HIGH-SPEED RAILWAY DEVELOPMENTS AND THE LOCATION CHOICES OF OFFICES THE ROLE OF ACCESSIBILITY

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Abstract

New high-speed railway infrastructure is to be implemented in the Netherlands in the year 2007. In the context of land-use/transport interaction, this paper ex ante evaluates the possible effects of this new infrastructure on employment location. A revealed choice model indicates that the current location of employment is not significantly influenced by the existing high-speed train services on conventional track. However, according to a stated choice model international high-speed train services do have an impact when running with frequencies higher than the current services. Experience with these model estimations suggests that using a combination of revealed choice and stated choice data might improve the capability of a land-use/transport interaction model to evaluate high-speed railway developments. Furthermore, the use of perceptions data additionally to calculated indicators can have a beneficial impact on model estimation.

Keywords: High speed rail; HST; Land use; LUTI model; Model
Topic area: F1 Transport and Spatial Development

1. Introduction

In the Netherlands, like in many other Western European countries, new high-speed railway lines are being developed or considered for the use by both national and international passenger trains. As a result of this, much interest has arisen in the appraisal of new railway infrastructure. Thereby, special attention is given to the indirect effects of the infrastructure. This interest is largely driven by the positive experiences with the first European high-speed railway line, the TGV line from Paris to Lyon (e.g. Rietveld et al., 2001).

For the assessment of long-term effects of transport infrastructure, account should be taken of the land-use/transport interaction mechanism. According to this mechanism the land-use system influences the transport system through the location of activities and, in turn, the transport system determines the accessibility of locations thereby influencing the land-use system (Wegener, Fürst, 1999). Several types of land-use/transport interaction models exist that take account of this mechanism (see Webster et al., 1988; Wegener, Fürst, 1999). These models are often applied for transport infrastructure assessment, both on an urban and regional scale.

However, although the link from the land-use system to the transport system is well understood, less is known about the link from the transport system to the land-use system. This is

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especially true for the role of accessibility by (high-speed) rail in the location choices of firms and institutions. Before a land-use/transport interaction model can be applied to the case of high-speed railway developments further research is required on how accessibility in general and accessibility by high-speed rail in particular is taken into account by decision makers of firms when making a location choice.

The current paper focuses on this topic by presenting the results of a quantitative empirical research. The aim of the research is to gain insight into what accessibility-related factors are important for the location choices of firms and institutions, how important these accessibility-related factors are relatively to other factors and how this importance differs among various types of firms. Thereby special attention is given to the extent to which calculated accessibility indicators, such as the potential indicators of the Hansen-type (Hansen, 1959) commonly used in land-use/transport interaction models, correspond to the perception of accessibility by the decision makers of offices. More specifically the paper aims to answer the next questions: (1) what effects can be expected of the implementation of high-speed railway infrastructure on the location choices of offices in the Netherlands;
(2) what are the specific advantages and disadvantages of stated choice and revealed choice data to model these effects in a land-use/transport interaction model; (3) what are the possibilities of using perceptions data for modelling office location choices?

The current paper aims to shed more light on the impact of high-speed rail on the location of economic activities for the specific Dutch case. This research is an ex ante research as it concerns the future accessibility by high-speed rail. Although several cities in the Netherlands are nowadays served by high-speed trains, these trains still make use of conventional railway track which does not allow for the high speeds and resulting shorter travel times that will be possible when the construction of the new high-speed railway infrastructure is finished. Current high-speed train connections in the Netherlands are the Amsterdam – Rotterdam – Brussels – Paris line and the Amsterdam – Arnhem – Cologne – Frankfurt line (see Figure 1 below). For the first line new high-speed infrastructure is being build; opening is projected for 2007. Furthermore a new high-speed railway line is considered between Amsterdam and Groningen in the north of the Netherlands.

The remaining part of this paper is organised as follows. Section 2 gives an overview of the literature on the interaction between high-speed rail and land use, especially with respect to accessibility in land-use/transport interaction models. The methodological issues of the research are described in section 3. Attention is given to the experimental design, survey methodology and methods of data analysis. Thereafter section 4 describes the results of the data analyses. These results are then interpreted and compared in section 5. Finally, section 6 draws some conclusions.

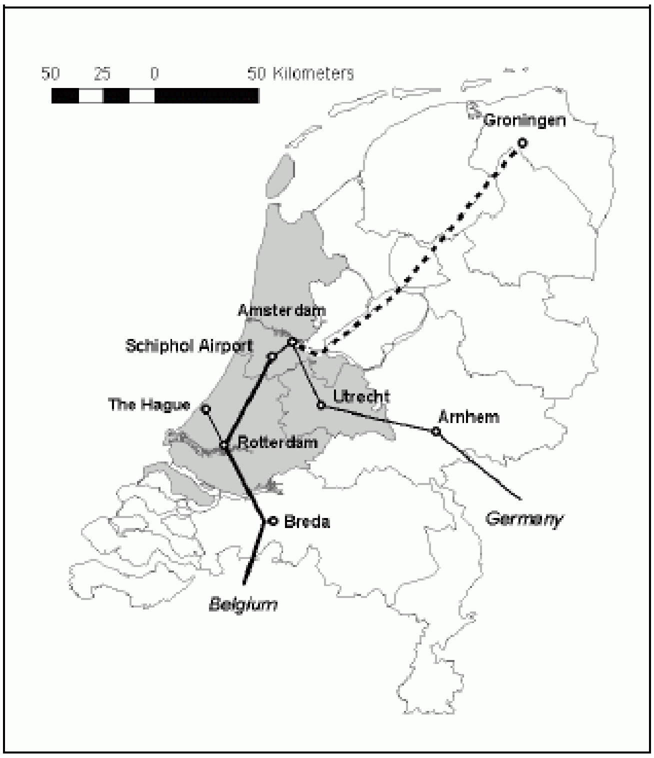

Figure 1: Location of the study area (grey) within the Netherlands, with cities (potentially) connected to the high-speed railway connections. The figure schematically indicates future high-speed railway infrastructure (thick line), high-speed train connections on conventional track (thin lines) and potential future high-speed railway infrastructure (dashed line).

2. High-speed rail and land-use/transport interaction

From several disciplines (notably economy, geography) theories have arisen that claim an interaction between land-use and the transport system (for an overview of these theories see Wegener, Fürst, 1999). Although the land-use/transport interaction theories differ in the exact formulation of this relationship, they are all consistent with the same conceptual framework that is recently described, amongst others, by Wegener, Fürst (1999) and Martínez (2000). According to this framework the land-use system determines the location of activities, thus affecting travel patterns. The transport system, in turn, influences the accessibility of locations, that is one of the factors on which location choices of households and firms are based.

For two reasons especially the long-term effects of interactions between infrastructure and land use are relevant for impact assessments of infrastructure. Firstly the land-use system is generally assumed to response relatively slow to changes in accessibility, making the land-use/transport interaction only of considerable significance for long-term developments. Secondly, transport infrastructures, such as high-speed railways, typically have long lifetimes and therefore long term impacts. Consistently, because land-use/transport interaction models (LUTI models) deal with these long-term impacts, they are often applied for the evaluation of infrastructure developments. However, whether or not a LUTI model is suitable for the evaluation of a specific case of infrastructure development, such as a high-speed railway line, largely depends on how the concept of 'accessibility is implemented in the model. Therefore, this section pays attention to the role of accessibility in la nd-use transport interaction models and to how the accessibility by high-speed train can influence the location choices of firms. Finally, a conceptual model is discussed that serves as a framework for the empirical research described in the following sections.

2.1. Accessibility and land-use/transport interaction

The concept of accessibility is used in several research fields and the meaning of this concept varies strongly across disciplines. As a result, many definitions of accessibility exist in literature (for an overview see Bruinsma, Rietveld, 1998). In the context of land-use/transport interaction accessibility is the property of a location and incorporates how the location is situated relative to the transport system as well as to the (potential) origins and destinations of trips to and from this location. Therefore, in the current research accessibility is defined as:

> *The extent to which a location can be reached by individuals via the transport system and the extent to which from this location other activities can be reached via the transport system, given the spatial dispersion of the individuals' origins and the location of the activities*

In LUTI modelling there are, broadly, two distinct modelling techniques used to determine the location of firms and households (see Wegener, Fürst, 1999)[2]. Firstly, transport and location choices can be determined simultaneously by spatial-interaction models of the Wilson (1970; 1974) type. This technique has been used by the very first LUTI model, Lowry's Model of Metropolis (Lowry, 1964), and is still used in recent LUTI models, such as the MEPLAN model (Abraham, Hunt, 1999) and the LILT model (Mackett, 1993). Secondly, LUTI models can have separate transport and location modules, whereby the transport system influences the location system by means of accessibility indicators. This technique is amongst others used in the Dortmund model (Wegener, 1983) and the UrbanSim model (Waddell, Ulfarsson, 2003). The current paper particularly focuses on applications of the second modelling technique.

The several LUTI models using accessibility indicators do not show a consensus on the exact formulation of accessibility. For example, in the Dortmund model (Wegener, 1983) the accessibility indicator is derived from a multinomial logit model of origin-destination choice, consistent with a singly-constrained spatial-interaction model. The UrbanSim model (Waddell, Ulfarsson, 2003) and the employment location module of the IMREL model (Anderstig, Mattsson, 1991) use accessibility indicators that can be seen as variants on the classic potential indicator (well-known from its application by Hansen, 1959). These indicators summarise over geographical zones the product of an attraction factor (for example the number of potential employees living in the zone) and an impedance function (representing a distance decay). The impedance function of this type of indicator can take a variety of forms, although power functions and exponential functions (see section 3) are most common in literature. The above can be summarised as Equation 1:

$$A_i = \sum_j O_j f\left(d_{ij}\right) \tag{1}$$

Hereby is:
A_i the accessibility index for zone i,

[2] LUTI models can also make use of both modelling techniques in different parts of the same model. This is for example the case in the IMREL model (Anderstig, Mattson, 1991), in which the location of households is determined by a gravity-type model, while for the location of employment accessibility indicators are calculated that form an input to a multinomial logit model of location choice.

O_j an attraction factor for zone j, representing both quantitative and qualitative aspects of individuals or activities in that zone,

d_{ij} an impedance factor (for example generalized transport cost) for a trip between the zones i and j.

The potential indicators thus represent the centrality of a location relative to relevant origins and destinations. Apart from these centrality indicators LUTI models can also use accessibility indicators representing the connectivity to a transport network. For example the UrbanSim model (Waddell, Ulfarsson, 2003) uses ‘distance to a highway’ and ‘travel time to an airport’ as accessibility indicators.

2.2. High-speed trains’ impact on transport and land-use

Implementing new high-speed train services might have a considerable impact on both land-use and the transport system. Firstly, high-speed trains affect the transport system, as it can be seen as a new transport mode that is added. Compared to the conventional transport modes high-speed trains are especially competitive for interregional travel on distances between about 200 and 600 kilometres (Ferlaino, Garosci, 1996; Vickerman, 1997). Empirical evidence in other European countries shows significant impacts on both modal split and traffic induction, the most important examples being the Paris-Lyon line (Bonnafous, 1987) and the Madrid-Sevilla line (Rus, Inglada, 1997). However, these findings are not easily transferable to the specific Dutch case, in particular because the size of the countries differs considerably.

High-speed train services can also affect location choices, as they have an impact on the accessibility of places. Several authors (e.g. Bruinsma, Rietveld, 1998; Gutiérrez et al., 1996) found substantial impacts of the European high-speed railway network on the (calculated) accessibility of European metropolises. Additionally, empirical research suggest that high-speed trains can (but not in all cases will) influence the location of economic activities on both an urban and regional scale (for an overview of empirical research see Rietveld et al., 2001; Sands, 1993). However, as the transport land-use relation is indirect and time-lagged, possible empirical evidence is difficult to spot.

2.3. Conceptual framework

The current paper aims to shed more light on the impact of high-speed rail on the location of economic activities for the specific Dutch case. To do so, at first the concept of accessibility is further explored with respect to this theme. From the definition of accessibility, as mentioned above, several aspects of accessibility can be deduced. The first aspect concerns the several types of individuals that make trips and the several types of activities that can be distinguished. This refers to the purpose of the trips that are made to and from the location of a firm or institution (henceforth office). In this research four trip purposes are distinguished that all have their own accessibility properties:

1. the accessibility for commuting trips of their current and potential employees,
2. the accessibility for business trips of/towards current and potential customers,
3. the accessibility for trips towards other establishments of the firm, and
4. the accessibility for business trips of/towards other current and potential business partners of the firm.

The importance of each of these trip purposes is supposed to be dependent on the activities that take place at the office. For example, offices that are frequently visited by customers may regard the accessibility for customers more important than offices that are not or hardly visited by customers. Furthermore, the properties of individuals and/or activities are of importance as they can result in different values of time and thus influence the perception of accessibility.

A second point of interest regarding accessibility is the transport system that is examined. Offices may value the accessibility by the several competing transport modes differently, amongst others according to the profile of the visitors and the car availability among the employees.

Finally, the spatial dispersion of the individuals' origins and the location of the activities are of importance. This refers to the spatial orientation of the offices. Spatial orientation is defined as the geographical scale on which the major part of the individuals travelling to and from the office, or activities to and from which these individuals are travelling is located. Spatial orientation is supposed to be particularly important in the context of high-speed rail. For example, if the majority of the customers of an office are located in the same region as the office, then high-speed rail can be expected to be less relevant to the office compared to an office that has its customers more dispersedly located throughout the country or even internationally.

An important issue in the current subject is the contradiction between calculated accessibility indicators and data that are obtained from the respondents (called "perception data" as these data may be influenced by subjective factors). It has been argued (see e.g. Adamowicz et al., 1997) that choices are based on perceptions; thus model quality can – at least theoretically – improve when using perceptions data instead of or complementary to calculated accessibility indicators. Therefore, the current research pays attention to the differences between the perceptive values of accessibility aspects and the calculated values that are used in LUTI models.

3. Design of a discrete choice experiment on the location choices of offices

The research consists of a survey among decision makers or employees who are responsible for or closely involved in the location choices of their firm (establishment) or institution. The study is restricted to locations with an office function, because other types of institutions or firm establishments are often restricted in their location choices by specific needs, for example the availability of certain raw materials, or external factors such as environmental or safety legislations. Furthermore, the research is restricted to the three provinces of the Netherlands that make up the highly urbanised Randstad region (see Figure 1 above). In this region we expect that the proportion of firms, firm establishments and institutions (henceforth summarised as 'offices') that is relevant for the research is higher than in other parts of the Netherlands.

3.1. Orientating interviews

As a basis for the experimental design, a series of in-dept face-to-face interviews were held among decision makers of nine offices. The goal of these interviews was to gain information on what railway related accessibility aspects might be of importance for the location choices of offices. Therefore, the main focus of the interviews was on offices that were located close to a large railway station. Offices were selected that had relocated between mid-1998 and mid-2003; with this criterion the respondents were supposed to have the (re)location process still clear in mind. Of these offices 6 had chosen a location within 500 metres of a large railway station with high-speed train connection, while the 3 other offices had located further away from such a station and thereby function as a control group. The interview questions particularly focussed on the role of accessibility by (high-speed) train in their location choices, but also questions about accessibility in general and related location factors were asked. The interviews yielded qualitative information on which accessibility and non-accessibility factors are likely to be important for the location choices of offices. Furthermore, the interviews provided insight into what questions could be asked to the respondents and how these questions should be formulated.

Because of the low number of interviews and the role of these interviews in the overall research project (orientation for the design of a more quantitative research) we mainly present results qualitatively. In general, accessibility had been an important location factor to the respondents, but the exact elaboration differed greatly among the offices. Especially variation occurred in the relative importance of the transport modes (notably car and conventional train) and in the role of different trip purposes. The latter is likely to be explained by the activities that take place in the office, especially whether or not the location is regularly visited by customers. For the accessibility by train, the frequency and number of connectio ns on a station seemed to be important to the firms. Five out of six respondents located in a station area mentioned that the location choice had been largely influenced by the convenience of these level-of-service factors for employees and visitors. High-speed rail did not appear to have played an important role in any of the cases. This was not unexpected, as none of the respondents did have a predominantly international orientation. By the time of writing the two high-speed rail connections in the Netherlands do still provide a rather infrequent service and offer hardly any travel time advantages over conventional trains for domestic journeys.

To conclude, various railway-related accessibility factors seem to be relevant for at least part of the offices. The importance of different accessibility factors, relative to each other and to non-accessibility factors, varies strongly between different types of firms. Apart from the accessibility factors, especially the appearance of the building and its surroundings seemed to be relevant.

3.2. Theoretical framework

The methodology of the research is based on a discrete choice framework. This makes the research compatible with the mainstream of LUTI models, as most of these models are also based on discrete choice theory (Wegener, Fürst, 1999). Moreover, the discrete choice framework is rather analogous to the real location choice process (see also Earnhart, 2002). For the current research the application of discrete choice theory implies that the managers of offices are assumed to choose an office location from a limited choice set, based on certain characteristics of the building and its location.

The analysis of discrete choices can in general be based on two types of choice data: revealed choice data are based on the actual choices that are made by the actors in the 'recent' past, whereas stated choice data refer to choices that respondents say they will probably make in hypothetical future choice situations[3]. Both of these data types have their specific advantages and disadvantages (see also Louviere et al., 2000).

Revealed choice (henceforth RC) data have the advantage that they are based on actual decisions. As a result the choice alternatives are realistic and appropriate for the actors. However, in RC surveys it is often complicated to determine the choice set from which is chosen. Furthermore, model estimation by using RC data might be difficult because of variables showing little variability and /or variables being highly collinear to each other. RC data might also be severely influenced by restrictions on the supply side of the market, making it difficult to determine to what extent one is actually measuring preferences and to what extent the revealed choices are the consequence of supply side factors. Moreover, RC data often provide little or no

[3] In literature stated choice analysis is also referred to as choice-based conjoint analysis.

evidence on the causality of the relations that are found. For example, a positive correlation between accessibility and economic development in a region can be explained by good accessible regions attracting and facilitating economic activities, but also by economic activities stimulating governments and transport providers to improve transport infrastructure and services. Finally, in RC models all important explanatory variables should be embedded in the model. Omitted explanatory variables may cause large uncertainties in the resulting model.

Stated choice (henceforth SC) data does not have the problems of RC data mentioned above. Moreover, SC data can be used to ex ante model the effects of new products with new attributes or attribute levels for which no RC data is available. Besides of these favourable characteristics, SC data have some disadvantages. At first, respondents might behave differently in reality than they state in the survey. This might occur on purpose, when respondents use the survey to give a message, or unintentionally. Other disadvantages are the difficulties to take account of many attributes or complex attributes.

Large synergic effects occur if in a single interview data on both revealed and stated choices can be obtained as well as the respondent's characteristics. Both types of data were collected in the current research and were analyzed in separate discrete choice models of emplo yment location. As the independent variables differ for each of these models, the following subsections give a description of the RC and SC models separately.

3.3. Design of the revealed choice model

As is mentioned above, in a SC research it is difficult to take account of attributes that are not easily comprehended. Therefore, the complex accessibility indicators that are based on the centrality of a location, like the potential indicators (see Equation 1 above), are only dealt with in the RC part of this research. The accessibility indicators based on connectivity, which are more easily comprehended by the respondents, are included in both the SC research and the RC research.

In the RC model several types of centrality indicators are embedded. At first, this concerns the classis potential indicator of Equation 1 above, as this is the most common type of accessibility indicator in LUTI modelling. As impedance functions an exponential function (Equation 2) is applied:

$$f\left(d_{ij}\right) = \exp\left(-c \cdot d_{ij}\right) \qquad (2)$$

Hereby is c a distance decay parameter. Exponential specifications are most common in LUTI models. Contrary to a power function the exponential form does not suffer from conceptual problems with self-potential (for a reflection on the issues of self-potential, see Frost, Spence, 1995).

For the railway network a generalised transport time is calculated that serves as impedance factor *dij* in the accessibility indicators. This generalised time comprises in-vehicle time, transfer time (for the train network only) and monetary costs. The monetary cost is embedded into the generalised time by using the values of time reported by Gunn (2001) for the Netherlands. For access to the station we have assumed an average speed of 30 km/h with a crow flight conversion factor of 1,2 (from distances as the crow flies to real distances) and a monetary cost per kilometre equal to the average cost for the conventional train in the Netherlands (€ 0,10 per kilometre).

Because of the model[4] used no distinction was possible between average access speed in urban and non-urban areas. For the accessibility by car the impedance is solely based on travel time.

As attraction factors O_j the number of inhabitants of a zone was used for the representation of commuting and business-to-consumer relationships. Business-to-business accessibility indicators could not be taken into account separately, as a high correlation exists between these indicators and the potential indicators of commuting and business-to-consumer relationships. Spatial aggregation to the level of four-digit postal codes was used. Thereby the zones have an average size of 8,7 km^2, zones in urban areas generally being smaller than rural zones. To partially avoid border effects, possible origins and destinations throughout the whole of the Netherlands are taken into account, although the research area is restricted to the western part of the country.

Besides the centrality indicators, also accessibility indicators based on connectivity are taken into account. For the connectivity to the railway network the respondents are asked for the station that is most important for the accessibility of their location. This is not necessarily the nearest station. The ease of access to this railway station is expressed by the travel time to the station and whether or not the station can be reached on foot. The level-of-service of the station is represented by the type of train services (regional trains, intercity trains, high-speed trains) at the station. As an indicator for the connectivity to the road network the travel time to a motorway access is taken into account.

Finally, in the model also two non-accessibility related variables were included. The type of urban environment and the type of building are seen as important non-accessibility attributes. The connectivity indicators as well as the non-accessibility indicators were based on perceptive data.

3.4. Design of the stated choice experiment

Stated choice experiments are very well capable to evaluate the effects of new products such as high-speed train services. Where RC experiments suffer from the time lag that is usually involved in the land-use market, the SC experiment can give more information on possible future location choices and therefore long-term effects. The SC experiment is therefore used to evaluate the situation where the new high-speed railway infrastructure is fully functional. Furthermore, the difference in impact is studied between international and domestic services of high-speed trains.

In the SC experiment nine attributes were accounted for, of which three have four levels and the other six have two levels. Although the main emphasis of the experiment lies on the accessibility by rail, also the accessibility by car and non-accessibility factors are taken into account (see Table 1 below). Because nine attributes might be to many to implement in a single choice situation (for example, Green, Srinivasan, 1990, who recommand a maximum of (about) six attributes per choice situation) a so called bridging design is used, where the design of nine attributes in total is split into two designs of six attributes each, thus having three attributes in common. Table 1 denotes in which sub-design each of the attributes occur.

A fractional factorial design[5] was used to arrange the attributes in Table 1 into binary choice scenarios. For each sub-design a 32 orthogonal fraction was constructed that is sufficient for the 12 degrees of freedom for the main effects (for each sub-design separately) and would in a

[4] We used the software program Flowmap version 7.1 for calculation of the potential accessibility indicators.
[5] In contrary to a full factorial design in a fractional factorial design not all combinations of attribute levels are included. As a result, fewer observations are needed for the model. Because of the orthogonal property of the fraction still some interaction effects can be determined. However, calculating interaction effects would go beyond the scope of the current paper.

combined model also allow for some interaction effects to be estimated (however, as this would go beyond the scope of the current paper, interaction effects are not discussed here). Each of the respondents was send a questionnaire form containing 8 binary choice scenarios out of the total set of 64. Choice situations of the two sub-designs were to be assessed alternately to avoid patterned responses.

Table 1: Attributes and levels in the stated choice experiment

Attributes	**Levels**	**Sub-design**
Accessibility by train		
Travel time to a station	5, 10, 15 or 20 minutes	Both
Transport mode to this station	Walk or bus	1
Total frequency of trains departing from this station	4, 16, 28 or 40 trains per hour	Both
Type of train services departing from this station	Only local trains, also intercity trains, also domestic high-speed trains, also international high-speed trains	Both
Accessibility by car		
Travel time to a motorway access	5 or 15 minutes	1
Number of parking places per 100 employees	75 or 100	2
Non-accessibility factors		
Type of building	"Nice but not extraordinary" or "architectonic remarkable"	2
Type of environment	"In a city centre" or "in a city-rim	1
Price of real estate	office park" €150 or €200 per m2 per year	2

3.5. Survey methodology

To acquire addresses of office locations, a sample was taken from the LISA database, which contains practically all firm and government establishments in the Netherlands ordered by branch of industry, number of employees and geographical location. The sample comprises establishments that have at least 20 employees and are located in the provinces of North Holland, South Holland or Utrecht (see Figure 1 above). These three provinces make up the highly urbanised Randstad region. The database does not make a distinction between offices locations and other firms and institutions. Therefore, the type of location was verified prior to the interviews.

The sample was stratified with respect to the number of employees and the branch of industry. The number of employees was used as a stratification criterion because otherwise larger firms would be insufficiently present in the sample, while these firms have a relatively large effect on the location of employment. A distinction was made between firms with 20 up to 100 employees and firms with more than 100 employees.

The branch of industry was used as a stratification factor to have an acceptable proportion of offices in the business and financial services industries and other industries. In the business and financial services industries a relatively high proportion of the settlements have an office function, as many of these industries' main operational activities take place in office locations. In other industries (aggregated at the sector level) many of a firm's or institution's main activities take place in non-office locations. Furthermore, branches of industry from the database that are unlikely to contain office locations, and would therefore have a negative influence on the efficiency of the experiment, were excluded from the sample on forehand.

The establishments in the sample were contacted by telephone. The interviewers were mostly university students that were employed by an external agency. On forehand these interviewers had received a detailed instruction on the questionnaire and its purpose. Computer aided telephone interview (CATI) software was used to manage the interview process. A series of test interviews were held to try out the interview setup and the formulation of the survey questions. This did not reveal any significant problems.

In the first telephone contact with the establishment it was first verified that the location is an office location. Subsequently, an appropriate respondent within the office was searched. This is an important stage in the research as the reliability of the results as well as the response rate on individual questions depend on this. The respondent should be a member of the management who because of his function is (jointly) responsible for or otherwise closely involved in location decisions. In case the office directed to a decision maker in another office, this was accepted under the condition that the latter office itself was in the research area. After an appropriate respondent was found, this respondent was sent a letter introducing the research and announcing a telephone call in which the main interview took place. However, if a respondent was willing to participate in the research right away, as frequently occurred, the introduction letter was skipped.

In the second telephone call the main interview took place. Information was obtained on (the respondent's perception of) characteristics of the office, its employees and customers and on contacts with other business partners and other offices of the same firm or institution. Furthermore, properties of the current location of the office were collected, yielding revealed choice data. Stated choice questions were not part of this telephone interview, as it would have been difficult to explain the different choice alternatives by telephone. Instead, at the end of the telephone call the respondents were asked if they were willing to fill in a stated choice questionnaire that could be send to them by e-mail or post.

The stated choice questionnaire consisted of eight binary choice scenarios accompanied by a short introduction. The introduction firstly dealt with an instruction to the questionnaire form. This is kept straightforward, avoiding unnecessary details to keep the instructions easily understandable (for a discussion on issues involved in stated choice questionnaire design, see Louviere, 1988). Secondly, a brief description was given of current high-speed railway developments in the Netherlands. Although introductions like this can have an impact on the results, it was considered necessary for the unambiguousness of the questionnaire. A considerable part of the respondents is assumed to be unfamiliar with high-speed trains and/or the governments' (infrastructure) policy in this field. Therefore, omitting a description might lead to differences in interpretation of the alternatives.

As was already mentioned above, the questionnaire could be send to the respondent either as an electronic form by e-mail or as a paper form by post. Sending the questionnaire by e-mail has the advantage that the respondent receives the questionnaire shortly after the interview, when (s)he has the interview still clear in mind. However, some respondents might not have e-mailing facilities or might have a negative attitude towards electronic forms. Furthermore, sending the questionnaire by post has the advantage that due to the official university writing paper the letter might appear more impressive to the respondent than an e-mail and thus might accommodate a higher response-rate. To compensate for the lower response rate and for possible technical problems with the e-mail or the electronic form, the respondents receiving the questionnaire by e-mail were send a reminder with a paper questionnaire by post about a month after the initial e-mail.

3.6. Data analysis methodology

For the RC model choice sets are composed by coupling the chosen locations to nine randomly selected alternative locations (for the SC model this procedure is not necessary as the SC data are collected in fixed choice sets). McFadden (1978) shows, assuming independence of irrelevant alternatives, that this method of choice set restriction yields results that are consistent with using a larger choice set containing all alternatives. Separate models are estimated for three segments: offices in the business or financial services with no more than 100 employees, offices in the business or financial services with more than 100 employees, and offices in other industries. This segmentation is similar to the stratification described above, with the two strata without offices in the business or financial services merged into one segment. By means of a weighing factor the model is corrected for the number of employees per office.

The discrete choice data are analysed by a multinomial logit (MNL) model[6]. The MNL model is based on random utility theory, were the utility of a choice alternative consists of a set of attributes with observed values, and of an unobserved utility component that is represented by a random error term. In the MNL model the random utility component corresponds to a type-I extreme value distribution, which implies that (1) the probabilities for each choice alternative is independent of irrelevant alternatives (i.e. the probability of an alternative to be chosen relative to the probability of every other alternative to be chosen is independent of what other alternatives are present in the choice set) and that (2) the unobserved component is independently and identically distributed across alternatives. Furthermore it is assumed that decision makers maximise their utility when choosing an alternative out of a choice set. Based on these assumptions the MNL model estimates the chance that an individual *i* chooses an option *j* out of a choice set *J* as in Equation 3 (e.g. Louviere et al., 2000)[7]:

$$P(j) = \exp(\boldsymbol{\beta}\mathbf{x}_{ji}) \Big/ \sum_{j \in J} \exp(\boldsymbol{\beta}\mathbf{x}_{ji}) \qquad (3)$$

Hereby is
ß a vector of parameters,
$\mathbf{x}_{ji}$ a vector of individual-specific and alternative-specific attributes.

4. Results of the discrete choice models

The interviews yielded data sets with SC data and RC data. As stated choice data were collected by a separate questionnaire the data sets have different characteristics. For the SC data the stratum with small offices from non-service industries had a rather low net sampling fraction and was omitted from the data set to improve the reliability of the analysis results. Table 2 below shows the response and sample fractions of the SC and RC data. Hereby total population is determined from the portion of the initially sampled fraction that appeared to be located in an office location.

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[6] We used the software package NLogit version 3.0.3 (Econometric Software, 2003) for model estimation.
[7] Note that in this specification the alternative-specific constants are omitted and the parameter vectors are not alternative-specific. This is because in the current research the alternatives are unlabelled.

Table 2: Response characteristics

Data source	Absolute response	Response percentage	Sampling fraction	Net sampling fraction
RC data	296	35 - 40 %	8,8 %	3,3 - 4,0 %
SC data	149	24 - 26 %	13,5 %	3,3 - 3,6 %

Note: The uncertainty in response rate and net sample fractions is due to uncertainty about what portion of the non-response is part of the relevant population.

The characteristics of the offices that have responded to the interview are summarised in Table 3. The table shows that most of the offices are in the business services industries. Differences between the figures concerning the SC experiment and the figures concerning the RC data can for the greater part be ascribed to omission of one of the strata in the SC dataset.

Table 3: Characteristics of the responding offices

Office characteristic	**Category**	**Percentage RC**	**Percentage SC**
Number of employees	Less than 50	32%	27%
	50 - 100	20%	18%
	100 - 1000	44%	49%
	More than 1000	5%	5%
	Total	100%	100%
Branch of industry	Financial services	8%	10%
	Business services	52%	69%
	Government and other services	5%	0%
	Non-service industries	35%	21%
	Total	100%	100%
Year of last (re)location choice	2000’s	23%	26%
	1990’s	41%	41%
	1980’s	15%	13%
	Before 1980	21%	19%
	Total	100%	100%

In the next subsections the results will be described of the RC model and the SC model respectively. Subsequently, in section 5 follows a discussion on the interpretation and comparison of these results.

4.1. The revealed choice model

The results of MNL model estimation of RC data are shown in Table 4 below. The statistical analysis suggests that significant differences exist in the preferences of the office categories for the factors related to the connectivity of the railway network. Travel time to a station, transport mode to this station and the availability of intercity services all show a significant influence on office locations. However, each of these attributes has its largest impact on a different category of offices.

Smaller offices in the financial and business services industries give high value to the travel time attributes. Both travel time to a station and travel time to motorway are significant. Related to this is the tendency of these offices to locate in office parks alongside motorways. For larger offices in the financial and business services industries the access times seem to be less important than for the smaller offices. These offices give a higher value to the availability of intercity services. Finally, for offices in other industries it is important that a station can be reached on foot.

The availability of high-speed railway services does not have an impact on current employment location. This was expected on forehand, because the current high-speed railway connections do hardly or not improve travel times yet.

The potential accessibility indicator for the railway network shows significant results for the smaller offices in financial and business services and the other offices category. For the road network the potential accessibility indicators do not seem to be statistically significant at the 90% level.

Table 4: Results of the revealed choice multinomial logit model

Attributes	**Financial and Business Services (< 100 employees)**		**Financial and Business Services (= 100 employees)**		**Other Offices**	
	Parameter	(t-statistic)	Parameter	(t-statistic)	Parameter	(t-statistic)
Connectivity of the railway network						
Access time (min)	-0.0147	(-2.0)**	0.0088	(0.8)	-0.0008	(-0.1)
Access transport mode (walk = 0, bus = 1)	-0.1898	(-1.3)	-0.0045	(-0.0)	-0.2925	(-1.7)*
Intercity services	0.3004	(1.6)	0.7207	(2.4)**	-0.1173	(-0.7)
High-speed rail services	0.0627	(0.4)	-0.1566	(-0.9)	0.0219	(0.1)
Connectivity of the road network						
Motorway access time (minutes)	-0.0855	(-4.0)**	0.0232	(1.1)	-0.0092	(-0.4)
Non-accessibility factors						
Type of environment[I]:						
"City centre"	-0.5895	(-2.0)**	0.9580	(3.0)**	-0.6658	(-1.7)*
"Besides motorway"	0.8407	(3.5)**	–		–	
"In small town"	0.5641	(2.3)**	-1.7278	(-3.9)**	0.8426	(2.5)**
"None of these"	–		–		-0.7333	(-1.4)
Type of building[II]:						
"Sober"	-0.4917	(-3.3)**	-0.3476	(-1.7)*	–	
"Remarkable"	–		0.4306	(2.1)**	0.4999	(2.7)**
Potential accessibility with exponential function						
Population by train	$1.64 \cdot 10^{-6}$	(1.8)*	$-1.40 \cdot 10^{-6}$	(-1.3)	$2.13 \cdot 10^{-6}$	(2.4)**
Population by car	$-1.14 \cdot 10^{-6}$	(-1.5)	$1.22 \cdot 10^{-6}$	(0.9)	$-1.13 \cdot 10^{-6}$	(-1.2)
?^{2}	0.1848		0.1475		0.0981	
Number of observations	77		91		97	

I: Effect codes; "Office park" is reference category
II: Effect codes; "Average" is reference category

*Parameters significance is denoted by * (90%) and ** (95%)*

4.2. The stated choice model

Table 5 below shows the result of the MNL model estimation of SC data. Out of the eleven attributes two are insignificant; however, this does not have a serious drawback on model reliability, as the parameter estimates of both attributes are rather small and the sign is, as for all other parameters, as expected. The most important attributes are the price of real estate and the trave l time to a motorway access, as might be expected.

The connectivity by rail is also important for the location choices. Five out of six of attributes related to the accessibility by train have a significant and considerably large impact on location choices. Access to the station is important in both travel time and whether or not the station is within walking distance. Furthermore, also the level-of-service of the station is important: both the total frequency of trains and the presence of intercity services are significant.

International high-speed rail services are also seen as a valuable factor for a station area. Only domestic high-speed rail services do not result in a significant improvement of the attractiveness of a location compared to a location with conventional intercity services. This can be explained by the relatively short distances of domestic travel in the Netherlands.

Table 5: Results of the stated choice multinomial logit model Attributes Parameter (t-statistic)

Attributes	Parameter	(t-statistic)
Accessibility by train		
Travel time to the nearest station (minutes)	-0.1069	(-10.1)**
Access transport mode to this station (walk = 0, bus = 1)	-0.2075	(-3.1)**
Total frequency of trains departing from this station (per hour)	0.0158	(4.3)**
Station has intercity services	0.2186	(3.3)**
Station has domestic high-speed rail services[I]	0.1054	(1.4)
Station has international high-speed rail services[I]	0.1890	(2.8)**
Accessibility by car		
Travel time to a motorway access (minutes)	-0.1350	(-8.1)**
Number of parking places per 100 employees	0.0234	(3.5)**
Non-accessibility factors		
Type of building (average = 0, architectonic remarkable = 1)	0.0316	(0.4)
Type of environment (office park =0, city centre = 1)	-0.5019	(-6.0)**
Price of real estate (€ per m^2 per year)	-0.0337	(-10.7)**
?^{2}	0.2436	
Number of observations	1112	

I: Complementary to lower-level train services

*Parameters significant at the 95% level are denoted by ***

5. Interpretation and comparison of the statistical results

In the previous section the results have been described of discrete choice models that give information on the impact of high-speed railway developments on location choices of offices. This section compares the results of both models and discusses the advantages and disadvantages of the data sources (SC and RC) that have been used. Some notes are given on the use of perceptions data. Finally, attention is given to applications in the context of LUTI models.

5.1. Comparison of the results of the models

With respect to the accessibility by high-speed train, the RC model analyzes the current situation, while the SC model evaluates possible future situations. The RC model did not find any statistical evidence that the location of high-speed railway stations has an impact on the current location of employment in the study area. This was as expected, because although (international) high-speed trains have been operational in the Netherlands since 1996, the absence of corresponding infrastructure caused the high-speed trains to reach only marginal travel-time savings within the Netherlands.

The SC model, in contrary, showed a significant impact of international high-speed trains on employment location, under the assumptions that these train services run on dedicated infrastructure and are more frequent than they are at the moment of writing. For domestic high-speed railway services the parameter estimate is not significant at the 90% level. It can be assumed that for many offices the distances of domestic travel (and related travel times) are not long enough to reach substantial travel-time savings by using high-speed trains.

For other attributes the SC and RC models generally yield corresponding results. Both models show significant parameter estimates for the ease of access to the station and the presence of intercity services. Furthermore, the connectivity to the road network is a significant location factor in the SC and RC models.

5.2. Stated choice versus revealed choice models

For this particular application the SC model has appeared to have some advantages over the RC models. Firstly, the SC model gives statistically better results than the RC models. Probably one of the reasons for this is the strong dependency of office locations on supply factors. This is especially the case in a situation with a strongly regulated land use, as is the case in the Netherlands.

Secondly, RC models on location choices may suffer from time lags. In general, land-use is slowly responding to external changes because location decisions are not made as frequently as, for example, decisions in the transport system. The effect of the current high-speed rail services (on conventional track) might therefore not be complete yet.

Finally, SC models can be used for evaluating new technologies or new (combinations of) attribute levels. In the current paper this is the case with the implementation of high-speed railway infrastructure in the Netherlands. Models based on RC cannot evaluate future innovations and may have difficulties in evaluating recent implementations, as was illustrated by the RC model in the current paper.

On the other hand, SC models have the disadvantage that it requires a great effort to take account of a large number of attributes, although it is possible by using techniques such as hierarchical information integration (e.g. Molin, Timmermans, 2003). Furthermore, complicated attributes, such as the potential accessibility indicators, are very difficult to analyze in a SC model.

5.3. Perceptive data versus calculated indicators

The use of perception data instead of calculated indicators can have advantages in two different ways. Firstly, perceptions data can be used instead of calculated indicators to obtain a data set that more precisely matches the actual accessibility aspects (and maybe also data) on which the location choices have been based. For example, decision makers may estimate travel times to a station structurally different from the travel times calculated. Secondly, perceptions data can be used additionally to calculated indicators to obtain data that are not available from (GIS) analyses but that are relevant to location choices. This for example concerns soft location factors, such as the type of building.

An important issue in the current paper is the choice of the reference station in the RC model. GIS-based applications typically minimize distances or travel times. In the current research the reference station is the station that is “most important for the accessibility of the office location." In ma ny cases this station is different from the station that would be selected by a GIS approach. For example minimizing linear distance to a station would yield a different reference station in almost half of the cases for this particular data set. More precisely, this particular method would tend to underestimate the importance of larger stations relative to the smaller stations. This difference has large consequences for the attribute values in the model.

5.4. Implications for land-use/transport interaction models

As described in section 2 above, LUTI models typically make use of accessibility indicators that express the centrality of a location within the transport network, given the spatial dispersion of the origins and destinations of trips. However, the significance of the parameters related to the connectivity to the road and railway network supports the implementation of these attributes in LUTI models additionally to the centrality indicators. This especially accounts for the railway network, as public transport is less flexible than road traffic. Furthermore, in the case of high-speed rail connectivity might also give an indication about the image of a location; the presence of high-speed railway services at a nearby station can raise the status of a location.

As LUTI models normally make use of complex accessibility indicators (classic potential or other), the use of RC data for model estimation is common practice. However, for the evaluation of new technologies, such as the high-speed railway developments in the Netherlands, the use of SC data is strongly suggested. A possibility is to combine SC and RC data into a single model by a data enrichment procedure (see e.g. Earnhart, 2002; Hensher et al., 1999).

The use of perceptions data resulted in a satisfactory discrete choice model in the current paper. Furthermore, as described in this section above, the use of perceptive data can theoretically have advantages over the use of calculated indicators only. However, a disadvantage of perceptions data is that perceptions data can only be available for current locations and thus not for locations that might come available in the future. This makes the possibilities to directly use perception data in forecasting models rather limited; indirectly, calculated indicators can be derived from perception data. Perceptions data can therefore especially be useful in the calibration and validation process of LUTI models, but in many cases only in combination with calculated indicators.

6. Conclusions and further research

This paper focuses on how accessibility in general and accessibility by high-speed train in particular have an impact on the location cho ices of offices. The results have been presented of a quantitative empirical research in the form of stated choice and revealed choice models of employment location. In particular, the paper aims to answer the following questions: (1) what effects can be expected of the construction of high-speed railway infrastructure on the location choices of offices in the Netherlands; (2) what are the specific advantages and disadvantages of revealed choice and stated choice data to model these effects in a LUTI model; (3) what are the possibilities of using perceptions data for modelling office location choices.

The empirical research focuses on employment location in the three provinces of the Netherlands that make up the highly urbanised Randstad region. The results of the RC model show that the high-speed railway connections operational on conventional track since 1996 do not have a statistically significant impact on the location of employment in 2003. However, under the assumptions of high-speed trains running over dedicated infrastructure and with more frequent connections, the SC model results do show a significant impact on employment location for international high-speed train services. For domestic high-speed train services, the impact is not significant at the 90% level.

For application in LUTI models, the use of RC data has the advantage that it is easier to include many attributes and more complex attributes than is the case with SC data. Especially applying complex accessibility indicators, such as the potential accessibility indicators that appear significant in the current paper, is a reason for using RC data. On the other hand, SC data is more than RC data capable to take account of new developments, such as the implementation of high-speed rail in the Netherlands. By data enrichment the advantages of RC and SC data may be combined.

The use of perceptions data has the advantage over calculated indicators that attribute values might better match the data on which the decisions are based. Perceptions data might improve attribute values and provide data on soft location factors. However, as perceptions data is only available for (a part of) the current locations, and thus not for possible future locations, practical application would need a combination of perceptions with calculated indicators.

Further research might focus on the practical implementation of different types of data sources in a LUTI model. Thereby attention should also be given to the specification of the centrality indicators in addition to or instead of the traditional potential accessibility indicators used in the current paper. This research can result in a LUTI model better capable to evaluate the long-term effects of high-speed railway developments.

Acknowledgements

The research represented in this paper is funded by Connekt-NWO as part of the stimulation program “Gebruik en waardering van vervoersnetwerken” (Use and valuation of transport networks).

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