45th ERSA CONGRESS

Amsterdam, August 23-27, 2005

USING FIRMDEMOGRAPHIC MICROSIMULATION FOR LAND USE AND TRANSPORT SCENARIO EVALUATION: MODEL CALIBRATION

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ABSTRACT

This research presents a simulation approach that models the dynamics in the firm population in integrated land use and transport models. The approach first of all accounts for the individual firm as the decision making unit and secondly represents the urban system with high spatial detail. This provides the opportunity to account for firm specific behaviour, allowing a large variety in responses to changes in the simulated system. Moreover the firm level simulation output provides improved possibilities to evaluate the impact of spatial scenarios. The presented firm demographic approach models transitions in the state of individual firms by simulating events such as firm migration, firm growth or firm formation and dissolution. This firm demographic model will be linked to an urban transport model in order to obtain a dynamic simulation of mobility (and accessibility) developments. It can be applied for the analysis of effects of different spatial and transport planning scenarios on the firm population and mobility. The paper describes the firm demographic model specifications, as well as the calibration of the model components.

KEYWORDS: land use and transport models, micro simulation, firm demography

1 INTRODUCTION

Integrated land use and transport models explicitly model the effects of transport policies on the development of urban land use while reversely this land use development influence travel demand (Miller et. al., 1998; Wegener and Fürst, 1999; Timmermans, 2003). The general structure of these models consists of various actors and markets. Producers and residents are the actors that execute a demand on the property markets and through the labour and product/service markets they determine the demand on the transport market. The supply side of the property and transport market is very much influenced by the planning authorities and real estate developers. The planning authorities are regarded as a facilitator for spatial development: they regulate development plans. Developers/investors can be regarded as the executers of development: they determine the real estate supply within the boundaries set by the planning authorities. By modelling these actors and markets in an integrated model, the effects of infrastructure investments and spatial policy plans can be assessed.

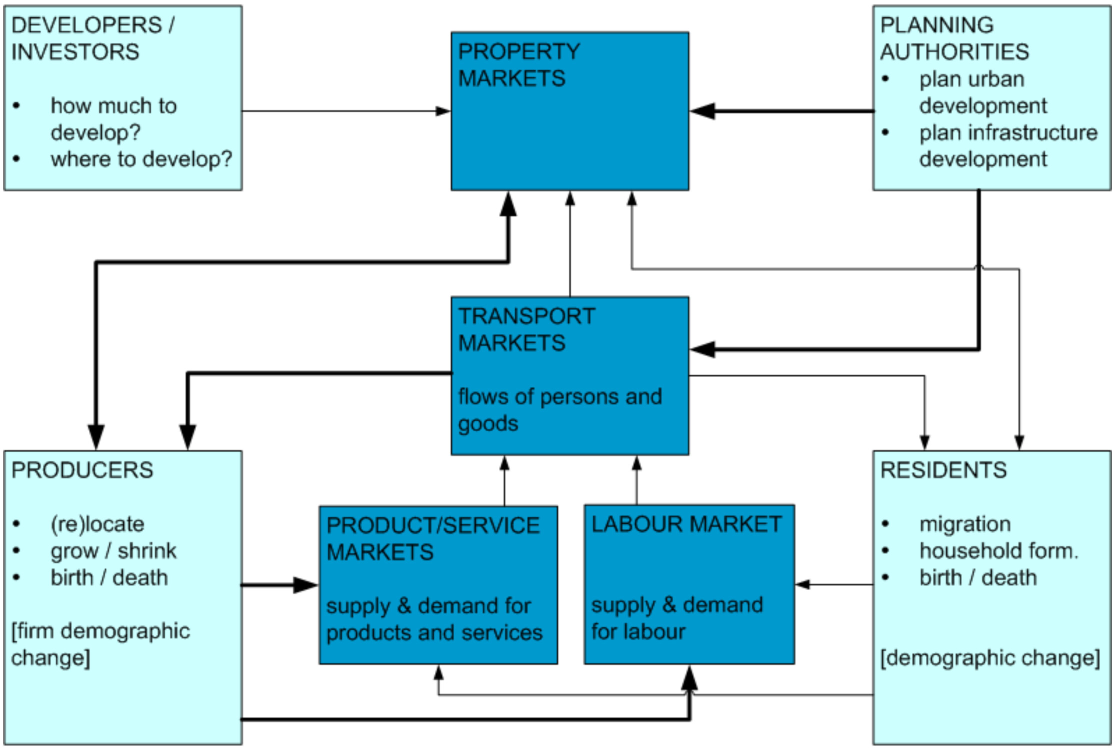

Figure 1: Actors and markets in land use transport models. Adapted from David Simmonds Consultancy and Marcial Echenique and Partners (1999).

Although much progress has been made in the field of integrated land use and transport models, the behavioural and theoretical aspects are considered as weak (Timmermans, 2003). More specifically, the spatial behaviour of individual firms is underrepresented in the field of integrated land use and transport models. Most existing models allocate jobs to zones. In other words: a job decides to relocate, whereas spatial developments are more a result of decisions made by firms. This research tries to make a empirical contribution to the behavioural foundation of these models by applying a micro simulation approach. The approach is founded on firm demography and simulates events in the firm population at the level of individual firms (micro simulation) in a disaggregate urban environment.

Firm demographic micro simulation has a long tradition and is founded by Birch (1979) and gained great interest in The Netherlands (Ekamper and Van Wissen, 1994; Van Wissen, 2000; Van Oort et. al. 1999). Although a few recent empirical contributions exist in the relationship between transport infrastructure and firm demographic events (De Bok and Sanders, 2005; Holl, 2004a and 2004b) the application of such studies in a micro simulation model seems unexplored.

Simulating events in the firm population at the level of the decision maker (micro level) offers a few advantages. First of all, the usage of individual firms allows accounting for firm specific behaviour or in other words: a large heterogeneity in responses. This heterogeneity is expressed in various firm specific attributes such as industry sector or size of the firm. Firm migration for instance, is regarded as being dependent on firm growth which is firm specific (Brouwer et. al., 2002; Louw 1996). Therefore individual information on firm size developments can improve the possibilities to predict events such as firm relocation. A second important advantage of a firm demographic approach is that it allows using distinctive accessibility measures as explanatory variables for each firm demographic event, such as firm relocation, firm performance, start ups or firm dissolution. For instance, literature provides evidence that some mobility sensitive firms indeed perform better in the proximity of motorway onramps (Hilbers et. al., 1994). Accessibility also has an impact on firm migration, but it is stressed that in case of such an event, accessibility might be expresses differently. The third advantage is the possibility to account for path dependency between the events. For example: an initial firm growth, perhaps triggered by a new motorway opening, might induce a firm relocation in the following years. By keeping record of the developments on the individual firm level, the causality between subsequent events can be modelled endogenously.

Furthermore it is stressed that it is necessary to use a high level of spatial detail when analysing distributive impacts of policy plans on the urban structure. A change in accessibility of locations may induce substantial distributive effects (Rietveld, 1994): the opening of an orbital motorway, can lead to a firm migration pattern from inner city locations to the orbital motorway. Furthermore, the high level of spatial detail allows accounting for spatial attributes that describe the quality of locations more accurately and in a way that it is directly observed by decision makers. A recent empirical study (De Bok and Sanders, 2005) suggests that straight forward distance measures to important infrastructure access nodes (e.g. distance to motorway onramps or train stations) have a greater explanatory power compared to gravity type measures that are derived from transport models. The model performance is believed to be better understood if detailed distance measures are used as well as gravity type measures.

This paper first of all describes the structure and main features of the proposed modelling approach. The possibilities of applying micro simulation are discussed and all firm demographic sub models are specified. Next, the calibration of these firm demographic sub models is discussed. Finally the paper is concluded with a short discussion and an indication of future research activities.

2 Model specifications

In an integrated land use and transport model, the firm population executes a demand for locations on the property market and influences the origins and destinations of trips on the transport market. The flows of persons and goods that come from the transport model can be used to quantify the accessibility of locations: for instance accessibility to labour (commuting patterns) or the accessibility to customers/suppliers. These accessibility attributes are assumed to influence the firm demographic events. A name for the simulation framework has not yet been determined but will be addressed in the future. The temporary working name that will be used is SFM, which is an acronym for Spatial Firm demographic Micro simulation.

2.1 Model structure

Micro simulation

The presented model simulates the transitions in the state of individual firms. These transitions are the result of firm demographic events such as a relocation decision, growth or shrinkage of firms or the death of a firm. Figure 2 gives an overview of the SFM-model and the interactions with other model components. In each time step of a model run, all firms in the firm population are processed through the firm demographic micro simulation.

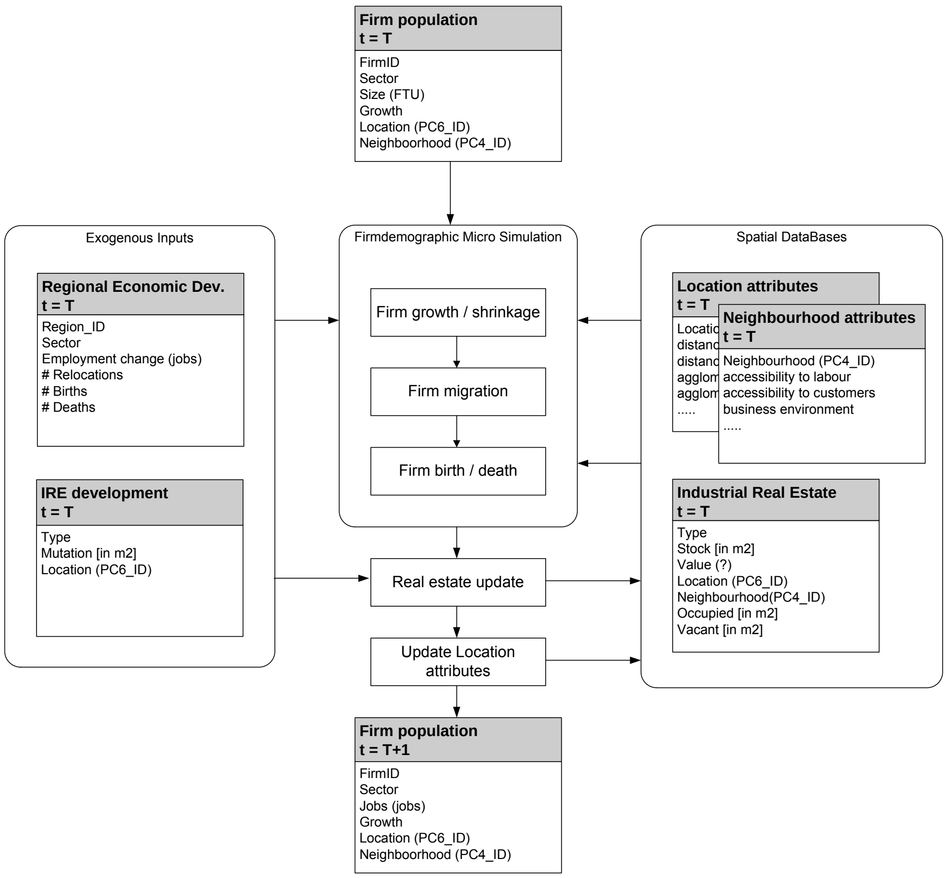

Figure 2: Outline of 1 time step in the SFM-model

During simulation runs, the model interacts with various spatial data bases. The firm population itself is updates within the firm demographic simulation model. During simulation interaction takes place with the industrial real estate stock and the location and neighbourhood attributes. The attributes of the real estate stock, locations and neighbourhood will be updated by separate modules that account for the dynamics in the urban environment. In such a way, exogenous forces, such as real estate developments, that influence these attributes are also accounted for.

Each object in the firm population or in the industrial real estate supply, can be geocoded in GIS or linked to location and neighbourhood attributes using unique keys. Firm and real estate data can be geocoded in ArcGIS using their 6-digit zip code (prox. building block) and the associated coordinates. The simulation model is developed in Visual Basic (VB), allowing an integration with ArcGIS. However, for computation time reasons, the prototype of the simulation model is developed outside ArcGIS. The integration of input and output into ArcGIS is allowed by using data formats that can be used directly in ArcGIS.

Transport interaction

Essential input for the micro simulation is the accessibility of locations and other transport related attributes. The influence of accessibility on events can be assumed to be firm specific. For its activities a firm is dependent on various types of inputs: for instance a specific specialised segment in the labour force or a high dependency on air travel for business trips (WSP, 2003). The dependency on these inputs might be reflected in a firms location preference. For instance, firms with a high dependency on inputs are likely to be much more aware of their location in the transport network while more 'foot loose' firms are more likely to be indifferent to transport infrastructure. A recent empirical study confirms this distinct location preference for firms from different industry sectors or firms with different sizes (De Bok and Sanders, 2005). Another issue raised in the WSP report (2003) deals with the distance minimisation principle. It is suggested that accessibility might be better understood in terms of threshold measures, also referring to satisfying behaviour instead of maximising behaviour. Especially in the case of specific events, such as regional migration, the behaviour of firms might be better understood by using threshold measures instead of generalised transport costs.

The prototype of the SFM-model is developed using fixed accessibility indicators. In doing so, this prototype lacks the dynamic feedback mechanism of relocating economic activities on the network flows and the accessibility of locations for practical reasons. However the implications of this lacking feedback mechanism is judged as acceptable. The structure of the SFM-model is such that a dynamic integration of an urban transport model is allowed in the future. In case of true integration, the transport model would update the accessibility measures in the neighbourhood attribute database, and vice versa the transport model could use the yearly, or five year update, of the SFM-model as trip production input.

Each firm demographic event will be elaborated in the next paragraphs. The events include: firm migration, firm performance and firm formation or dissolutions. For each event it is specified to what extent transport related variables are accounted for.

2.2 Specification of the Firm migration module

Background

Research has shown that on a yearly basis seven to eight percent of all firms move, a considerable share (Pellenbarg, 1996). Furthermore firms appear to move over relatively short distances, as a result of keep-factors (Pellenbarg, 1996). Factors influencing the propensity of a firm to move are referred to as push-factors. The decision to relocate is mainly determined by firm internal factors relating to the life-cycle of firms and to a lesser extent by site related factors (Louw, 1996; Van Dijk and Pellenbarg, 2000; Brouwer et. al., 2002). The attractiveness of a new location is described by pull-factors.

The influence of transport infrastructure on firm migration seems difficult to quantify, despite some empirical studies found in literature. In empirical literature in the Netherlands a significant influence is reported for motorway proximity by Hilbers et al. (1994) and De Bok and Sanders (2004, 2005). Similar evidence is found broadly in international literature (e.g. see Kawamura, 2001; Holl, 2004a). An explanation for this relationship can be found in the dependency on automobiles for most facets of their business activities (Hilbers et. al. 1994;

Kawamura, 2001). In terms of urban development this motorway orientation of economic activities has led to a suburbanisation pattern of economic activities (Kawamura, 2001; Shukla and Waddell, 1991). Research in the field of the New Economic Geography (Krugman, 1991) stresses the need to account for externalities and agglomeration advantages. These externalities are related to the transport infrastructure and have to be accounted for when analysing the location of economic activities.

Model specification

In previous empirical studies experience has been acquired with the dataset that is available for model calibration. These studies have focussed on the firm migration event and have delivered an estimated firm migration procedure (De Bok and Sanders, 2004, 2005). This migration procedure distinguishes a separate relocation decision and a conditional decision for a new location from a subset of alternative locations (Figure 3). The relocation decision is determined by the satisfaction of a firm at its current location. Once the decision to move is made, the firm will search for alternative locations. These are sampled from the available (unused) real estate supply. The probability that an alternative is being chosen depends on its attributes and the expected utility of this alternative.

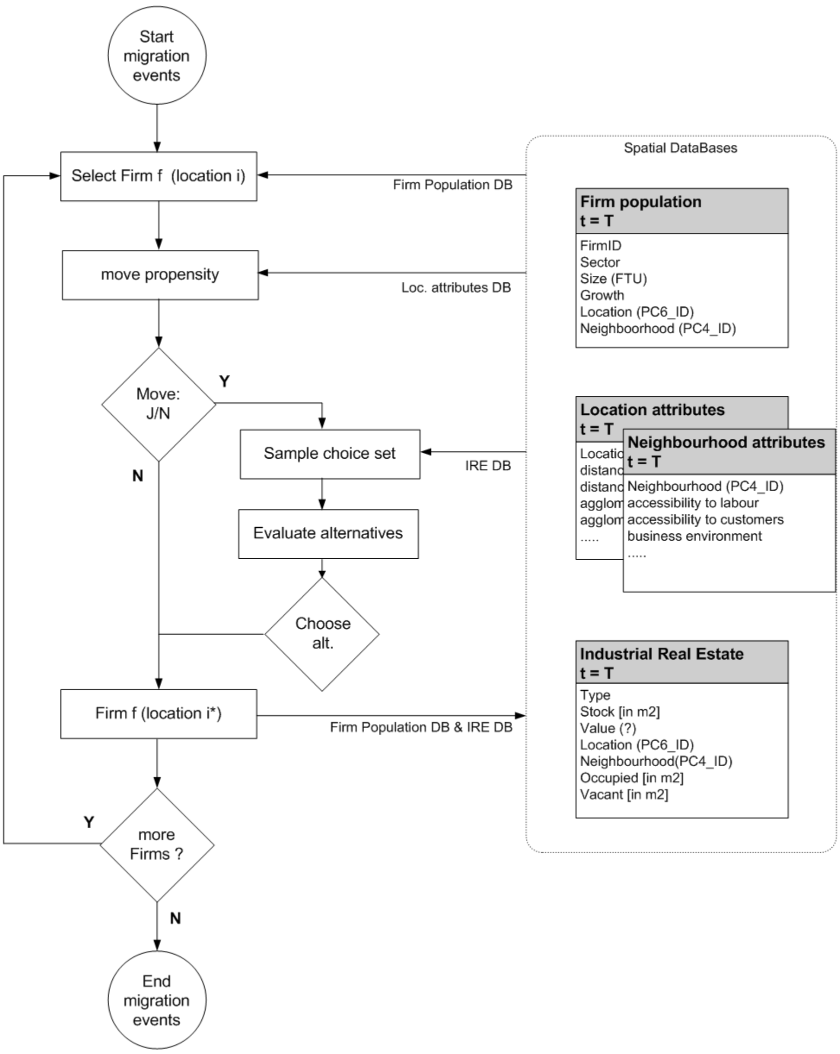

Figure 3 : Firm migration procedure

Similar to Van Wissen (2004), firm migration is modelled as a joint decision to relocate, and the decision for a new location. This joint decision of firm *i* to move and to relocate to location *j* is the product of the probability firm *i* will move and the conditional probability that firm *i* chooses location *j* from a subset of alternatives:

$$P_{ij}^{M} = P_i^{M(1)} \cdot P_{j|C_i}^{M(2)} \tag{1}$$

with:

P_{ij}^{M} : probability firm *i* will relocate and chooses location *j*

$P_i^{M(1)}$: probability firm *i* will relocate

$P_{j|C_i}^{M(2)}$: probability that firm *i* chooses location *j* from a unique subset C_i

The first step in the migration procedure is to calculate the probability to relocate, $P_i^{M(1)}$. This probability is described with a binary regression model. The probability of relocating is determined by the firm characteristics and the attributes of its current location.

$$P_i^{M(1)} = \frac{1}{1 + \exp(C + \beta_1 g_i(t) + \tilde{\beta}_{2i} + \tilde{\beta}_{3i})} \tag{2}$$

with:

$g_i(t)$: growth rate of firm *i* at time *t*

β_1 : coefficient for the growth rate of firm *i*

$\tilde{\beta}_{2i}$: location type specific dummy's for firm *i*

$\tilde{\beta}_{3i}$: industry specific dummy's for firm *i*

C : constant

The probability to relocate is translated into a move/stay decision using Monte Carlo simulation. If the relocation decision is made, a choice set is sampled from the available and feasible real estate. Feasibility is determined by the size of the firms and the real estate object and the type of real estate. Each choice set contains maximum 20 alternatives. The choice probability of each alternative is calculated with a spatial preference model in the form of the multinomial logit (MNL) model, based on random utility theory. By definition, the utility of an alternative consists of an observed and an unobserved (random) component but if the unobserved component is assumed to be Gumbel distributed (McFadden, 1974), the MNL-model results in:

$$P_{j|C_i}^{M(2)} = \frac{e^{V_j}}{\sum_{k \in C_i} e^{V_k}} \tag{3}$$

with:

V_j : the observed utility of location *j*

C_i : subset C_i for firm *i* with *K* alternative locations

The observed utility has the form of a linear additive utility function. Separate choice models have been estimated for each industry sector so no extra firm specific attributes had to be added to the utility function. The observed utility is therefore specified as a function of *M* alternative specific attributes multiplied by *M* estimable coefficients, describing the preference structure of the industry sector.

$$V_j = \sum_{m=1}^{M} \beta_m \cdot x_{mj} \qquad (4)$$

with:

x_{mj} : alternative specific attribute *m* for location *j*

β_m : utility coefficient of attribute *m*

Once a choice set has been sampled for a relocated firm, the observed utility, V_j, is determined. Next these utilities are used to compute choice probabilities for each alternative in the choice set. The actual decision for one of these alternatives is determined with the choice probabilities and Monte Carlo simulation. Figure 3 describes the procedure which is repeated at each time period for each firm in the firm population. At certain points during the procedure, information flows occur between the model and the various databases. These flows can be the distraction of information on an individual firm in the firm population or an update on the Occupancy or Vacancy level, inflicted by a firm relocation.

2.3 Specifications of the Firm growth module

Background

Even though it is hard to find one general accepted theory of the effect of infrastructure on firm growth and firm performance, some empirical evidence is available. The basic assumptions for the firm growth module will be specified based on previous research. In the firm demographic simulation model of Van Wissen (2000), it is assumed that the growth of firms is dependent on the size of the firm, its lifecycle and the market pressure (regional economic developments). The first two assumptions are operationalised by adding the natural log of the firm size at time t and the natural log of the firm size squared. The market pressure is operationalised by the 'carrying capacity' concept: the maximum size a population can attain under the conditions of the current environment. Another contribution to firm performance and infrastructure is made by Hilbers et. al (1994). Their research stresses the need to account for highway sensitivity of firms. For the region of Amersfoort in The Netherlands they found evidence that firms from specific industry sectors indeed have a better performance in the proximity of motorway onramps.

Model specification

The presented approach is not capable of predicting or account for specific structural developments within the industry sectors. Therefore the regional employment per industry sector is an exogenous input to the simulation model. It is important to stress that the presented firm demographic approach, does not aim at predicting generative effects of transport infrastructure at the regional level. The scope of this research is primarily on distributive effects of transport infrastructure. However it is argued that the approach does allow a more accurate prediction of the location of economic activities and the distribution of economic developments.

The firm growth module is used to fit the economic developments to an exogenous regional economic total. The first step in the firm growth procedure is to determine a tentative firm size for each firm in the firm population. The tentative firm size $s_i^*(t+1)$ of firm *i* at time *t+1* is determined with a similar exponential model structure as has been applied in Van Wissen (2000):

$$s_i^*(t+1) = \exp(C + \beta_1 * \ln(s_i(t)) + \beta_2 * (\ln(s_i(t)))^2 + \tilde{\beta}_{3i} + \tilde{\beta}_{4i} + \varepsilon_i) \quad (5)$$

Where:

$s_i^*(t+1)$: estimated tentative firm size at time *t+1* (micro simulation)
$s_i(t)$: firm size at time *t*
β_1 : coefficient for the log of firm size of firm *i*
β_2 : coefficient for the log of firm size of firm *i* squared
$\tilde{\beta}_{3i}$: location type specific dummy's for firm *i*
$\tilde{\beta}_{4i}$: industry specific dummy's for firm *i*
C : constant
ε_i : firm specific random term

This tentative firm size at time *t+1* is estimated, based on the attributes of firm *i* and the attributes of its location at time *t*. The selection of firm and location attributes in the growth function is iterative and is expected to yield the most optimal growth function. The prototype of the firm growth function will at least consist of firm size attributes, firm sector and the αβγ-location typology that refers to the distance to onramps and train stations. In this micro simulation we focus on local impacts of transport infrastructure. The market pressure variable will be modelled using neighbourhood level accessibility measures.

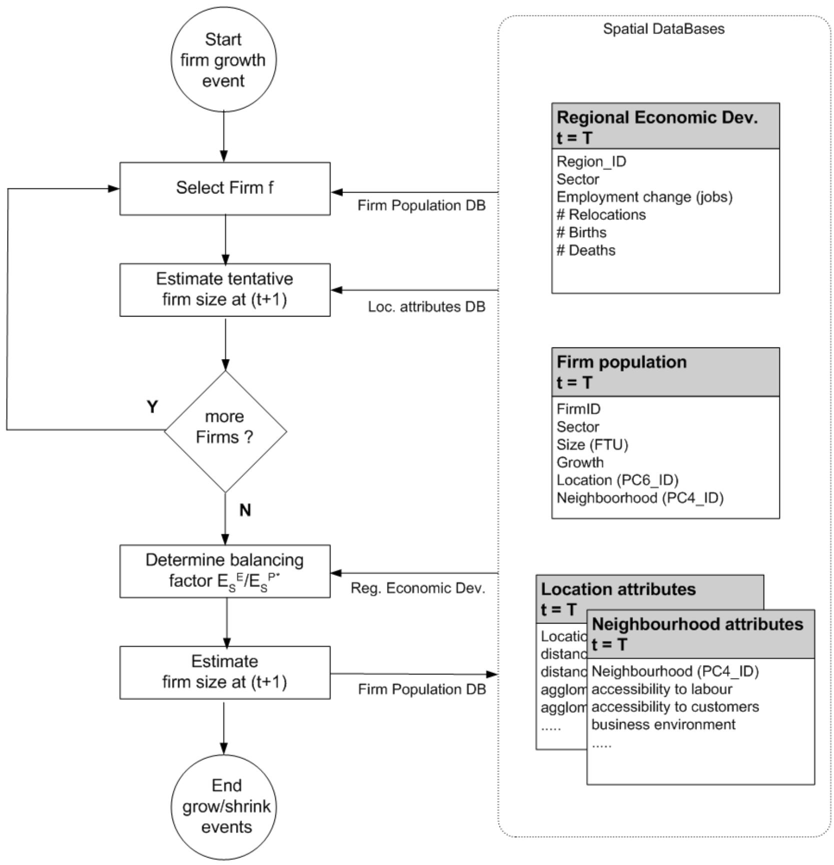

Figure 4: Firm growth procedure

The regional development in the employment per industry sector, E_s^E, is introduced in the model after having processed all firms in the firm demographic micro simulation (see Figure 4). The firm demographic micro simulation has estimated the initial firm size $s_i^*(t+1)$. This firm size is corrected with a sector specific regional balancing factor. This balancing factor adjusts $s_i^*(t+1)$ in order to fit the total employment of a specific firm sector in the firm population $E_s^{P^*}$ to the exogenous regional employment total in this sector E_s^E .

$$s_i(t+1) = s_i^*(t+1) * \frac{E_s^E(t+1)}{E_s^{P^*}(t+1)} \tag{6}$$

Where:

$s_i\ (t+1)$: firm size at time t+1

E_s^E : regional employment in industry sector *s*

$E_s^{P^*}$: initially estimated regional employment in industry sector *s*

2.4 Specifications of the firm formation & dissolution module

Background

Firm formation concerns a complex process of starting up a new firm. An important engine behind firm formation is the existing firm population (Van Wissen, 2000). The firm is at risk of giving birth to a new firm, for instance by splitting up or starting a new branch. This leads to a firm birth rate. Another instigator for firm birth is the labour population: firms can also be formed by firm employees, school-leavers or an unemployed. The urban environment is also regarded to have an effect on firm formation. Van Oort et. al. (1999) found evidence for a distinctive relationship between firm formation rates and the urban environment for different industry types. Firm formation in the non-basic sector seemed more likely to occur in the urban area, which is explained by the incubation and seedbed theory. Furthermore it was found that sectoral diversification has a positive effect on the firm formation rate. Not much empirical examples are found on the influence of infrastructure on the firm formation event. A positive exception is provided by Holl (2004a, 2004b), with firm level data on the location of new manufacturing establishments in Spanish municipalities. It was found that results show that new motorways affect the spatial distribution of manufacturing establishments.

With respect to the influence of firm characteristics on firm dissolution, a lot of evidence can be found in firm demographic literature: size, sector, age and dynamic character of the firm (Van Wissen, 2000). The dissolution probability decreases with firm size as of a result that larger firms are more likely to survive a time interval. With respect to age size the ‘liability of newness’ and the ‘liability of adolescence’ hypothesis is found (Ekamper, 1996). Literature providing empirical evidence for a relation between firm dissolution and accessibility, is minimal. Nevertheless accessibility attributes will be used in the calibration of the dissolution probability. The estimation results can provide improved understanding of the relationship between accessibility and firm dissolution.

Model specifications firm dissolution

The probability of dissolution P_i^D is described with a binary regression model that includes firm specific attributes as well as location attributes. The firm specific attributes include the size of the firm, the growth rate and a firm specific dummy. It was not possible to calibrate the influence of firm age, because this attribute was not available in the observations. Therefore it is omitted from the model specification.

$$P_i^D = \frac{1}{1+\exp(C+\beta_1 g_i(t)+\beta_2 \ln(s_i(t))+\tilde{\beta}_{3i}+\tilde{\beta}_{4i})} \quad (7)$$

with:

$g_i(t)$: growth rate of firm *i* at time *t*
$s_i(t)$: firm size of firm at time *t*
β_1 : coefficient for the log of firm size of firm *i*
β_2 : coefficient for the log of firm size of firm *i* squared
$\tilde{\beta}_{3i}$: location type specific dummy's for firm *i*
$\tilde{\beta}_{4i}$: industry specific dummy's for firm *i*
C : constant

During micro simulation the dissolution probability is determined for each firm. The event of an actual dissolution is simulated by Monte Carlo simulation. This means that if the dissolution probability is smaller than a random drawn number between 0 and 1, the firm is dissoluted. In case of a firm dissolution event, the status of the corresponding firm is set to 'Death' and the firm is removed from the firm population.

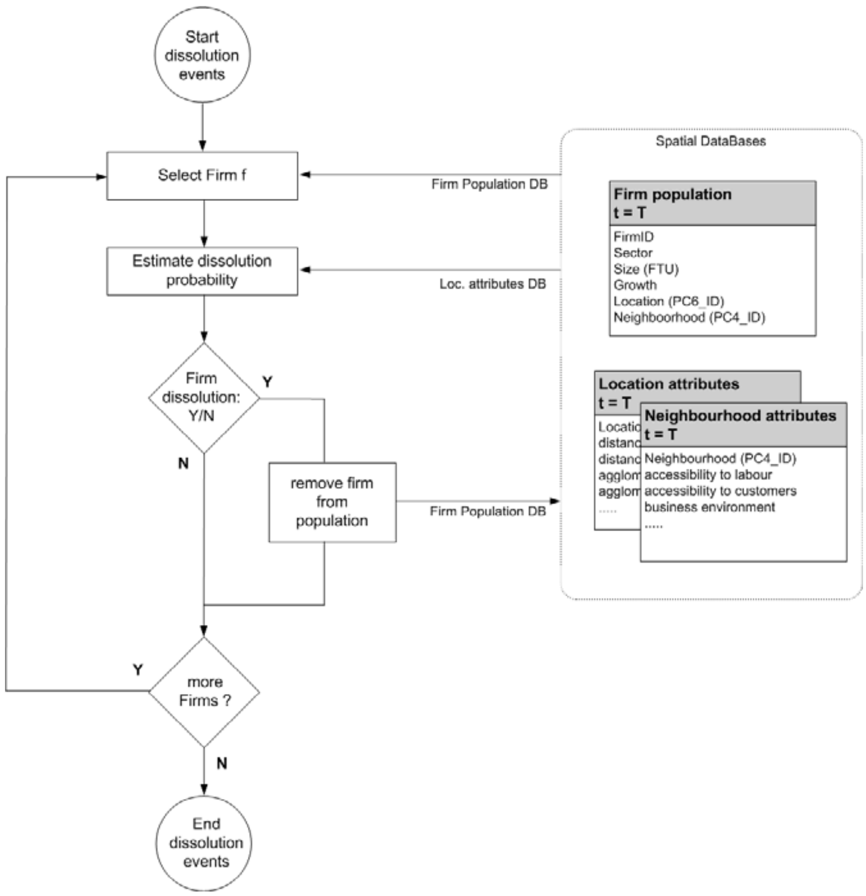

Figure 5 : Firm dissolution procedure

Model specifications firm formation

Firm formation is modelled as a sequential macro to micro simulation. First of all the number of firm formations by industry sector is determined at the level of the neighbourhood, using formation rates. The formation rates depend on the firm sector, neighbourhood characteristics and the firm population in this neighbourhood. Next the firms that are being formed are further specified by determining the exact location and the size of the new firm. First the size of the new firm is determined by a drawn from a negative exponential function. Secondly the exact location is determined by allocating the firm to the available real estate supply.

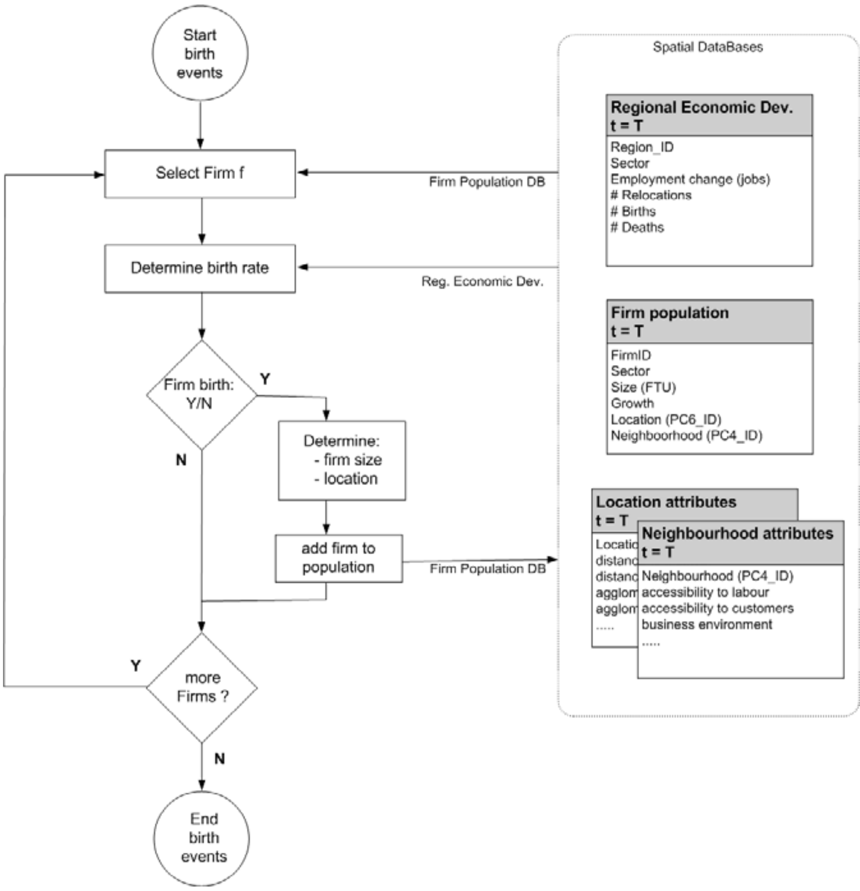

Figure 6 : Firm formation procedure

3 Calibration of the model components

The calibration process of integrated land use and transport models is difficult. The SFM-model is calibrated separately from the transport model. Next it is stressed that the presented model specifications in this paper, apply to a prototype of the model. It is very likely that calibration and application experience will lead to adjustments in these specifications. Subsequently the calibration data is discussed as well as the estimation results for each model component.

3.1 Calibration data

The firm demographic model components are calibrated using RP firm data, describing the developments in the firm population. These developments are explained with firm characteristics and the characteristics of the urban environment in which these firms are located. The firm population is provided by the LISA dataset: the National Information System of Employment. The available LISA data provide a longitudinal micro level data of the firm population in the province of South Holland for the period 1988 to 1997. For all firms in the population the 6-digit postal zone of their location is known. This is nearly the address level: each 6-digit postal zone contains 10 addresses on average. Next, multiple firm attributes are available, such as firm size (number of jobs) and business sector (5-digit sector code). In future research activities the estimated coefficients for the 1988 to 1997 period will be validated with the LISA data from 1997 to 2004. These more recent data, will be made available in the near future.

The accessibility of location is accounted for in various definitions. First of all in terms of the distance to the physical infrastructure: the nearest highway onramp and nearest train station. These attributes are calculated in GIS, using coordinate information. The resulting distance attributes appeared to be highly correlated which might lead to biased estimation results. This was solved by recoding the distance measures into a categorical variable describing the position of a location in relation with the physical infrastructure. First of all α-locations are typical train stations locations: within 800 m. of a train station and not too close to a highway onramp. Locations nearby highway onramps (within 2000 m.) are labeled as γ-locations. If a locations is close to a train station as well as a highway onramp (within 800 m and 2000 m respectively) it is labeled as a β-location. If a location has a considerate distance to both the nearest train station and highway onramp it is labeled as a ρ-location.

The second set of accessibility attributes describe the accessibility to labour and the accessibility to customers or suppliers. Accessibility is measured using a regular gravity type accessibility measure in which the opportunities at each possible destination is weighed with a distance decay function. Travel times from the national transport model for The Netherlands (the LMS) were used for the derivation of these measures. The opportunities come from the WMD-dataset, the Living Environment Database. This dataset contains an extensive variety of socio economic variables at neighbourhood level for the Netherlands. The accessibility to labour is computed with the number of inhabitants at each destination. The accessibility to customers or suppliers is computed with the number of employees at each destination. Both variables were highly correlated so during the estimation of the choice models, only one of these two variables is entered at a time.

3.2 Firm migration

The firm migration module has been subject of previous studies. For specification of the estimation results for this module can be found in the following empirical papers: De Bok and Sanders (2004, 2005). The model estimates correspond to firm demographic literature and reveal a modest importance of accessibility as pull-factor when a firm is searching for a new location. Another finding is the strong influence of keep-factors which indicate that a firm that relocates strives to maintain the existing spatial relations. As expected transport infrastructure plays a minor role as a push-factor: the motives to relocate are often firm-internal. Furthermore outspoken differences in location preference between industry sectors are measured. Firms in business services and manufacturing appear to have a preference for locations near motorway on-ramps. Furthermore the results reveal a suburbanisation pattern of the trade & retail sector. Firms in the government sector and in general services appear to prefer locations near train stations as well as motorway on-ramps. Education and health services show a preference for locations near train stations.

3.3 Firm growth

Firm growth is assumed to be industry specific. Therefore distinct growth functions have been estimated for each industry sector. The log-linear firm size function specified in equation (5) is estimated by linearising equation 5. If we take the natural log of equation (5), we yield the following (linear) function:

$$\ln(s_i^*(t+1)) = C + \beta_1 * \ln(s_i(t)) + \beta_2 * (\ln(s_i(t)))^2 + \tilde{\beta}_{3i} + \tilde{\beta}_{4i} + \varepsilon_i \quad (8)$$

The parameters in this function are estimated with a multiple linear regression. Table X shows the estimated parameters for the firm size module. The firm size module is segmented in industry sectors.

The standard error of the estimate is presented as well. This standard error is used in the growth function in the micro simulation. It is necessary to account for the unexplained variance in the estimate of the growth function. Otherwise the firms from similar size would show similar growth patterns. This does not correspond to real life and would lead to unwanted results. Therefore the error component ε is modelled explicitly in each firm size estimate, with ε ~ N(0,Sig^2). The Sig^2 follows from the S.E. of the estimate in the linear regression models.

Table 1: Estimated coefficients in growth function

	office market											
	Finance		Business services		Government		Education		Health services		General services	
	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.
Constant	0.053	0.009 **	0.054	0.005 **	0.107	0.031 **	0.037	0.004 **	0.079	0.003 **	0.048	0.002 **
Firm attributes												
Log of size(T)	0.938	0.004 **	0.931	0.002 **	0.934	0.011 **	0.994	0.004 **	0.932	0.003 **	0.923	0.003 **
Log of size(T) squared	0.009	0.001 **	0.010	0.001 **	0.006	0.002 **	-0.001	0.001	0.010	0.001 **	0.014	0.001 **
Accessibility attributes												
α-location; nearby trainstation [-]	0.007	0.008	0.010	0.004 *	-0.021	0.019	0.008	0.008	0.006	0.006	0.007	0.005
β-location; nearby trainstation & onramp [-]	-0.001	0.006	0.008	0.003 *	-0.001	0.014	0.011	0.005 *	0.008	0.004	0.001	0.004
γ-location; nearby motorway onramp [-]	-0.008	0.005	0.005	0.003	-0.015	0.013	0.011	0.004 **	0.000	0.003	-0.001	0.003
ρ-location; neither [-] REF.												
Accessibility to labour [-]		#			0.009	0.005						
Business accessibility [-]	0.006	0.007	0.004	0.004								
R2 (adjusted)	0.943		0.931		0.942		0.965		0.951		0.929	
S.E. of estimate	0.292		0.320		0.372		0.269		0.295		0.276	

	industrial real estate								retail real estate			
	Agriculture		Manufactering		Construction		Tr. wareh & comm.		Trade and Retail		Restaurants & Food services	
	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.
Constant	0.110	0.003 **	0.063	0.003 **	0.055	0.003 **	0.070	0.004 **	0.077	0.001 **	0.132	0.003 **
Firm attributes												
Log of size(T)	0.871	0.004 **	0.943	0.003 **	0.935	0.003 **	0.926	0.004 **	0.905	0.001 **	0.850	0.004 **
Log of size(T) squared	0.020	0.001 **	0.007	0.001 **	0.010	0.001 **	0.010	0.001 **	0.018	0.000 **	0.026	0.001 **
Accessibility attributes												
α-location; nearby trainstation [-]	-0.013	0.009	0.003	0.006	-0.013	0.007	0.009	0.007	0.005	0.002 *	0.014	0.006 *
β-location; nearby trainstation & onramp [-]	-0.008	0.015	-0.006	0.004	0.003	0.005	0.016	0.006 **	0.003	0.002	0.007	0.004
γ-location; nearby motorway onramp [-]	0.002	0.003	0.007	0.003 *	0.007	0.003 *	0.023	0.004 **	0.006	0.001 **	0.002	0.004
ρ-location; neither [-] REF.												
Accessibility to labour [-]												
Business accessibility [-]												
R2 (adjusted)	0.856		0.956		0.945		0.941		0.921		0.856	
S.E. of estimate	0.292		0.293		0.298		0.326		0.280		0.323	

** = significant at the 0,99 level ; * = significant at the 0,95 level

The estimation results correspond to the expectations based on literature. Most important condition for the growth function is the industry sector and firm attributes relating to the size of the firm. Accessibility plays a modest role. For most sectors only the distance to train station and/or motorway onramps proved significant and plausible. For instance: firms in business services, transport, trade and to a lesser extend manufacturing, appear to perform better in the proximity of motorway onramps (γ or β-locations). Gravity type accessibility measures are only presented for industry sectors were these attributes had plausible values. However these coefficients are often insignificant.

3.4 Firm dissolution

The sensitivity of firm dissolution to accessibility is not expected to be an important explaining variable, or even that this sensitivity varies greatly between industry sectors. Therefore one binary probability model is estimated for firms from all industry types.

Table 2 : Estimated coefficients for dissolution

	B	S.E.	
Constant	-2.118	0.032	**
Firm attributes			
Growth rate	-0.220	0.021	**
Log of size	-0.460	0.006	**
Industry sector			
Agriculture	-0.792	0.040	**
Manufacturing	-0.066	0.038	
Construction	-0.305	0.038	**
Trade and Retail	-0.239	0.032	**
Restaurants and Food services	-0.765	0.040	**
Transport, Warehousing and Communication	-0.017	0.038	
Finance	0.020	0.040	
Business services	0.035	0.034	
Government	0.795	0.061	**
Education (ref.)			
Health Services	-0.519	0.040	**
General Services	-0.524	0.037	**
Accessibility attributes			
α-location; nearby trainstation [-]	0.083	0.022	**
β-location; nearby trainstation & onramp [-]	0.076	0.016	**
γ-location; nearby motorway onramp [-]	0.045	0.013	**
ρ-location; neither [-] REF.			

The results show evidence for a higher dissolution probability in the proximity of train stations or highways. This seems an unexpected results, for there is no reason to assume infrastructure proximity has a negative influence on survival changes for firms. A possible explanation might be a higher dynamic profile of the firms at these locations.

3.5 Firm start up

First step: firm births out of firm population. These events are simulated by an industry specific birth rate (Table 3). If a firm is started up, the firm inherits the industry sector of the mother firm. Next the size of the new born fir is to be determined. This size will be estimated based on the observed distribution over the size of all new born firms in the dataset. The distribution of initial firm sizes is assumed to be industry specific: for example the birth of a large firm in the government sector proves to occur more frequently compared to the other sectors.

Table 3: Birth rate for each industry sector

Sector	Birth Rate
Agriculture	2.4%
Manufacturing	6.5%
Construction	7.0%
Trade and Retail	7.1%
Restaurants and Food services	4.9%
Transport, Warehousing and Communication	8.4%
Finance	6.6%
Business services	15.7%
Government	7.7%
Education	5.2%
Health Services	6.5%
General Services	7.7%

Table 4 : Distribution initial firm size

Industry sector	Firm size (classes)						
	0-4	5-9	10-24	25-49	50-99	>100	Tot
Agriculture	78.7%	14.9%	5.2%	0.6%	0.4%	0.1%	100.0%
Manufacturing	75.7%	11.5%	7.3%	3.2%	0.9%	1.4%	100.0%
Construction	82.8%	8.0%	5.8%	2.2%	0.8%	0.4%	100.0%
Trade and Retail	89.1%	7.0%	2.6%	0.8%	0.4%	0.1%	100.0%
Restaurants and Food services	85.0%	9.1%	4.1%	0.8%	0.6%	0.3%	100.0%
Transport, Warehousing and Communication	80.5%	8.8%	6.1%	2.2%	1.1%	1.2%	100.0%
Finance	86.3%	6.6%	4.3%	1.9%	0.6%	0.3%	100.0%
Business services	88.6%	6.0%	3.5%	1.1%	0.4%	0.3%	100.0%
Government	30.4%	15.0%	20.5%	13.9%	8.7%	11.5%	100.0%
Education	75.6%	8.3%	10.4%	3.6%	1.9%	0.3%	100.0%
Health Services	73.8%	12.2%	9.8%	2.2%	1.1%	1.0%	100.0%
General Services	92.4%	4.5%	2.1%	0.7%	0.4%	0.0%	100.0%
All sectors	85.5%	7.6%	4.3%	1.4%	0.7%	0.5%	100.0%

4 CONCLUSIONS AND DISCUSSION

The presented firm demographic model aims to address some research challenges in the field of integrated land use and transport models. Most important advantage of the presented approach is the usage of the firm as the decision making unit, which improves the behavioural foundation of integrated land use and transport models. This micro approach allows a large heterogeneity in responses by using firm specific attributes in the behavioural models for these firms.

A secondly advantage is the improved possibilities to evaluate the impact of spatial scenarios, which is provided by the firm level simulation output. For instance, this output can be used to analyse which firms gain most benefits from specific investments, for example in terms of improved accessibility to inputs. Once a full integration with a transport model has been accomplished, the mobility effects of the changes in land use patterns can be analysed. By quantifying the effects of different planning scenarios in terms of economic development and mobility effects, the most sustainable or desirable scenario can be found. The results can be used to address enhanced policy questions that deal with effects of spatial policy plans on the firm population: which firms will benefit most from the policy plans and what firms are likely to be put at a disadvantage? These benefits and disadvantages can be analysed in terms of various mobility derivatives from the transport model. Furthermore effects on the urban structure and the industrial real estate stock can be quantified.

Future papers will elaborate on the further development in which several important research directions can be distinguished. Fisrt of all other accessibility measures, such as log sum measures will be tested for their explanatory value. An argument for such measures is the possibility to evaluate effects on congestion or road pricing policies. Secondly the validation of the model will be needed as well as some tests on the sensitivity to policy inputs. Furthermore, to analyse scenario outputs, transparent and meaningfull indicators need to be defined, that summarise the simulation results. Another practical issue concerns the information on the industrial real estate supply. For this issue a procedure is being developed that estimates a synthetic real estate supply, by using various available datasets.

5 Acknowledgements

The authors would like to acknowledge their appreciation for the following persons or institutes that have made a valuable contribution to the research:

- Frank van Oort from Utrecht University and the Netherlands Institute for Spatial Research, The Hague.
- Geo-Database Management Center at the Department of Geodetic Engineering at the Delft University of Technology.
- ABF Research, Delft.

6 REFERENCES

Birch, D. (1979) *The Job Generating Process.* Cambridge (Mass.), Cambridge University Press.

Brouwer, A., I. Mariotti and J.N. van Ommeren (2002). The firm relocation decision: a logit model. Paper presented at the 42nd ERSA conference, Dortmund, Germany.

David Simmonds Consultancy and Marcial Echenique and Partners (1999) *Review of land-use/transport interaction models*, London: Department of the Environment, Transport and the Regions.

De Bok, M. and F. Sanders (2004) Infrastructure and firm migration. Proceedings of the 31st Colloquium Vervoerplanologisch Speurwerk, Zeist, pp. 275-291.

De Bok, M. and F. Sanders (2005) Firm location and the accessibility of locations: empirical results from the Netherlands. Paper presented at the 84th Annual meeting of Transportation Research Board, Washington DC.

Ekamper, P. (1996) Opheffing van bedrijfsvestigingen: een sterftetafelbenadering. *Planning* 48, pp. 12-21.

Ekamper, P. and L. Van Wissen (1994) *SIMFIRMS: Firmografische microsimulatie van bedrijfsvestigingen in Nederland*. The Hague: NIDI.

Hilbers, H, P. Jorritsma and P. Louter (1994) The relationship between accessibility and regional development explored for the region of Amersfoort. Paper presented at the 21[tst] Colloquium Vervoerplanologisch Speurwerk.

Holl, A. (2004a) Manufacturing location and impacts of road transport infrastructure: empirical evidence from Spain. *Regional Science and Urban Economics* 34, pp. 341-363.

Holl, A. (2004b) Start-ups and relocations: Manufacturing plant location in Portugal. *Papers in Regional Science* 83, pp. 649-668.

Kawamura, K. (2001). Empirical examination of the relationship between firm location and transportation facilities. In: *Transportation Research Record: Journal of the Transportation Research Board*, 1747, pp. 97-103.

Krugman, P. (1991). Increasing Returns and Economic Geography. *Journal of political economy*, 99, pp. 483-499.

Louw, E. (1996) *Kantoorgebouw en vestigingsplaats*. OTB Research Institute: Delft.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behaviour. In: P. C. Zarembka (Ed.). *Frontiers in Econometrics*. New York and London: Academic Press, pp. 105-142.

Miller, E. J., D.S. Kriger and J.D. Hunt (1998) *TCRP project H-12: Integrated urban models for simulation of transit and land-use policies*. Toronto, University of Toronto.

Pellenbarg, P. (1996) Structuur en ontwikkeling van bedrijfsmigratie in Nederland. *Planning* 48, pp. 22-32.

Rietveld, P. (1994) Spatial economic impacts of transport infrastructure supply. *Transportation Research Part A: Policy and Practice*, 28, pp. 329-341.

Shukla, V. and P. Waddell (1991). Firm location and land use in discrete urban space: A study of the spatial structure of Dallas-Fort worth. *Regional Science and Urban Economics* 21, pp. 225-253.

Timmermans (2003) The saga of integrated land use-transport modeling: how many more dreams before we wake up? 10th International Conference on Travel Behaviour Research, Lucerne.

Van Dijk, J., Piet Pellenbarg (2000). Firm relocation decisions in The Netherlands: An ordered logit approach. *Papers in Regional Science* 79, pp. 191-219.

Van Oort, F., Bert van der Knaap and Wilfred Sleegers (1999) New firm formation, employment growth and the local environment: emperical observations in South-Holland. In: J. Van Dijk and. P. Pellenbarg (Ed.) *Demography of firms; Spatial Dynamics of Firm Behaviour*. Utrecht/Groningen: Netherlands Geographical Studies 262, pp. 173-204.

Van Wissen, L. (2000) A micro-simulation model of firms: Applications of concepts of the demography of the firm. *Papers in Regional Science*, Vol. 79, pp. 111-134.

Wegener, M and F. Fürst (1999) TRANSLAND Deliverable D2a, Land-Use Transport Interaction: State of the Art. Dortmund, University of Dortmund.

WSP (2003) *Workshop on the Modelling of Household and Employment Location*. Final report prepared for the Department for Transport, Cambridge, WSP.