Infrastructure and Firm Dynamics: Calibration of a Micro Simulation Model for Firms in the Netherlands

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ABSTRACT

Firm location is an important component in integrated land use and transport models. However, firm behavior and firm locations are often represented too aggregate to adequately model firm behavior. A calibrated simulation approach is presented that models dynamics in the firm population at the level of individual firms. A number of firm demographic events and transitions in the state of individual firms are simulated: firm migration, growth, formation and dissolution. This provides the opportunity to account for firm specific behavior, allowing a large variety in responses to changes in urban environment. The model quantifies the effects of different spatial and transport planning scenarios on the firm population and mobility. Moreover, the firm level simulation output provides improved possibilities to evaluate the impact of spatial scenarios. It can be linked to an urban transport model in order to obtain a dynamic simulation of urban development and mobility. The model specification is presented, as well as the calibration of the individual firm demographic processes. The behavior of the calibrated model is verified with multiple test runs.

INTRODUCTION

Integrated land use and transport models are becoming increasingly disaggregate, both in the spatial environment as the behavior of agents within this environment (*1*). More specifically, in most operational models firm location and the behavior of firms is too aggregated to adequately represent firm behavior (*2*), (*3*), (*4*), (*5*). In literature some empirical studies can be found into the relationship between transport infrastructure and firm demographic events, such as (*6*), (*7*), (*8*), (*9*) or (*10*), but none of these studies have actually been applied in integrated land use and transport models.

This research tries to make an empirical contribution to the behavioral foundation of these models by presenting a calibrated micro simulation model for firms. The simulation approach is based on firm demography and features a disaggregate urban environment. In recent literature a few similar empirical contributions exist that apply micro simulation, firm behavior and firm demography as well (*11*), (*12*). However, some differences exist in the level of aggregation of sub models or in data availability. In (*11*), firm demographic components of change are modeled explicitly, however the number of firms lost- and gained is modeled at the census tracts level instead of firm level. (*12*) applies theoretical valid location factors that are derived from a Cobb-Douglas production function. However the validity of the parameters is limited due to a lack of empirical micro data.

Firm demographic micro simulation, in literature also referred to as firmography, has a long tradition that started with (*13*). It gained great interest in The Netherlands as well: (*14*), (*15*) and (*16*). Firm demographic micro simulation offers several advantages. First, it represents firm specific behavior and a heterogeneity in responses: firm behavior is to a large extent influenced by firm internal processes. An example: the most important reason for firms to relocate is firm growth (*17*), (*18*). Second, it allows distinctive accessibility measures as explanatory variables for each event, such as firm relocation, firm performance, start ups or firm dissolution. For instance, some firms perform better in the proximity of motorway onramps (*19*), while in a relocation decision, accessibility is evaluated in a different way. Third advantage is the possibility to account for path dependency between events. For example, firm growth – e.g. 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 modeled endogenously.

The presented firm demographic model aims to address some research challenges in the field of integrated land use and transport models. First of all, the usage of the firm as decision making unit improves the behavioral foundation of integrated land use and transport models. Secondly, the firm level simulation output provides an improved flexibility to evaluate the impact of spatial scenarios. For instance, accessibility gains or losses that are the result of a policy investment can be analyzed for any desired segment of the firm population. If the model is integrated with a transport model, the mobility effects of the simulated land use changes can be analyzed as well. Quantifying the spatial economic and mobility effects of different planning scenarios, provides required input to determine the most sustainable or desirable scenario.

First, the structure of the simulation model and all firm demographic sub models will be specified in this paper. Next, the calibration of these sub models is discussed. Finally the calibrated model is verified by discussing a number of simulation runs. The paper concludes with a short discussion and an indication of future research activities.

MODEL DESCRIPTION

Model structure

The proposed Spatial Firm demographic Micro simulation (SFM) model simulates the transitions in the state of individual firms. These transitions are the result of firm demographic events such as relocation, firm growth, firm dissolution or start up. Figure 1 gives an overview of the simulation procedure and associated firm demographic events. In each time step of a model run, the firm population is processed through the firm demographic micro simulation. During simulation, the model interacts with various spatial databases that describe the location and neighborhood attributes of the industrial real estate stock. The attributes of the real estate stock, locations, and neighborhood are updated by separate modules that account for exogenous influences and changes in the urban environment.

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 that case, the transport model would update the accessibility measures in the neighborhood attribute database, and vice versa the transport model could use the yearly, or five year update, of the SFM model as trip generation input.

Each object in the firm population or in the industrial real estate supply can be geo-coded in GIS, or linked to location and neighborhood attributes using unique keys. Firm and real estate data can be geo-coded in ArcGIS using their 6-digit zip code (approximates building block) and the associated coordinates.

Firm migration

With seven to eight percent of all firms relocating in a year (*20*), firm migration has a considerable influence on the spatial pattern of the firm population. The move propensity of a firm is mainly determined by firm internal factors relating to the life-cycle of firms and to a lesser extent by site related factors (*18*), (*21*), (*17*). The number of empirical studies in the literature is modest, so one general accepted approach to modeling the influence of transport infrastructure on firm location does not exist. In the Netherlands a significant influence is reported for motorway proximity by (*19*), (*9*). Even though the approach might vary, similar evidence is found widely in international literature, see (*6*), (*22*), (*8*) or (*10*). In terms of urban development, this motorway orientation of economic activities has led to a suburbanization pattern of economic activities: (*22*), (*23*). Moreover, proximity and accessibility of other producers might lead to externalities and agglomeration advantages, analyzed extensively in the New Economic Geography literature (*24*).

Similar to the simulation approach applied by Van Wissen in (*15*), firm migration is modeled as a joint decision to relocate, and the decision for a new location. The relocation decision is determined by the satisfaction of a firm at its current location. Once the decision to relocate has been 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.

For each simulation time interval *t*, let $P_{ij}^{m}(t)$ denote the probability that a firm *i* will relocate and chooses location *j*. This probability is the product of the probability that the firm will relocate, $P_i^{m(1)}(t),$ and the probability that it chooses location *j* (out of a unique subset of available alternatives for firm *i* at time *t*, $L_i(t)$), $P_{ij|L_i(t)}^{m(2)}(t):$

$$P_{ij}^{m}(t) = P_i^{m(1)}(t) \cdot P_{ij|L_i(t)}^{m(2)}(t). \tag{1}$$

The first step in the migration procedure is to calculate the probability to relocate. This probability is described with a binary regression model. The probability of relocating for each time interval is determined by the firm characteristics and the attributes of the current location:

$$P_i^{m(1)}(t) = \frac{1}{1 + \exp[-(\beta_0^{m(1)} + \beta_1^{m(1)} g_i(t) + \beta_2^{m(1)} \delta_{1i}^{m(1)} + \beta_3^{m(1)} \delta_{2i}^{m(1)})]}, \tag{2}$$

where $g_i(t)$ is the growth rate of the firm at time *t*, and $\delta_{1i}^{m(1)}$ and $\delta_{2i}^{m(1)}$ are dummy variables for the location and industry type, respectively. The parameters $\beta_x^{m(1)}$ need to be calibrated. The probability to relocate is translated into a move/stay decision using Monte Carlo simulation.

When a firm has decided to relocate, 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 component $V_{ij}(t),$ and an unobserved (random) component. Assuming that the unobserved components are all independently and identicallly Gumbel distributed (*25*), the MNL-model results in:

$$P_{ij|L_i(t)}^{m(2)}(t) = \frac{e^{V_{ij}(t)}}{\sum_{k \in L_i(t)} e^{V_{ik}(t)}}. \tag{3}$$

A linear additive utility function has been applied for the observed utility. Separate utility functions have been estimated for each industry sector. The observed utility is therefore specified for each industry sector *s* as a function of location attributes and socio-economic firm attributes,

$$V_{ij}(t) = \sum_p \beta_{sp}^{m(2)} x_{jp}(t) + \sum_q \beta_{sq}^{m(2)} y_{iq}(t), \qquad \text{where firm } i \text{ belongs to industry sector } s. \tag{4}$$

The variables $x_{jp}(t)$ describe the level of attribute *p* at location *j* for firm *i* at simulation time *t*, for instance: the distance to infrastructure. Variables $y_{iq}(t)$ describe the firm characteristics, such as size or growth rate. The parameters $\beta_{sp}^{m(2)}$ and $\beta_{sq}^{m(2)}$ are to be estimated for each industry sector *s*. The attributes are assumed to be generic within each industry sector.

In the simulation, choice probabilities are translated into decisions with Monte Carlo simulation. The changes in occupation of industrial real estate are processed with every relocation decision.

Firm growth

The main objective of the presented model is to determine the distributive effects of transport infrastructure. The regional economic development is exogenous input to the simulations. These distributive effects have proven to be far more substantial compared to generative effects, as proven in (*26*). It is stressed that our presented approach neglects the generative effects of transport infrastructure but accounts for structural developments within the industry sectors through economic scenarios. A two step approach has been applied in computing the expected firm size. First of all a tentative firm size is estimated based on firm- and location attributes. Next, this tentative firm size is corrected to fit the total employment in the firm sector to the exogenous regional totals.

Firm performance is first of all expected to be influenced by the proximity of transport infrastructure. In (*19*) evidence was found that specific industry sectors perform better in the proximity of motorway onramps. However, firm size is mostly explained by firm attributes, relating to the size and lifecycle of a firm. Previous model specifications where based on a log linear firm size model, but led to unrealistic results. Hence, following recent studies (*27*) and (*28*), an improved autoregressive model has been applied that estimates the size of a firm, relative to the average firm size in the industry sector. The tentative firm size, $z_{is}(t)$, is defined as the deviation of the log of the firm size from the average log of firm size:

$$z_{is}(t) = \log s_{is}^{*}(t) - \frac{\sum_{k=1}^{N_s(t)} \log s_{ks}(t)}{N_s(t)}, \tag{5}$$

where $s_{is}^{*}(t)$ is the tentative size of firm *i*, that belongs to sector *s* at time *t* and $N_s(t)$ is the number of firms in sector *s*. Following (*27*) and (*28*), $z_{is}(t)$ is derived form the firm specific z-values for the two previous years and a location attribute. This first order autoregressive model includes a slope coefficient β_0^s and a first-order autocorrelation coefficient ρ_0^s:

$$z_{is}(t) = (\beta_0^s + \rho_0^s) z_{is}(t-1) + (-\beta_0^s \rho_0^s) z_{is}(t-2) + \beta_1^s \delta_{1i}^s + \varepsilon_{is}(t), \tag{6}$$

where δ_{i1}^s is a dummy variable for the location type and $\varepsilon_{is}(t)$ is a stochastic disturbance term. The parameters β_x^s, ρ_0^s and $\varepsilon_{is}(t)$ need to be calibrated. The tentative firm size $s_{is}^{*}(t)$, can be derived by rewriting equation (5) and substituting equation (6). Next, $s_{is}^{*}(t)$ is corrected with a sector specific regional balancing factor in order to fit the total employment to the regional economic scenario:

$$s_{is}(t) = s_{is}^{*}(t) \frac{E_s(t)}{E_s^{*}(t)}, \tag{7}$$

where $s_{is}(t)$ is the firm size at time *t*, $E_s(t)$ is the regional employment in industry sector *s*, and $E_s^{*}(t)$ is the initially estimated regional employment.

Firm dissolution

An exploration of firm demographic literature shows that firm dissolution is mainly determined by firm characteristics: size, sector, age and firm growth (*15*), (*29*). It is obvious that larger firms have a higher probability of surviving a time interval. With respect to age, the ‘survival of the fittest’ is apparent among young firms: the first years after start up firms have a relative high dissolution probability. Even though no empirical evidence has been found for a relation between firm dissolution and accessibility, accessibility attributes will be included in the estimation of the dissolution probability. The probability of dissolution $P_i^d(t)$ is described with a binary regression model that includes firm and location attributes:

$$P_i^d(t) = \frac{1}{1+\exp[-(\beta_0^d + \beta_1^d g_i(t) + \beta_2^d \ln s_i(t) + \beta_3^d (1/a_i(t)) + \beta_4^d \delta_{1i}^d + \beta_5^d \delta_{2i}^d)]}, \tag{8}$$

where $g_i(t)$ is the growth rate of the firm, $s_i(t)$ the size of the firm, $a_i(t)$ the age of the firm and δ_{1i}^d, and δ_{2i}^d, are dummy variables for location and industry type. All β_x^d parameters need to be calibrated. During micro simulation the dissolution probability is determined for each firm.

The dissolution probabilities are translated into dissolution events with Monte Carlo simulation. In case of a firm dissolution event, the status of the corresponding firm is set to 'Dissolved' and the occupation of industrial real estate is cleared.

Firm formation

Firm formation concerns a complex process of starting up a new firm. An important engine behind firm formation is the firm population itself (*15*). An existing firm can induce a firm start up, for instance by splitting up or by starting a new branch. Another instigator for firm birth is the labor 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. In (*16*) evidence is found 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 many empirical examples have been found on the influence of infrastructure on the firm formation event. A positive exceptions are (*8*) and (*9*), with firm level data on the location of new manufacturing establishments in Spanish municipalities. Results show that new motorways affect the spatial distribution of manufacturing establishments.

Firm formation is an exception to the micro simulation approach for it simulates firm start ups as sequential macro to micro steps. First of all the number of firm formations is determined by industry specific birth rates and the industry population per region. Next, an initial firm size is randomly drawn from an observed distribution of firm sizes at start up. Finally the firm is allocated to a random location drawn from all available locations that are feasible as well.

CALIBRATION

Micro simulation is data demanding and the estimation of such models is complex (*30*). In this case a strategy has been applied in which the parameters in the firm demographic submodels are estimated directly from micro observations. While most existing micro simulation models are forced to use synthetic datasets of firms (*12*), (*31*), the presented model is calibrated with a firm level, population size dataset. Subsequently the calibration data is discussed as well as the estimation results for each model component. The model has been developed for the province of South Holland in The Netherlands, see Figure 2. This area contains a firm population of approximately 90.000 firms that are distributed across 70.000 6-digit zip code locations.

Data

The model has been calibrated on a longitudinal dataset, covering all developments in the firm population. This dataset has been constructed by linking annual LISA datasets (National Information System of Employment) from 1988 to 1997. Firm attributes that are available include: industry sector, size (in full time employment units), the change in size compared to previous year, the location (6 digit zip code) and dummy's for firm demographic events. The spatial detail of firm locations allows a detailed analysis of spatial attributes of each location.

Various accessibility attributes are linked to the locations. First, in terms of distance to physical infrastructure: nearest highway onramp and nearest train station. These attributes are calculated in GIS, using coordinate information. However, the 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. An α-location is within 800m. of a train station and not too close to a highway onramp. Locations nearby highway onramps (within 2000m.) are labeled as γ-locations. If a location is close to a train station as well as a highway onramp (within 800m. and 2000m. respectively) it is labeled as a β-location. Remote locations that are relatively far from train stations and highway onramps, are labeled as ρ-locations.

The second set of accessibility attributes includes the accessibility to labor and to customers or suppliers. These attributes are computed with a regular gravity type model that weighs the opportunity at each possible destination 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 (Living Environment Database) containing an extensive variety of socio economic variables at the neighborhood level for the Netherlands. The accessibility to labor 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. In the estimation of the choice models only one of these variables could be entered, because both were highly correlated.

Estimation results

The estimated parameters for each module are presented in tables 1 and 2. The firm migration module has been realized in previous studies and is specified more elaborately in (*7*). The migration parameters in Table 1A and 2A correspond to firm demographic literature and reveal a modest importance of accessibility as pull-factor. Another finding is the preference for locations in the proximity of the original location. This is interpreted as evidence for keep-factors: a relocating firm strives to maintain their existing spatial network. 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. Locations in the proximity of highways appear to be preferred by firms in manufacturing, transport warehousing and communication and the trade and retail sector. Most of the industry sectors on the office market appear to prefer locations near highways as well as train stations (β-locations): finance, business services, government and education.

The firm growth model is segmented to 12 industry sectors as well. The parameters in the autoregressive firm size models are estimated with a non-linear regression and are listed in Table 1B. In order to avoid identical growth patterns for firms with similar sizes, it is necessary to account for the unexplained variance in the estimate of the growth function. The stochastic disturbance term ε is included in the firm size model, with $\varepsilon \sim N(0,\Sigma)$, where Σ follows from the mean square of the residual of the estimate. The estimated autoregressive coefficients for firm size correspond to firm demographic literature. For all sectors, $\beta_0^s < 1$, which means that large firms are expected to grow more slowly than smaller firms. All estimated ρ_0^s parameters have a negative sign, which implies a negative correlation between firm growth in subsequent years. In other words: a firm with a relative substantial growth in one year, is expected to grow less quickly the next year. Finally it was found that infrastructure proximity has a significant effect on firm performance for various industry sectors.

Table 2C shows the estimated parameters for firm dissolution. As expected, the dissolution probability decreases with size and growth rate: large and growing firms are more likely to survive. Moreover, dissolution decreases with age. The results prove that accessibility is not very important for firm dissolution, although the parameter for locations in the proximity of train stations or highways is just significant and positive. This seems an unexpected result, for there is no reason to assume that infrastructure proximity has a negative influence on survival probability of firms. A possible explanation might be a higher dynamic profile of the firms at these locations. Table 2B presents the parameters for the firm formation model. The firm formation rates are specified for each industry sector, as well as a size distribution for start up firms.

SIMULATION RESULTS

To verify the behavior of the model and to explore the possibilities with micro output, multiple test runs have been performed with the calibrated model. Each test run is based on identical scenario input. In order to verify the results, these will be compared with the observed developments in the population. The results are analyzed at population level, the neighborhood level, and on a sample of individual firms.

Input scenario

Objective of the micro simulation is to quantify the effects of spatial policy scenarios. These scenarios can include infrastructure investments or industrial and commercial site planning. Scenarios are implemented in the SFM model in terms of accessibility measures from a transport model and industrial real estate developments. Figure 3 gives an indication of the input. The office stock at the beginning of the simulation (1990) is visualized, as well as the office development that is executed during simulation (from 1990 to 1996). The main infrastructure networks are visualized as well.

Another exogenous model input is the regional economic development. A model run requires an economic scenario in terms of number of employees per industry sector for each year in the simulation period.

The economic scenario that has been used for as simulation input is taken from the observed economic development of the study region.

Results

The graphs in Figure 4A and 4B visualize the simulation results at population level. In each figure the observed developments are visualized in combination with three test runs. The differences between the runs are the different instances of the stochastic components of the simulation, not the model formulation itself. The firm population and employment developments are visualized. The employment development in the test runs follow the shape of the observed employment development. This is of course how it should be: the employment development is exogenous input. The small differences in aggregates between runs are the result of rounding off individual firm size. The size of the simulated firm population shows a more constant development compared to the size of the observed firm population, but on average it seems consistent. In previous model specifications, the population size showed a continuous increasing growth pattern, leading to an exponential growth of the firm population. However, the current model specification with the inclusion of age in the dissolution model and the improved firm size model, yields consistent results.

Figure 4C and 4D present scatter plots of simulated developments with observed developments at the neighborhood level. For most contemporary integrated land use and transport models, the employment at the neighborhood level is used as a determinant for transport demand. At this aggregation level the results seem robust compared to the observed developments. The differences between different model runs also turned out to be minimal. The number of firms per neighborhood appears less sensitive compared to employment. The size of the firm population only changes at start up, dissolution or relocation events which are less dynamic events compared to firm growth, which occurs for each firm every year. Nevertheless, with an average probability of once every 10 year for each event, a six year simulation could show a distinct development in the population per neighborhood.

Micro simulation describes behavior at the most disaggregated level possible: in this case firms. Figure 4E and 4F show the microscopic results for two random firms. Their simulated size is compared to their observed size in the simulation period. The stochastics in the various demographic events prove to lead to very distinct developments at the micro level. For example: in one specific run a firm with 10 employees grows in 6 years to a firm with 18 employees, while in another run the same firm is dissolved after one year. This might appear to be unwanted. However, the results at the aggregate level appear to be less variant and more robust compared to observed developments. So, despite the stochastics, it is argued that the results seem valuable for projecting local demand for traffic or real estate supply. It might even be argued that the stochastics in the model introduce an improved representation of the behavior of firms, for they introduce coincidence in all kinds of decisions and events.

CONCLUSIONS AND FURTHER RESEARCH

The calibration and first results of a firm demographic micro simulation model have been presented. The general conclusion of the presented approach is that it provides reliable estimates of future firm location, consistent with the behavior of the individual firms within the research area. The simulation model features several stochastic procedures: migration and dissolution decisions include Monte Carlo simulation, and the firm growth routine includes a stochastic component for unexplained variance. The simulation runs show that this leads to distinct developments at micro level. However, the aggregated results seem robust. We realize that the results do not prove that our micro approach performs better at neighborhood level compared to approaches that apply aggregated behavior. However, the representation of the individual firm allows for improved possibilities for implementing individual responses to policy measures. This may lead to future projections with a higher validity.

Micro simulation offers a few advantages in modelling the behavior and developments of the firm population. First of all it allows firm specific behavior. Second, it enables the application of accessibility effects on different components of economic development, such as firm migration or firm growth. Finally, it allows a path dependency between events. The micro simulation is developed in a disaggregate urban environment and allows detailed spatial attributes. This improves the specification of location utilities and provides an improved flexibility to evaluate policy impacts. An issue that will be addressed in the future concerns the way in which spatial scenarios are evaluated. When integrated land use transport interaction models are applied, the output is often assessed in terms of a number of indicators, describing the developments in mobility, land use, demography and the regional economy. The output of the firm demographic micro simulation is analyzed with similar indicators.

Future publications will elaborate on ongoing model developments. The validity of the model will be tested on firm data for the period 1997 until 2004. A possible extension of the approach is the application of log sum accessibility variables, which are assumed to provide a better estimate of the quality of accessibility (*32*). Another practical issue concerns the information on the industrial real estate supply. For this issue a synthetic real estate supply is generated by using various available datasets. Finally, the model will be applied in an ex ante evaluation of policy scenarios for the period 2005 to 2020. These scenarios include the development of industrial locations, development of transport infrastructure and different economic scenarios. The model quantifies the impacts of these scenarios on the spatial distribution of firms and on mobility developments.

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REFERENCES

1. Timmermans, H. The saga of integrated land use-transport modeling: how many more dreams before we wake up? Key note paper at the 10th International Conference on Travel Behavior Research, Lucerne, 2003.
2. Miller, E.J., D.S. Kriger and J.D. Hunt. A research and development program for integrated urban models. In *Transportation Research Record: Journal of the Transportation Research Board*, 1999. No. 1685, TRB, National Research Council, Washington, D.C., pp. 169-176.
3. Wegener, M. and F. Fürst. *Land-Use Transport Interaction: State of the Art*. Deliverable D2a TRANSLAND. Dortmund: University of Dortmund, 1999.
4. Waddell, P. and G.F. Ulfarsson. Accessibility and Agglomeration: Discrete-Choice Models of Employment Location by Industry Sector. Paper presented at the 82nd Annual Meeting of the Transportation Research Board, Washington, D.C., 2003.
5. Abraham, J.E. and J.D. Hunt. Firm location in the MEPLAN model of Sacremento. In *Transportation Research Record: Journal of the Transportation Research Board*, 1999. No. 1685, TRB, National Research Council, Washington, D.C., pp. 187-208.
6. J.D. Hunt. Stated-preference examination of location choice behavior of small retail firms. In *Transportation Research Record: Journal of the Transportation Research Board*, 1997. No. 1606, TRB, National Research Council, Washington, D.C., pp. 25-32.
7. De Bok, M. and F. Sanders. Firm relocation and the accessibility of locations: empirical results from The Netherlands. In *Transportation Research Record: Journal of the Transportation Research Board*, 2005. No. 1902, TRB, National Research Council, Washington, D.C., pp. 35-43.
8. Holl, A. Manufacturing location and impacts of road transport infrastructure: empirical evidence from Spain. *Regional Science and Urban Economics*, Vol. 34, 2004, pp. 341-363.
9. Holl, A. Start ups and relocations: manufacturing plant location in Portugal. *Papers in Regional Science*, Vol. 83, 2004, pp. 649-668.
10. Leitham, S., R. W. McQuaid, et al. The influence of transport on industrial location choice: a stated preference experiment. *Transportation Research Part A: Policy and Practice*. Vol. 34, 2000, pp. 515-535.
11. Maoh, H., P. Kanaroglou and R. Buliung. Modeling the location of firms within an integrated transport and land-use model for Hamilton, Ontario. CSpA Working Paper No. 06, Centre for Spatial Analysis, McMaster University, 2005.
12. Moeckel, R. Microsimulation of firm location decisions. Paper presented at the 9th CUPUM Conference, London, 2005.
13. Birch, D. *The job generating process*. Cambridge University Press, Cambridge (Mass.), 1979.
14. Ekamper, P. and L. Van Wissen. *SIMFIRMS: Firmografische microsimulatie van bedrijfsvestigingen in Nederland*. NIDI, The Hague, 1996.
15. Van Wissen, L. A micro-simulation model of firms: Applications of concepts of the demography of the firm. *Papers in Regional Science*, Vol. 79, 2000, pp. 111-134.
16. Van Oort, F., B. van der Knaap and W. Sleegers. 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 Behavior*. Utrecht/Groningen: Netherlands Geographical Studies 262, 1999, pp. 173-204.

17. Brouwer, A. E., I. Mariotti and J.N. Van Ommeren. The firm relocation decision: a logit model. Paper presented at the 42nd ERSA conference, Dortmund, 2002.
18. Louw, E. *Kantoorgebouw en vestigingsplaats*. OTB Research Institute, Delft, 1996.
19. Hilbers, H., P. Jorritsma and P. Louter. The relationship between accessibility and regional development explored for the region of Amersfoort. Paper presented at the 21st Colloquium Vervoerplanologisch Speurwerk, 1994.
20. Pellenbarg, P. H. Structuur en ontwikkeling van bedrijfsmigratie in Nederland. *Planning*, Vol. 48, 1996, pp. 22-32.
21. Van Dijk, J. and P. Pellenbarg. Firm relocation decisions in The Netherlands: An ordered logit approach. *Papers in Regional Science*, Vol. 79, 2000, pp. 191-219.
22. Kawamura, K. Empirical examination of the relationship between firm location and transportation facilities. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1747, 2001, TRB, National Research Council, Washington, D.C., pp. 97-103.
23. Shukla, V. and P. Waddell. Firm location and land use in discrete urban space: A study of the spatial structure of Dallas-Fort worth. *Regional Science and Urban Economics*, Vol. 21, 1991, pp. 225-253.
24. Krugman, P. Increasing returns and economic geography. *Journal of political economy*, Vol. 99, pp. 483-499.
25. McFadden, D. Conditional logit analysis of qualitative choice behavior. in: P. C. Zarembka (Ed.) *Frontiers in Econometrics*. Academic Press, New York and London, 1974, pp. 105-142.
26. Rietveld, P. Spatial economic impacts of transport infrastructure supply. *Transporation Research Part A: Policy and Practice*, Vol. 28, 1994, pp. 329-341.
27. Audretsch, D. B., L. Klomp and A.R. Thurik. Gibrat's law: are the services diffirent? ERIM Report Series No. ERS-2002-04-STR, Rotterdam, 2002.
28. Van Wissen, L. and C. Huisman. Firm growth across regions: a regional test of Gibrat's Law. Paper presented at the 43rd ERSA conference, Jyvaskyla, 2005.
29. Ekamper, P. Opheffing van bedrijfsvestigingen: een sterftetafelbenadering. *Planning*. Vol. 48, 1996, pp. 12-21.
30. Abraham, J. E. and J.D. Hunt. Parameter estimation strategies for large-scale urban models. In *Transportation Research Record: Journal of the Transportation Research Board*, 2000. No. 1722, TRB, National Research Council, Washington, D.C., pp. 9-16.
31. Abraham, J. E. T. Weidner et. al. Three methods for synthesizing base-year built form for integrated land-use transport models. In *Transportation Research Record: Journal of the Transportation Research Board*, 2005. No. 1902, TRB, National Research Council, Washington, D.C., pp. 114-123.
32. De Jong, G., A. Daly , M. Pieters and T. Van Der Hoorn. The Logsum as an evaluation measure: review of the literature and new results. Paper presented at the 45th ERSA conference, Amsterdam, 2005.

LIST OF TABLES AND FIGURES

TABLE 1 Estimated parameters location decision and firm growth models

TABLE 2 Estimated parameters move probability, firm formation and dissolution models

FIGURE 1 Structure of the simulation model and specification of firm demographic events.

FIGURE 2 Research area.

FIGURE 3 Scenario input for region of The Hague.

FIGURE 4 Simulation results.

1A FIRM MIGRATION: location choice

	office market											
	Finance		Business services		Government		Education		Health services		General services	
Variable	β	t-stat.	β	t-stat.	β	t-stat.	β	t-stat.	β	t-stat.	β	t-stat.
Migration attribute												
Distance to original loc.[$km^{1/2}$]	-2.00	-14.02 **	-1.84	-33.39 **	-1.81	-12.24 **	-2.62	-15.99 **	-2.49	-19.17 **	-2.03	-14.64 **
Accessibility attributes												
α-location; near trainstation [-]	-0.08	-0.33	-0.03	-0.23	-0.18	-0.49	0.33	1.09	0.05	0.14	-0.16	-0.39
β-location; near trainstation & highway onramp [-]	0.49	2.76 **	0.20	2.04 *	0.62	3.02 **	0.43	2.16 *	0.20	1.17	0.52	2.20 *
γ-location; near highway onramp [-]	-0.03	-0.19	0.06	0.83	0.10	0.56	-0.36	-2.21 *	-0.17	-1.11	0.16	0.84
ρ-location; neither [-]	-0.38		-0.23		-0.54		-0.40		-0.09		-0.53	
Accessibility to labour [-]	7.29E-07	0.37	9.31E-07	1.49	-1.99E-06	-1.45	-2.39E-07	-0.15	1.12E-06	0.92	-7.26E-07	-0.52
Business accessibility [-]												
Urban environment attributes												
City Centre [-]	0.15	1.02	-0.04	-0.64	0.41	2.54 *	-0.69	-3.73 **	-0.38	-2.74 **	0.26	1.81
Urban Business District [-]	0.81	3.68 **	1.12	14.69 **	0.54	2.95 **	0.96	5.11 **	0.19	1.08	1.02	5.63 **
Mixed Urban [-]	-0.37	-2.14 *	-0.33	-4.70 **	-0.30	-1.66	-0.16	-1.02	0.11	0.91	-0.51	-3.04 **
Residential [-]	-0.88	-4.05 **	-0.90	-10.37 **	-0.53	-2.30 *	0.15	0.96	0.19	1.45	-0.47	-2.39 *
Non-urban [-]	0.28		0.15		-0.13		-0.25		-0.11		-0.31	
Number of observations	249		1184		199		281		425		240	
Init log-likelihood	-698		-3501		-549		-797		-1223		-674	
Final log-likelihood	-390		-2022		-350		-349		-589		-372	
Rho-square	0.441		0.422		0.363		0.562		0.519		0.448	

	industrial estate market								retail estate market			
	Agriculture		Manufactering		Construction		Transport, Warehousing & Comm.		Trade & retail		Restaurants & Food services	
Variable	β	t-stat.	β	t-stat.	β	t-stat.	β	t-stat.	β	t-stat.	β	t-stat.
Migration attribute												
Distance to original loc.[$km^{1/2}$]	-2.79	-13.67 **	-1.70	-24.46 **	-1.88	-26.07 **	-1.53	-24.16 **	-2.01	-32.97 **	-2.75	-5.40 **
Accessibility attributes												
α-location; near trainstation [-]	-1.74	-2.68 **	-0.72	-2.34 *	0.00	0.00	-0.29	-1.08	-0.31	-1.39	0.24	0.42
β-location; near trainstation & highway onramp [-]	0.82	1.19	0.09	0.40	0.04	0.21	0.24	1.35	-0.08	-0.61	0.48	0.82
γ-location; near highway onramp [-]	0.28	0.83	0.42	3.12 **	0.11	0.89	0.32	2.64 **	0.52	5.26 **	-0.10	-0.25
ρ-location; neither [-]	0.64		0.21		-0.15		-0.27		-0.13		-0.61	
Accessibility to labour [-]	1.64E-06	0.71	-2.34E-06	-3.00 **	-1.23E-06	-1.41	-3.96E-06	-6.22 **	-1.98E-06	-3.44 **	5.39E-07	0.08
Business accessibility [-]												
Urban environment attributes												
City Centre [-]	-0.82	-2.06 *	-0.38	-2.95 **	-0.94	-6.46 **	0.19	1.80	-0.58	1.80	-0.38	-0.92
Urban Business District [-]	-0.04	-0.09	1.29	12.77 **	1.12	10.10 **	1.04	10.58 **	1.28	10.58 **	0.94	1.90
Mixed Urban [-]	-0.70	-2.04 *	-0.18	-1.59	0.08	0.73	-0.26	-2.24 *	-0.34	-2.24 *	-0.21	-0.45
Residential [-]	0.53	1.65	-0.65	-4.46 **	-0.16	-1.45	-1.06	-6.32 **	-0.79	-6.32 **	-0.52	-1.17
Non-urban [-]	1.02		-0.08		-0.09		0.09		0.42		0.16	
Number of observations	201		564		691		586		1149		59	
Init log-likelihood	-557		-1643		-2024		-1708		-3390		-132	
Final log-likelihood	-172		-898		-1069		-1056		-1625		-49	
Rho-square	0.692		0.453		0.472		0.381		0.521		0.629	

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

1B FIRM GROWTH

	office market											
	Finance		Business services		Government		Education		Health services		General services	
Variable	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Firm attributes												
Size previous years: slope coefficient BETA	0.984	0.001 **	0.978	0.001 **	0.985	0.003 **	0.994	0.001 **	0.988	0.001 **	0.985	0.001 **
Size previous years: autocorrelation coefficient RHO	-0.164	0.007 **	-0.113	0.004 **	-0.063	0.015 **	-0.153	0.007 **	-0.188	0.005 **	-0.157	0.005 **
Accessibility attributes												
α-location; near trainstation [-]	0.024	0.005 **	-0.012	0.003 **	0.033	0.012 **	-0.003	0.005	0.000	0.004	0.009	0.003 **
β-location; near trainstation & highway onramp [-]	-0.004	0.004	0.005	0.002	-0.004	0.009	0.003	0.004	0.004	0.003	-0.001	0.003
γ-location; near highway onramp [-]	-0.008	0.003 *	0.007	0.002 **	-0.016	0.009	0.005	0.003	-0.001	0.003	-0.003	0.002
ρ-location; neither [-]	-0.011		0.000		-0.012		-0.006		-0.003		-0.005	
Number of observations	22342		87780		5684		21220		41350		51813	
R2 (adjusted)	0.949		0.941		0.945		0.969		0.955		0.938	
Mean square of the residual	0.077		0.093		0.125		0.061		0.079		0.069	

	industrial real estate								retail real estate			
	Agriculture		Manufactering		Construction		Transport. wareh & comm.		Trade and Retail		Restaurants & Food services	
Variable	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
Firm attributes												
Size previous years: slope coefficient BETA	0.953	0.002 **	0.986	0.001 **	0.981	0.001 **	0.981	0.001 **	0.984	0.000 **	0.964	0.002 **
Size previous years: autocorrelation coefficient RHO	-0.153	0.005 **	-0.122	0.005 **	-0.123	0.005 **	-0.134	0.006 **	-0.160	0.002 **	-0.164	0.005 **
Accessibility attributes												
α-location; near trainstation [-]	-0.008	0.008	0.012	0.004 **	0.003	0.005	0.002	0.005	0.014	0.002 **	0.039	0.004 **
β-location; near trainstation & highway onramp [-]	0.048	0.008 **	-0.008	0.003 *	0.000	0.004	0.002	0.004	0.001	0.001	-0.002	0.003
γ-location; near highway onramp [-]	-0.019	0.002 **	0.001	0.002	0.002	0.003	0.007	0.003 *	-0.004	0.001 **	-0.013	0.003 **
ρ-location; neither [-]	-0.021		-0.006		-0.005		-0.010		-0.011		-0.024	
Number of observations	48631		39960		42045		32044		208664		42964	
R2 (adjusted)	0.868		0.964		0.951		0.948		0.927		0.864	
Mean square of the residual	0.077		0.072		0.080		0.095		0.072		0.096	

** = significant at the 0,99 level ; * = significant at the 0,95 level
Coefficients are estimated with the Levenberg - Marquardt procedure

TABLE 1 Estimated parameters location decision and firm growth models

2A FIRM MIGRATION: move probability

Variable	β	S.E.	
Constant	-3.866	0.063	**
Individual firm attributes			
Log of size [ln(emp)]	-0.043	0.006	**
Growth rate, absolute [|%|]	0.394	0.026	**
Industry sector			
Finance [-]	0.328	0.053	**
Business services [-]	0.630	0.044	**
Government (Ref.) [-]	0.444	0.077	**
Education [-]			
Health service [-]	0.088	0.050	
General Services [-]	-0.090	0.050	
Agriculture [-]	-0.440	0.056	**
Manufactering [-]	0.130	0.050	**
Construction [-]	0.460	0.048	**
Transp., Wareh. & Comm. [-]	0.603	0.048	**
Trade & Retail [-]	-0.175	0.044	**
Restaurants & Food service [-]	-1.373	0.068	**
Accessibility attributes			
α-location; near trainstation [-]	0.028	0.021	
β-location; near trainstation & highway onramp [-]	-0.010	0.016	
γ-location; near highway onramp [-]	-0.063	0.013	**
ρ-location; neither [-]	0.045		
Accessibility to labour [-]	0.073	0.008	**
Urban environment			
City Centre [-]	0.057	0.014	**
Urban Business District [-]	0.147	0.017	**
Mixed Urban [-]	-0.062	0.014	**
Residential [-]	0.035	0.014	*
Non-urban [-]	-0.177		
Number of observations	641469		
Cox and Snell	0.007		
Nagelkerke	0.029		

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

2C FIRM DISSOLUTION

Variable	β	S.E.	
Constant	-1.651	0.082	**
Individual firm attributes			
Log of size [ln(emp)]	-0.352	0.008	**
Growth rate [%]	-0.270	0.026	**
1 / age [year $^{-1}$]	0.749	0.025	**
Industry sector			
Finance [-]	-0.572	0.087	**
Business services [-]	-0.630	0.081	**
Government (Ref.) [-]			
Education [-]	-0.666	0.090	**
Health service [-]	-1.227	0.086	**
General Services [-]	-1.095	0.084	**
Agriculture [-]	-1.281	0.090	**
Manufactering [-]	-0.635	0.084	**
Construction [-]	-0.816	0.085	**
Transp., Wareh. & Comm. [-]	-0.623	0.084	**
Trade & Retail [-]	-0.742	0.080	**
Restaurants & Food service [-]	-1.272	0.086	**
Accessibility attributes			
α-location; near trainstation [-]	0.018	0.020	
β-location; near trainstation & highway onramp [-]	-0.027	0.015	
γ-location; near highway onramp [-]	0.025	0.012	*
ρ-location; neither [-]	-0.015		
Number of observations	307215		
Cox and Snell	0.015		
Nagelkerke	0.037		

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

2B FIRM FORMATION

Industry sector	Number of start ups '90-'96	Start up size (in %) 0-4	5-9	10-24	25-49	50-99	>100	Birth rate (% of pop.)
Agriculture	1 171	78.7	14.9	5.2	0.6	0.4	0.1	2.44
Manufacturing	2 432	75.7	11.5	7.3	3.2	0.9	1.4	6.55
Construction	2 712	82.8	8.0	5.8	2.2	0.8	0.4	6.96
Trade and Retail	13 883	89.1	7.0	2.6	0.8	0.4	0.1	7.11
Restaurants and Food services	2 004	85.0	9.1	4.1	0.8	0.6	0.3	4.92
Transport, Warehousing and Communication	2 437	80.5	8.8	6.1	2.2	1.1	1.2	8.39
Finance	1 399	86.3	6.6	4.3	1.9	0.6	0.3	6.58
Business services	11 449	88.6	6.0	3.5	1.1	0.4	0.3	15.70
Government	381	30.4	15.0	20.5	13.9	8.7	11.5	7.70
Education	1 062	75.6	8.3	10.4	3.6	1.9	0.3	5.24
Health Services	2 439	73.8	12.2	9.8	2.2	1.1	1.0	6.49
General Services	3 674	92.4	4.5	2.1	0.7	0.4	0.0	7.74

TABLE 2 Estimated parameters move probability, firm formation and dissolution models

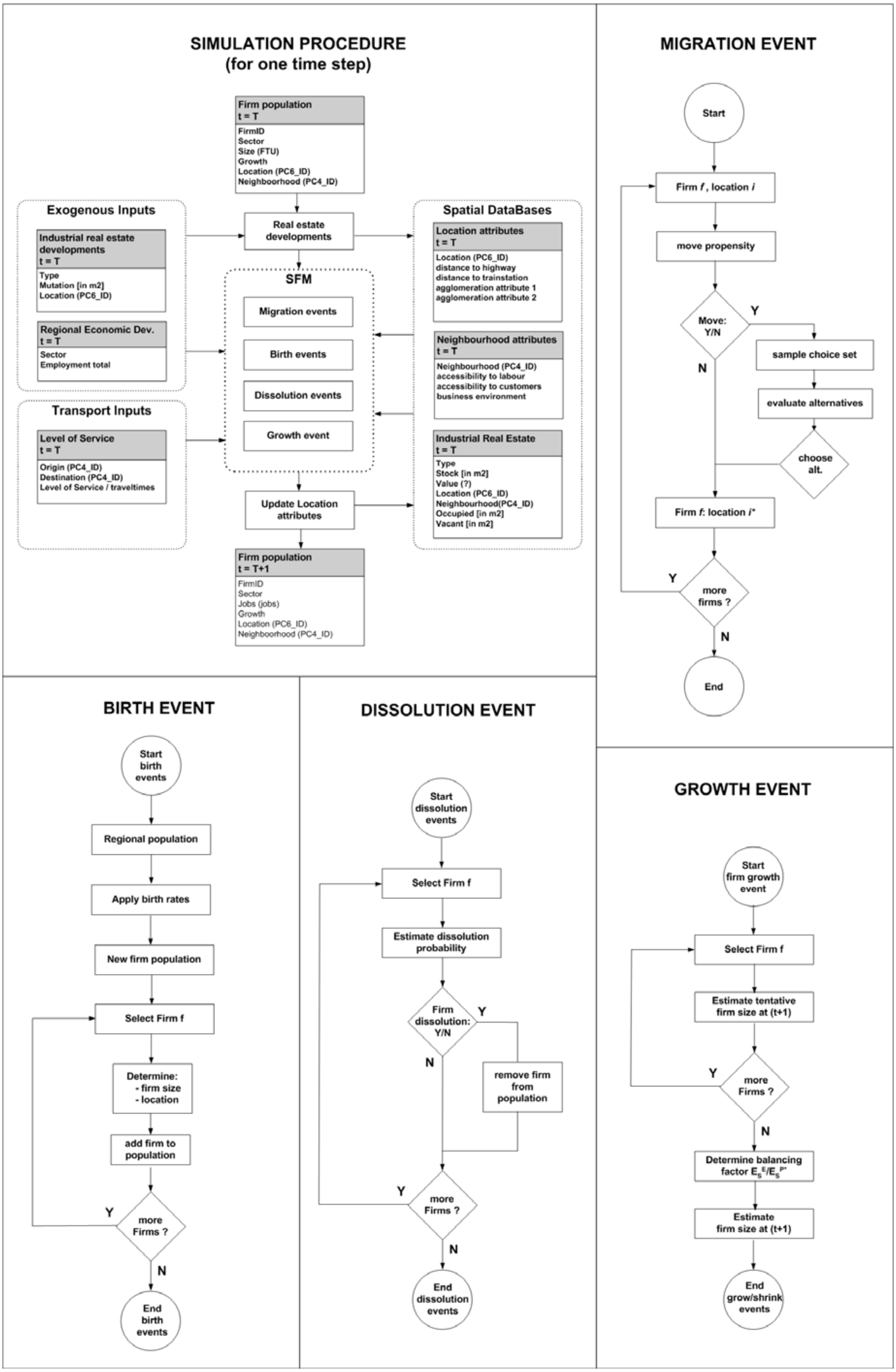

FIGURE 1 Structure of the simulation model and specification of firm demographic events.

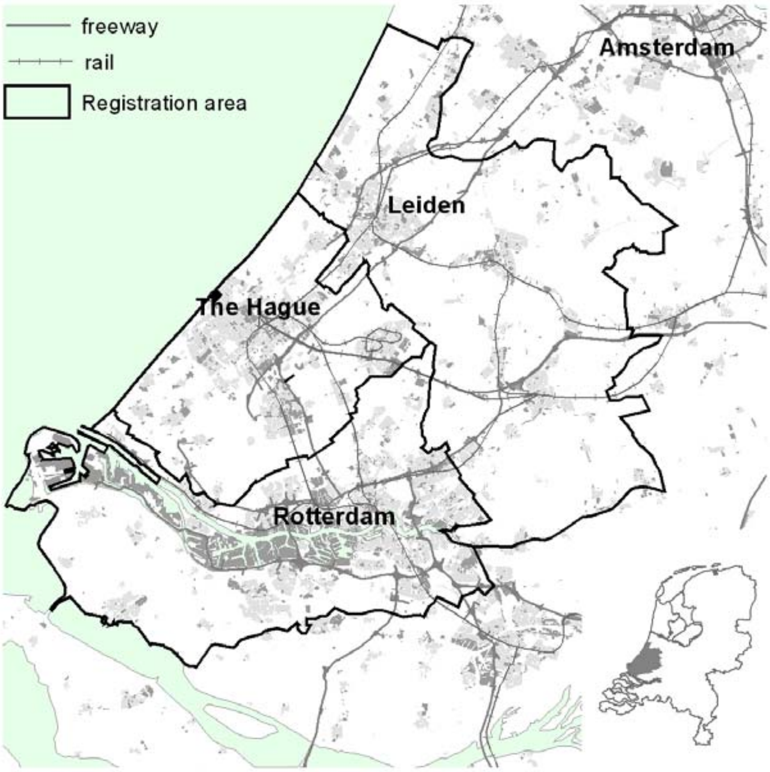

FIGURE 2 Research area.

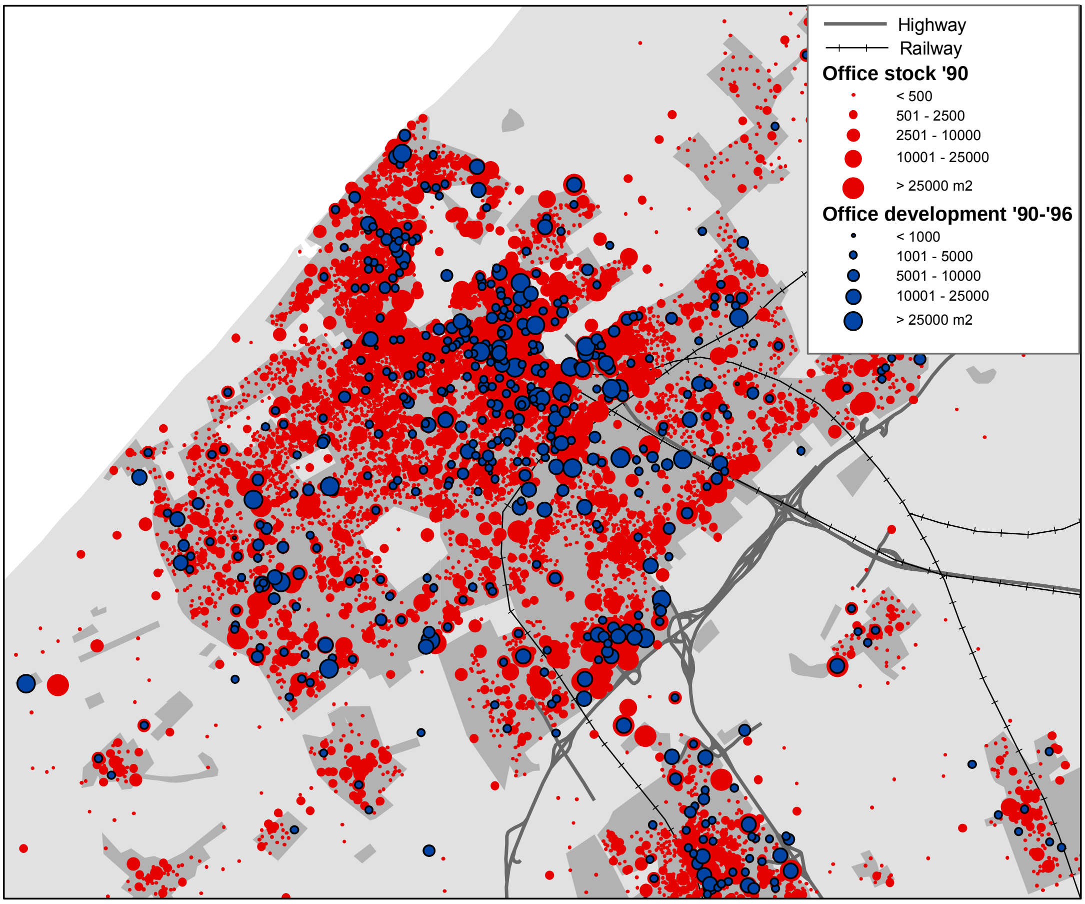

FIGURE 3 Scenario input for region of The Hague.

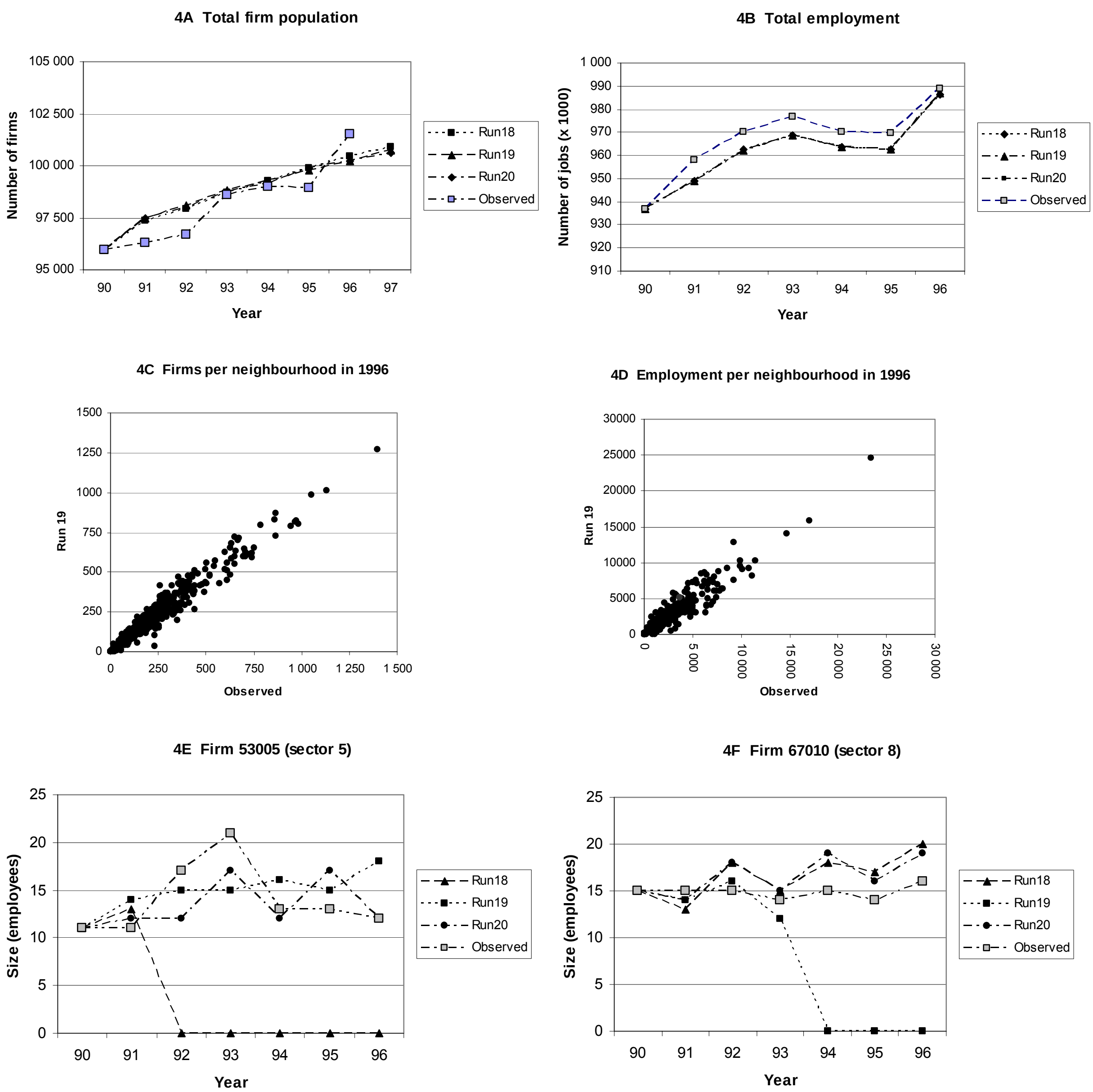

FIGURE 4 Simulation results.