanded model is superior to the base model. Table 2 shows that, for medium- and longer-distance commuting, the variables measuring differences in travel time between train and car are more important for mode choice than the absolute travel time. As expected, the results suggest positive cross-elasticities: the car becomes more attractive as the difference between travel time by train and car increases. We find that the ratio of the total travel time for rail and car can better explain mode choice than the absolute difference in travel times, which suggests that the valuation of the difference in travel times per mode depends on the total travel time.

Owing to the inclusion of the travel time variable, some variables from the base model have been dropped from the expanded specification. Nevertheless, the signs for the socioeconomic and land use attributes retained in the expanded model are identical to those in the base model. A new variable is the land use balance index, which is positively associated with the probability of choosing the train alternative. In line with Cervero (2002), we find that commuters are more likely to travel by train when travelling to a workplace with consumer services, urban facilities, and other activities nearby. Similar conclusions can be drawn for the national

[3] Calculated in spreadsheet by the authors.

specialisation index for services. The fact that proximity to a railway station affects mode choice for medium- and longer-distance commuting is reflected in the finding that commuters residing in the more or less urbanised municipalities outside the Randstad with access to a feeder railway station are more likely to travel by train. On the destination side, the influence of the presence of a railway station also prevails. For the more urbanised municipalities outside the Randstad, the probability of commuting by train is significantly higher when an inter-city railway station is available.

6.2. Medium- and longer-distance business trips

Of the personal and household attributes, the car availability index has the strongest relationship with mode choice. If a car is available, it is likely to be used for medium- and longer-distance business trips. The main effect of gender is not statistically significant, but the results demonstrate that women in two-worker couples are more inclined to travel by train. Furthermore, the estimated coefficients show that highly educated business travellers and those from two-worker families are more likely to use the train. The lack of a significant difference between household types suggests that other factors pertaining to the occupation type and employing firms are probably more relevant determinants for mode choice for medium- and longer-distance business trips. Furthermore, the model does not show evidence of a statistically significant impact of household income on mode choice for business trips. This may, however, stem from the fact that income brackets are not well-defined in the NTS. Because 49.1% of the respondents in the household for which the income is known fall in the high-income category, this variable mainly captures differences between low- and (lower) middle-income households.

When the influence of the socioeconomic attributes is taken into account, land use factors still affect mode choice. For the more urbanised municipalities the presence of an inter-city railway station on either the origin or destination side increases the probability of travelling by train. Similarly, the probability of a traveller choosing to travel by train is much higher when departing from a municipality with a high score on the national specialisation index for services and heading towards a higher-density municipality.

As for commuting, the adjusted ρ^2 test indicates that the inclusion of travel time in the expanded model results in a statistically significant increase of the model fit. The results show that the propensity to travel by train rises as the absolute travel time by car increases. Note, however, that the opposite does not occur. At least for our data, an increase in the travel time by train does not lead to a statistically significantly lower probability of choosing the train. In other words, travel time appears to have little impact on the attractiveness of the train alternative for medium- and longer-distance business trips. Several reasons may be put forward to account for this rather counter-intuitive finding. First, many business travellers in the Netherlands are provided with employer-sponsored train tickets or passes, which are more generous than the cost compensation for private car use. Second, the train offers travellers the opportunity to use their time more productively than when driving a car, hence lowering the disutility associated with travel time (Mokhtarian and Salomon, 2001). Third, our travel time estimates may be subject to measurement error, resulting among other things from the fact that the NTS data are measured at the municipal level, which is aggregated spatially.

When the travel time variable is included, the model indicates that train use is significantly lower in less urbanised areas outside the Randstad. In addition, the variable indicating the presence of an inter-city railway station in more urbanised areas became insignificant and was dropped from the specification. For those variables that have been included in both specifications, the estimated coefficients have identical signs.

6.3. Medium- and longer-distance leisure trips

As for commuting and business trips, car availability is an important determinant of mode choice for medium- and longer-distance leisure trips. A higher level of car availability reduces the probability of choosing the train alternative. Again, the main effect of gender is not statistically significant, although some of the interactions with household type are. While one-worker couples are in general more inclined to travel by private car, women in this household type are more likely to travel by train for medium- and longer-distance leisure trips. The same is true for females in one-worker families. Furthermore, train use is higher among two-worker families.

As was the case with the results for commuting, the more highly educated travellers and those on low incomes are more likely to travel by train. The latter result may reflect the fact that travel by train tends to be cheaper, especially in the off-peak period when it is possible to get a 40% fare reduction with a railway pass in the Netherlands. With respect to age, the model shows that young and elderly travellers are most likely to travel by train. Both students and elderly enjoy reduced travel fares because of transit passes available to them specifically. Almost all students can travel free of charge on the train, bus, tram, and metro for at least three days per week in the Netherlands.

Land use attributes at destinations are far more important than at the origin side. Only two indicators for the origin side are included in the base model. The national specialisation index for services is positively

correlated with train use; the propensity to travel by train is lowest when departing from a suburban municipality without a train station. On the destination side population density, land use balance, and the national specialisation indices for the urban centre and service are all positively associated with train use. The model also shows that, when all else is equal, the probability of choosing the train is higher when the trip originates from a core city other than Amsterdam, Rotterdam, or The Hague but with access to a feeder train station. The reverse is true for trips to less urbanised municipalities without a train station.

For leisure trips, the statistical test on adjusted ρ^2s also suggests that the inclusion of travel time improves the goodness of fit of the model. Table 2 shows that an increase in the absolute travel time by private car increases the propensity to travel by train. In contrast with business trips, however, travellers seem to be more sensitive to the travel time by train, as the results for the ratio of travel times by rail and car suggest. Again, the result reveals positive cross-elasticities, but the relationship is weaker than for commuting trips.

When travel time costs are taken into account, the population density, the local specialisation index for urban centre, the land use balance, and the national specialisation index for services are negatively correlated with car use. For the origin side, the local specialisation for services is positively associated with transit use. When a municipality does not have a train station, the propensity to travel by train is reduced, but not to the same degree as for commuting. This finding concurs with those in Section 5.

7. Conclusion and discussion

In this paper we have employed data from the 1998 Netherlands National Travel Survey to investigate the question as to how socioeconomic characteristics, land use attributes, and travel time affect mode choice for medium- and longer-distance travel and how their role varies across trip purposes: commute, business, and leisure trips. We have tested the impact of several land use variables that have not been used extensively in the literature on medium- and longer-distance travel, including indicators of land use density and diversity and specialisation indices at the local and national geographical scale as well as proximity to transport infrastructure.

The analysis has confirmed that the spatial configuration of land use and transport infrastructure has a significant impact on mode choice processes for medium- and longer-distance trips, even when the impact of travellers' socioeconomic characteristics and travel time are taken into account. Land use factors should therefore be included as potential determinants of mode choices and related decisions in future studies of medium- and longer-distance travel. In addition, socioeconomic factors in general and car availability in particular have a strong influence on mode choice for every trip purpose.

Our results also demonstrate that the weights associated with the land use variables vary across trip purposes, indicating that the variables are not equally important for all types of trips. Furthermore, we find that most of the land use variables included in the expanded models that include travel time have stronger effects than in the base models. This finding suggests that the impacts of land use may be underestimated if travel time elements are not taken into account.

These results could have important implications for planning. In the near future, we expect an increase in the share of medium- and longer-distance trips in Europe (e.g., Orfeuil and Soleyret, 2002). There are two arguments for this. First, there have been large-scale investments in Trans-European Networks of high-speed railways, and the integration of the European Community. Second, research (Van Ham, 2002; Mulder, 1993) shows that the migration tolerance (people's willingness to migrate) is decreasing, so that (two-worker) households are particularly less inclined to move and are more willing to accept medium- and longer-distance commuting trips.

Although this increase in long-distance travel may not translate into a dramatic growth of the share of medium- and longer-distance trips in the total number of trips, it should be recognised that the consequence of this growth are larger in terms of total kilometres travelled and therefore also in terms of environmental impacts. A key challenge facing policymakers is how these medium- and longer-distance trips can be made more sustainable. Our results suggest that physical planning may assist in reducing private car use and the associated negative external effects. We believe that building in higher-densities and the development of national and local specialisation for urban activities and services can play an important role in promoting the use of public transport. We hypothesise that in the future the train will be a more attractive transport mode for leisure and business trips, especially when the degree of land use mixing around railway stations will be increased. Moreover, the fact that leisure trips are less sensitive to travel time considerations may suggest that individuals can be enticed to shift to train use especially when they are travelling to a leisure activity. On the other hand, the prospects for making commuters switch from the car to the train appear not so bright given the high, positive cross-elasticities in travel time for commute trips. In this case, employer-based initiatives like financial discentives for car use and restricted parking supply may be instrumental in discouraging car use for medium- and longer-distance trips.

Nevertheless, as with any cross-sectional statistical analysis and in light of the methodological limitations

inherent in this line of research, the results must be interpreted carefully for they provide limited insights into causality. One notable limitation is that it is not a priori clear that residential location choice is exogenous to the relationship between land use configuration and mode choice. Households with a predisposition toward a certain type of travel may choose to locate in a neighbourhood enabling the pursuit of the preferred type of travel. This phenomenon is referred to as residential self-selection in the literature on travel behaviour and urban form (Steiner, 1994). Since land use variables may act as proxies for attitudinal and life-style predisposition to using particular travel modes (Kitamura et al., 1997), it would be interesting to include such variables in future studies about mode choice for medium- and longer-distance trips.

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