SPATIO-TEMPORAL AGGREGATION EFFECTS AND PATH-DEPENDENCE IN A LAND-USE MICRO-SIMULATION SYSTEM

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Abstract

The aim of the present study is to investigate the effects of the unit of analysis, in time and space, in a land-use micro-simulation model, and to present a pilot model by adequately considering both these effects. A new residential micro-simulation model, which considers the flexibility of the simulation time step length and spatial disaggregation, was developed by introducing a survival duration analysis. After the modeling concept, the basic structure of the model is shown, and the detailed designs of its sub-models are described. As a model application, a sensitive analysis of temporal and spatial aggregation was executed and discussed in a linear virtual city. Finally, the stability of the simulation results over the iteration is examined using the error by number of simulations.

Keywords: Land-use model; Micro-simulation; Multi-agent; Spatial and temporal aggregation; Path-dependability
Topic Area: F1 Transport and Spatial Development

1. Introduction

It is widely recognized that land-use and transportation have a strong interaction, and many integrated land-use/transportation models have been developed with the aim of travel demand forecasting and/or transportation project evaluation (Wegener 1999). In recent years, popular models have been those that operate a transport and a land-use model one after the other at a short time step, and predict the future in quasi-dynamics, for instance, TRANUS (ODOT 2001), DELTA-START (Simmonds 1999), and MUSSA-ESTRAUS (Martinez 1996). However, most of the urban models are built based on the equilibrium theory for aggregated locators and zones. In the case of the transportation model, the equilibrium assumption can be generally accepted, because in such a situation short-time equilibrium can be realized shortly after a disturbance in the transportation market. However, land use gradually and continuously changes after the transportation project. In addition, demographic and economic structures are also continuously changing with time. Moreover, these changes are path-dependant. Therefore, these facts do not satisfy the assumptions of the equilibrium model framework. In this respect, the traditional equilibrium approach used in the land-use model has a critical fault.

On the other hand, the micro-simulation model expresses the transition in an entire city as a result of each activity's behavior. It offers a high possibility of providing a more realistic forecast, since its functions include accounting the detailed attributes of each activity, describing the sufficient interactions between them, and expressing the complexity of the urban transition, which is a result of the path-dependability of locators. In recent years, some projects on the land-use/transportation micro-simulation model are being conducted in Europe and the United States. However, there are some problems in the existing studies, in which the disaggregative representation is limited to the locator as follows:

(1) None of these models considers "spatial" disaggregation, which is the object of location. Furthermore, the effect of spatial aggregation on prediction has not been investigated.

(2) Little is known about the logical conformity of the simulation time step in model dynamics.

(3) The simulation results are stochastic. Therefore, they will differ from each other even if the simulation conditions are exactly the same. However, few substantial discussions on the interpretation of the simulation results have been conducted.

The aim of the present study is to investigate the effects of the unit of analysis, in time and space, in a land-use micro-simulation model, and to present a pilot model by adequately considering both these effects. In this paper, after the modeling concept, the basic structure of a new residential micro-simulation model that considers temporal and spatial disaggregation is shown, and the detailed designs of its sub-models are described. The model has a function to alleviate the distortion, which the length of time step generates, by introducing a hazard model. Secondly, parameters of the sub-models are estimated, and set using statistical survey data. Finally, essential performance is examined by a sensitivity analysis, and discussed in relation to temporal and spatial aggregation.

2. Residential micro-simulation model

2.1 Modeling concept

In recent years, micro-simulation models based on land-use/transportation models have been developed, for example, URBANSIM (Waddell 1998, 2000, 2001), IRPUD (Wegener 1996), TLUMIP2 (Hunt 2001), ILUTE (Miller 2002), and so on. Since such experimental models have only recently been developed, their performance, characteristics, and capability in terms of land-use/transportation modeling has not been sufficiently discussed.

Their simulation time steps are generally set at one year, and a quasi-dynamic structure is adopted. It is assumed that locators select their location under a long-term future plan. However, validity of the fixed time step set up in these models is not clarified, and it cannot be confirmed whether the occurrence of an event is adequately calibrated to time procession. Although micro-simulation offers the possibility of a detailed description of the interactions during activities and the price adjustment process, which cannot be described in the equilibrium model, it cannot be said whether the existing model, which conducts quasi-dynamic simulation under a fixed time step, adequately utilizes this ability.

Moreover, the unit of analysis, in space, in these models is spatially aggregated to some extent, while locators are represented disaggregatively. The spatial aggregation level ranges from a large-scale zone to 30 m grid cell, depending on data availability, however, its validity is not investigated. While expressing the location competition, a mismatch between the aggregated space, which is the object of location, and the locator may give rise to distortion.

Therefore, it is necessary to clarify the logical conformity in model dynamics based on an analysis which explicitly considers the time element to the event probability and the spatial aggregation effect to the simulation results. For these reasons, this study proposes a new residential micro-simulation model considering a disaggregative unit of analysis, in time and space, in order to investigate these effects on the simulation results.

2.2 Structure of the model

An outline of the model is shown in Fig. 1. In this model, non-residential, transport, and spatial development are not considered modeling objects given that these do not directly affect the residential location choice, and are exogenously represented as commercial facility, transportation accessibility, and housing attribute, respectively. In each simulation time step, which is exogenously set by the model user, the household and member transition model, moving model, dwelling type and location choice model, and land price model are operated in that order, and the household distribution for the next period is outputted.

The model dynamics and structure are shown in Fig. 2. In this study, a point in time and period are represented by t and T, respectively. Residential duration of household T_h, age of household member T_j, and simulation time step ΔT, are independent temporal elements. The probabilities of household and member attribute transition, and moving occurrence are defined as the function of T_h, T_j, and ΔT, using the survival duration analysis method.

In each simulation time step, first, the household and member transition model is operated. This submodel describes six individual attribute transitions, which occur in each household member, namely, aging, death, school or employment state transition, leaving, marriage, and birth. As a result, the household attribute transitions, such as income, number of household members, and generation of new household, which consists of leaving household member, are represented. Second, the moving model is operated. This submodel describes the occurrence of relocation in each household. A household associated with a change in location is listed as a relocated household. On the other hand, a household that does not undergo a change in location is retained in the household distribution database for the next period. Third, in the dwelling type and location choice model, households associated with a change in location and newly generated households choose a dwelling and location for next period. In the case of the foregoing three submodels, simulations are performed using the Monte Carlo technique. Finally, the land price of each residence, for the next period, is calculated using the land price model. This is described by the Hednic regression model. By performing the above mentioned four steps, the database for the next period is outputted.

2.3 Definition of probability considering the flexibility of simulation time step

Here, the event occurrence probability considering ΔT is defined by introducing a hazard model, which is used in the survival duration analysis. The survival and hazard functions are used as mathematical tools to describe the survival duration distribution. Defining the survival duration T as the positive random variable, the survival function $S(t)$ means the probability that a random variable T will exceed at a certain point in time t. On the other hand, the hazard function $h(t)$ means the conditional probability at the next moment under the conditions of $t \leq T$. Therefore, the survival and the hazard functions are expressed by equations (1) and (2), respectively.

$$S(t) = prob(T \geq t) \tag{1}$$

$$\begin{aligned} h(t) &= \lim_{\Delta t \to 0} \frac{prob\,(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t} = \lim_{\Delta t \to 0} \frac{S(t) - S(t + \Delta t)}{\Delta t \cdot S(t)} = -\frac{dS(t)}{dt} \cdot \frac{1}{S(t)} \\ &= -\frac{d(\log S(t))}{dt} \quad \Leftrightarrow \; S(t) = \exp\left(\int_0^t h(u)du \right) \end{aligned} \tag{2}$$

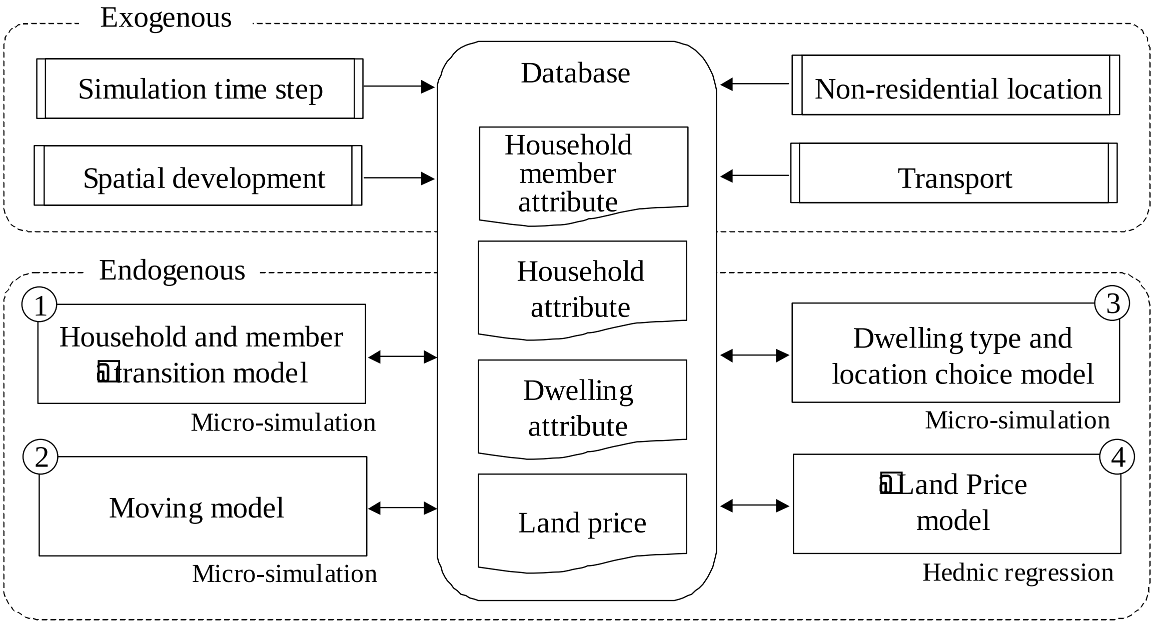

Figure 1. Model outline

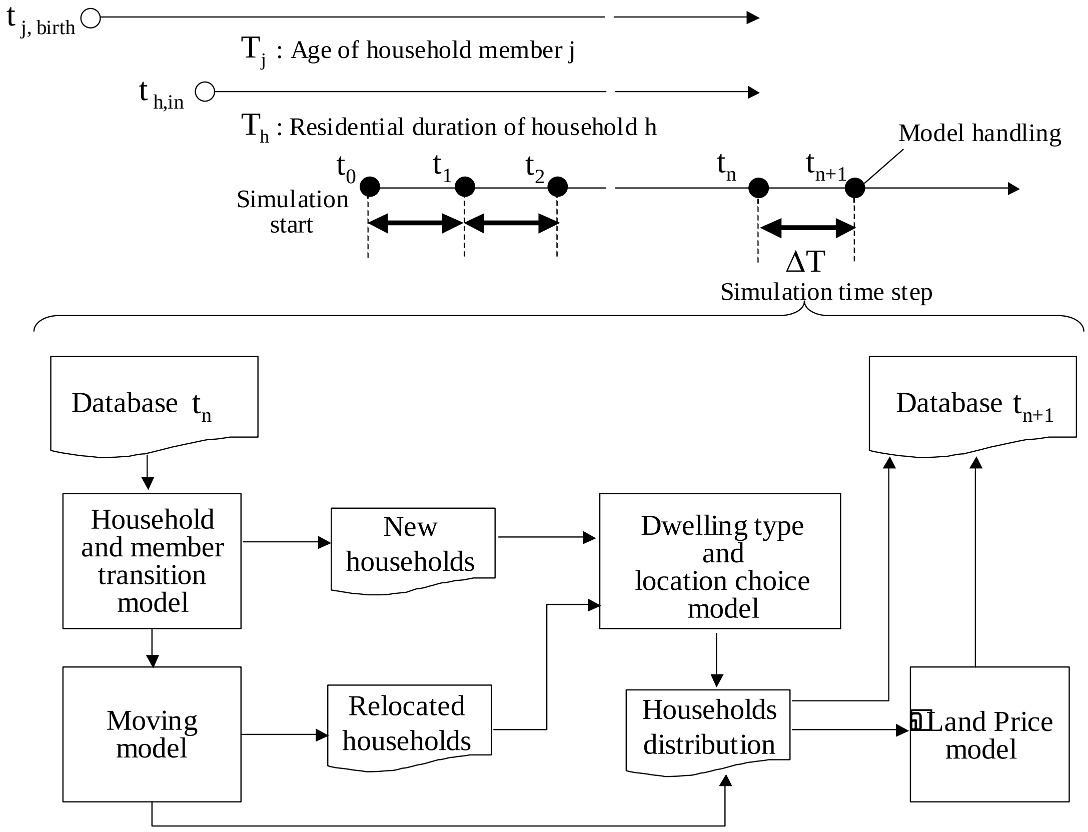

Figure 2. Model dynamics and structure

The density function $f(t)$ is given by equation (3) as the product of the probability that a event will not occur until a point in time t, and the probability that a event will occur at time t on the condition that it has not yet occurred.

$$f(t) = S(t) \cdot h(t) \tag{3}$$

Integration of the density function introduces the cumulative function $F(t)$, as shown in equation (4).

$$F(t) = \int_0^t f(s)ds = prob(T \le t) \tag{4}$$

It represents the probability that a event will occur by a point in time t, and the following relationship is materialized with $S(t)$.

$$S(t) = 1 - F(t) = \int_t^\infty f(s)ds = prob(T > t) \tag{5}$$

The probability defined in this study is the conditional probability that an event will occur until a point in time $t_n + \Delta T$ on the condition that it has not occurred until a point in time t_n. Defining T_k as the survival duration of activity k at a point in time t_n, the probability P' that an event will occur from t_n to $t_n + \Delta T$ is shown by equation (6).

$$P'(T_k, \Delta T) = F(T_k + \Delta T) - F(T_k) \tag{6}$$

Accordingly, the conditional probability P is represented as equation (7).

$$P(T_k, \Delta T) = \frac{F(T_k + \Delta T) - F(T_k)}{1 - F(T_k)} = 1 - \frac{1 - F(T_k + \Delta T)}{1 - F(T_k)} = 1 - \frac{S(T_k + \Delta T)}{S(T_k)} \tag{7}$$

It is evident that the event occurrence probability rises due to the condition that the event has not occurred in time T_k.

2.4 Household and member transition model

The household location simulation cannot be modeled over a long period without considering life cycle progress. It is essential to change the attributes of households and members along with the procession of the simulation step, and to create a disaggregate database in the future. Therefore, in this study, a method for expressing individual attribute transitions, which occur in each household member, and the resulting household attribute transitions are developed.

This submodel describes the transitions of the following six attributes, in order, for each household member. Except for aging, the Monte Carlo simulation is executed to represent occurrence using the transition probability of each attribute that corresponds to equation (7), derived from the standard cumulative probability calculated in demographical statistics.

a) Aging

Aging is represented by adding ΔT to the individual's age. The transition probabilities of the other attributes are given by their updated ages and sex.

b) Death

The standard cumulative probability is calculated from the annual death data by age and sex. The maximum lifespan is set at 94 years, regardless of sex. The dead are deleted from the database, and are not dealt with either in the current simulation step or thereafter.

c) School or employment state

All household members aged 6 to 18 years are considered as school children. In this simulation step, children whose age exceeds 18 years, choose their future course, after high school graduation from going to college, getting a job, or otherwise, in accordance with the rate obtained from basic school surveys. College students, whose age exceeds 22 years, stochastically decide their employment after college graduation based on the employment rate. The employment states of other household members are given based on the employment rate by age and sex, regardless of ΔT.

d)Leaving

The event of leaving the household resulting from college education, change of employee state, marriage, and so on is considered for all unmarried household members. The standard cumulative probability is calculated from the leaving rate by age and sex. The leaving probability of women is calculated without considering marriage, since it is assumed that in the event of a marriage the man takes his wife to his household. The leaving household member forms a new, single household, which is added to the list of new households. Here, the constraint that the leaving event does not occur in single, fatherless, and motherless households is considered.

e) Marriage

The conditional standard cumulative probability is calculated from the marriage rate by age and sex, for all unmarried and non-school household members. Divorce is not considered, and remarriage is considered only in the case of widowed household members. In the case of a man, the data of a woman of the same age is added to his household, whereas in the case of a woman, her data is deleted from the belonging household, since it is assumed that the woman moves to the household of the man in the event of a marriage.

f) Birth

For a married woman the occurrence of a birth event is expressed once at each simulation time step. The standard cumulative childbirth probability is calculated from the annual birth rate by age and her parity. The data of the new household member, whose age in years is zero and sex is randomly given by the same probabilities, is added to her household.

After updating the household member database as mentioned above, these are aggregated by the belonging household, and household attributes such as number of members and workers, and householder age are updated. Household income, which is given exogenously by the number of members and workers, is also updated.

2.5 Moving model

In the moving model, the choice whether each household relocates to another dwelling or continues residing in the present dwelling is expressed considering the attributes of household and dwelling. Moreover, it includes an allowance for moving possibility being restrained by household income. The moving probability, which corresponds to equation (7), is derived from the hazard model as a function of T_h. Here, the accelerated lifetime model, which assumes parametric distribution in baseline density function, is adopted. In this model, the survival time is described with the baseline survival time and the covariates which rescale time directly in a baseline survival function, which means a survival function when all covariates are zero. In the case of residential duration T_h, it is represented as

$$\log T_h = V_{hi} + \log T_0 \Leftrightarrow T_h = \exp(V_{hi}) \cdot T_0 \qquad (8)$$

where, V_{hi} is the residential environment covariate function of household h in dwelling i and T_0 is the residential duration of baseline household $(V_{h,i} = 0)$. The residential environment covariate function V_{hi} is given by equations (9) and (10),

$$V_{hi} = \alpha X_{hi} + \beta z_h \tag{9}$$

$$y_h = r_i q_i + z_h \tag{10}$$

where, X_{hi} is the covariate vector, z_h is the consumption of composite good, y_h is the household income, r_i is the unit floor price of dwelling i, q_i is the floor area of dwelling i, and α and β are parameters. Equation (10) represents the household income constraint. Consequently, the moving probability, P, is expressed as

$$P(T_h, V_{hi}, \Delta T) = \frac{F(T_h + \Delta T, V_{hi}) - F(T_h, V_{hi})}{1 - F(T_h, V_{hi})} = 1 - \frac{S(T_h + \Delta T, V_{hi})}{S(T_h, V_{hi})} \tag{11}$$

2.6 Dwelling type and location choice model

For the households associated with a change in location as described in the moving model and newly generated households in 2.4 d, dwelling type and location for the next period is determined by the Monte Carlo simulation, using logit type probability that considers the household and dwelling attributes. The residential utility of household h for dwelling i, U_{hi}, is expressed as

$$U_{hi} = \xi z_h + \zeta X'_{hi} \tag{12}$$

$$y_h = r_i q_i + z_h \tag{13}$$

where, X'_{hi} is the explanation variable vector, and ξ and ζ are parameters. The choice probability for dwelling i, P_{hi}, is given by equation (14),

$$P_{hi} = \frac{\exp U_{hi}}{\sum_{k=1}^{n_r^e} \exp U_{hk}} \tag{14}$$

where, n_r^e is the number of vacant dwellings. The households have complete information on all the vacant dwellings in the city at the starting point of each simulation time step, and stochastically choose the next dwelling from among them, considering the household and vacant dwelling attributes. The location competition is described by a simulation method that relocates households, which consist of moving and newly-generated households that are randomly sorted, and decides their location in turn. When location competition occurs for a moving household, relocation is considered impossible because the desired dwelling has already been occupied, and therefore, the present residence is retained. In the case of a newly-generated household, choice probabilities are recalculated for the vacant dwellings in turn, and the location choice is invariably achieved. In the case of the household that achieves relocation, the residence data is updated and the dwelling duration is set at an initial value of zero.

2.7 Land price model

The land price model describes the fluctuation in land price that is affected by the location density of the household. Fluctuation in land price causes fluctuation in the unit floor rent, and consequentially affects the probability of moving occurrence and dwelling choice. The land price of dwelling i, p_i, is defined by equation (15),

$$p_i = \gamma X_i + \lambda d_i \tag{15}$$

where, X_i is the explanation variable vector, d_i is the household density around dwelling i, and γ and λ are parameters. The unit floor price, r_i, (assuming 5% interest) is given as

$$r_i = 0.05 \cdot p_i \tag{16}$$

3. Model estimation result

3.1 Moving model

The residential environment covariate function V_{hi} in equation (9) is estimated using data obtained from the Residential Demand States Census in 1998. Data from the existing future definite plan for residential improvement is used in order to make the residential duration data. Households without a definite plan are right-censored samples, and those with one are non-censored samples. The log-likelihood results in each case, namely, log-logistic, Weibull, lognormal, and exponential were assumed in the baseline density function and are listed in Table 1. In this study, log-logistic was adopted considering its handling facility, although both lognormal and log-logistic give better results. The density function of log-logistic is given by equations (17), (18), and (19),

$$f(t) = \frac{\gamma \lambda t^{\gamma-1}}{(1+\lambda t^{\gamma})^2} \tag{17}$$

$$\gamma = 1/\sigma \tag{18}$$

$$\lambda = \exp(-\mu/\sigma) \tag{19}$$

where, shape parameters γ and λ are defined using intercept μ and scale σ of $\log T_0$, respectively. The estimated coefficients of the moving model for log-logistic are listed in Table 2.

3.2 Dwelling type and location choice model

The residential utility function U_{hi} in equation (12) is estimated using data obtained from a questionnaire on the actual condition of transportation utilization in 1996. The estimation results are listed in Table 3.

3.3 Land price model

The land price model expressed in equation (15) is estimated using data obtained from the Land Price Survey in 1998, the Basic Planning Survey in 1998, and the Person Trip Survey in 1992. The estimation results are listed in Table 4, where the commercial facility is given by the number of commercial buildings per unit land area, and the household density is calculated in the surrounding 1 km^2 area.

4. Execution of the residential micro-simulation

4.1 Simulation setting

By applying the developed model, the household relocation micro-simulation is executed in the virtual city shown in Fig. 3. The virtual city is set as a linear city with an extent of 10 km, in which two types of dwelling, own-detached and rent-apartment, exist at intervals of 20 m, respectively. There are 500 dwellings of each type, therefore, a total of 1,000 dwellings exist. Migration in and out of the city is not considered. Moreover, new residential development is also not considered, and the amount and quality of each dwelling is not changed. The commercial facility I_i is given by equation (20), which is estimated from the Basic Planning Survey in 1998,

$$I_i = \underset{(14.91)}{1401.8}\frac{1}{x_i} - \underset{(1.78)}{90.36} \qquad (20)$$

where, x_i is the distance from CBD of dwelling i, and parenthetic values are t-statistics. Accessibility to CBD, which represents the transport condition, is given by equation (21), which is estimated from the Person Trip Survey in 1992.

$$A_i = \underset{(19.95)}{3.80}(\ln x_i)^2 + \underset{(26.37)}{20.56} \qquad (21)$$

Household Density is calculated from the number of households located 500 m from each dwelling on both sides of the linear virtual city. Since its scale differs from that of the household density used in parameter estimation, a correction coefficient is considered, which is calculated from a proportion of the total population in the virtual city, and in estimation data. At the beginning of the simulation, the total population is 1,000 and the total number of households is 500, which consist of married couples of 25 years old, who have lived alternately in each type of dwelling with a residential duration of 10 years. Analyses are executed from the results of 100 simulations spanning 60 years.

Table 1. Log-likelihood results

Log-logistic	-1976.7
Weibull	-1985.2
Lognormal	-1974.7
Exponential	-2024.7

Table 2. Estimation results of the moving model

Variable	Coefficient
Detached own house (dummy variable)	1.761**
Age of head over 60 (dummy variable)	0.640**
Age of head under 35 (dummy variable)	-0.942**
Floor area per household member	0.00449**
Composite goods consumption	-0.00058**
μ	2.865**
σ	0.665
Sample size	4611
Non-censored	694
Right-censored	3197

** : Significant at 1%

Table 3. Estimation results of the residential type and location choice model

Variables	Coefficient (t-statistics)
Age of head 30-44 for own-detached house (dummy variable)	0.901 (1.40)
Age of head 45-59 for own-detached house (dummy variable)	0.662 (1.03)
Age of head over 60 for own-detached house (dummy variable)	3.516 (3.96)
Floor area per household member	0.530×10^{-2} (0.96)
Accessibility to CBD	-0.0296 (-1.84)
Composite goods consumption	0.213×10^{-2} (0.54)
Sample size	102
Log-likelihood	-120.227
Likelihood ratio	0.14976

Table 4. Estimation results of the land price model

Variables	Coefficient (t-statistics)
Commercial facility	0.023 (21.1)
1/Distance from CBD	15.87 (3.62)
Household Density	0.47×10^{-3} (6.76)
Constant	2.34 (2.86)
Number of observations	1042
Multiple correlation coefficient	0.811
R^2	0.658

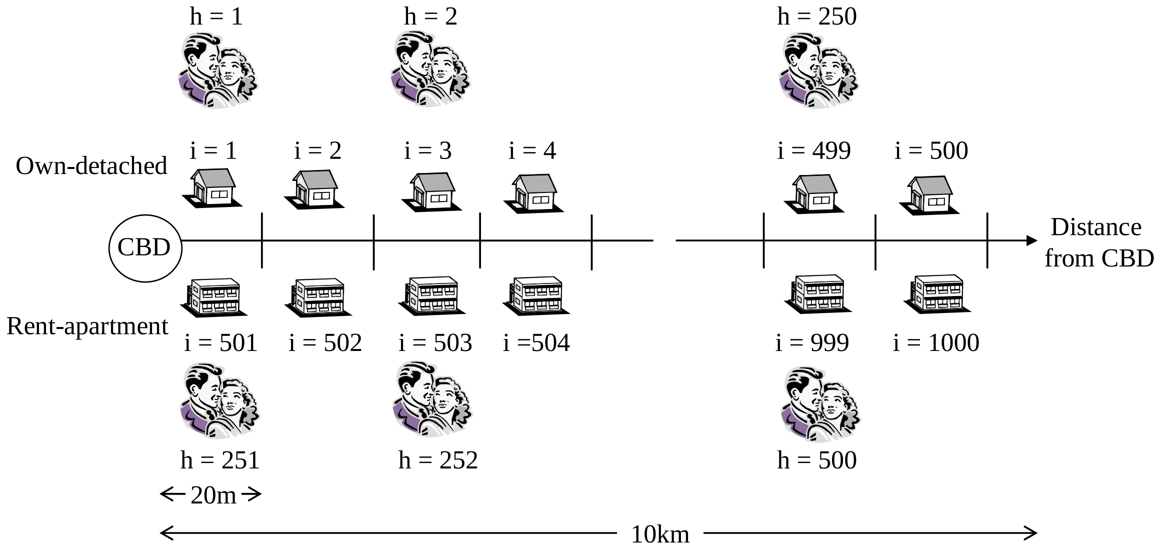

Figure 3. Virtual city

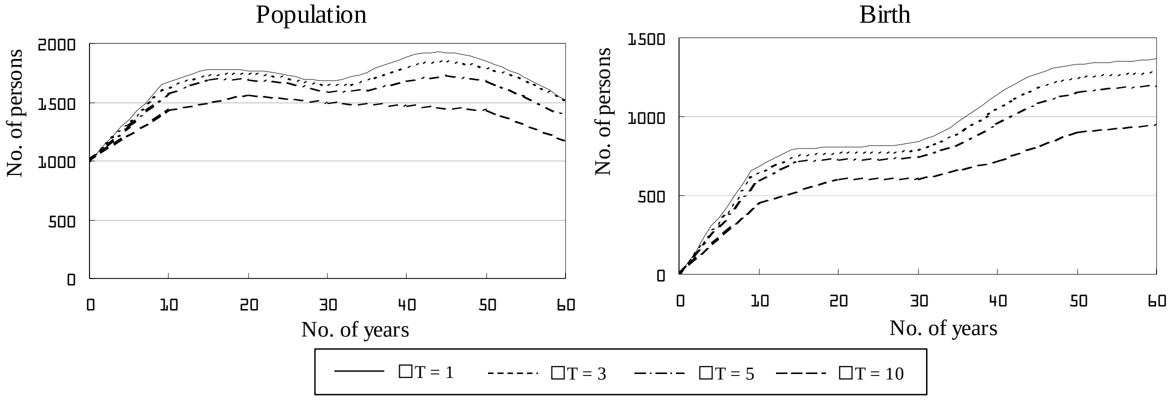

Figure 4. Effect of simulation time step length on population and birth (appropriate demographical transition probability analysis)

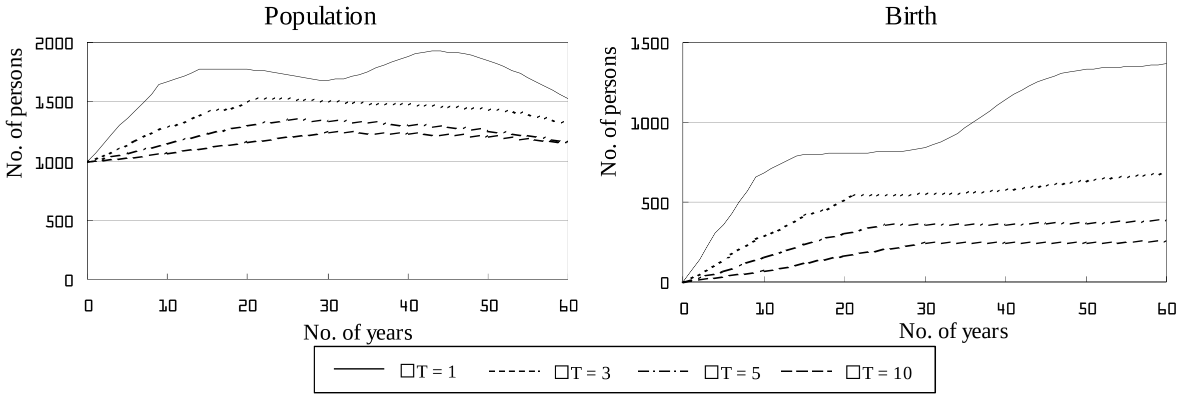

Figure 5. Effect of simulation time step length on population and birth (fixed demographical transition probability analysis)

4.2 Effect of simulation time step length

Figure 4 shows the transition of population and cumulative number of births, where the simulation time step ΔT is set at 1, 3, 5, and 10. Figure 5 shows similar results in the case where fixed demographic transition probabilities of $\Delta T = 1$ are given for all ΔT settings. Comparison of these results reveals that although similar results are obtained for each ΔT setting in Fig. 4, consistency across the simulation results is gradually lost with the time as shown in Fig. 5, since distortion of event occurrence appears with an increase in ΔT. Accordingly, the probability definition, considering ΔT, proposed in this study has a function to alleviate the distortion generated by the length of the simulation time step. However, population and birth are underestimated in the case where $\Delta T = 10$. This is because the birth event is expressed only once in each simulation time step. In the case where a comparatively long-term simulation time step is set up in the existing micro-simulation model with the quasi-dynamic structure, there is a limit to express the event which happens two or more times for a short period of time. This indicates that a more dynamic approach needs to be developed.

Figure 6 shows the cumulative number of relocated households achieved, and not achieved by location competition among them for each ΔT. The longer the simulation time step ΔT, the greater number of households fail to relocate due to location competition.

This is the reason why the interaction between activities and path-dependability is not represented under temporally aggregative treatment of household relocation, which occurs over a long period. It is also considered that our micro-simulation model has a setup limit in terms of simulation time step despite taking the variability of ΔT into consideration, and the quasi-dynamic approach does not have sufficient flexibility for temporal aggregation.

4.3 Effect of spatial aggregation

A simulation, in which three types of spatial aggregation levels 200 m, 400 m, and 1,000 m, are set, and the simulation time step $\Delta T = 1$, is executed. In each special aggregation, 10, 20, and 50 dwellings of two residential types are included in one zone, respectively, irrespective of location choice. Location competition will arise only when all the residences in a zone are occupied. Figure 7 shows the cumulative number of relocated households, achieved and not achieved, by location competition among them for each special aggregation level and disaggregation case. With regard to the transition of relocated households, the results in every spatial aggregation case are underestimated by approximately 20% as compared to the disaggregation case. This is because relocation to a desirable dwelling is achieved since location competition in the former part of the simulation period is difficult, and as a result moving occurrence is restrained. However, in the cases where more than 400 m aggregation, households, whose relocation are not achieved, increase rapidly in the latter part of the simulation period. This is because there are some zones where most of the relocations are concentrated, which means that all the dwellings are occupied and additional relocation is impossible. Although this is because the housing supply corresponding to the increase in location demand is not represented in our model, excessive spatial aggregation may cause distortion, since location competition is not consistently evaluated with time. Therefore, it is necessary to critically inspect the effect of the spatial aggregation on the micro-simulation results.

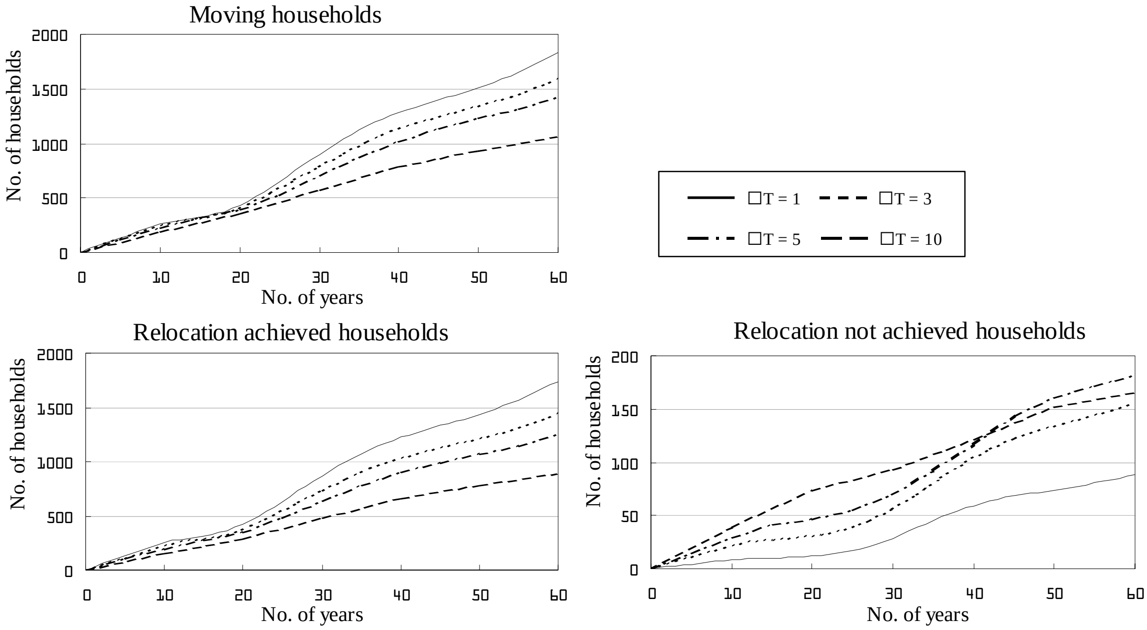

Figure 6. Effect of simulation time step length on moving and relocation

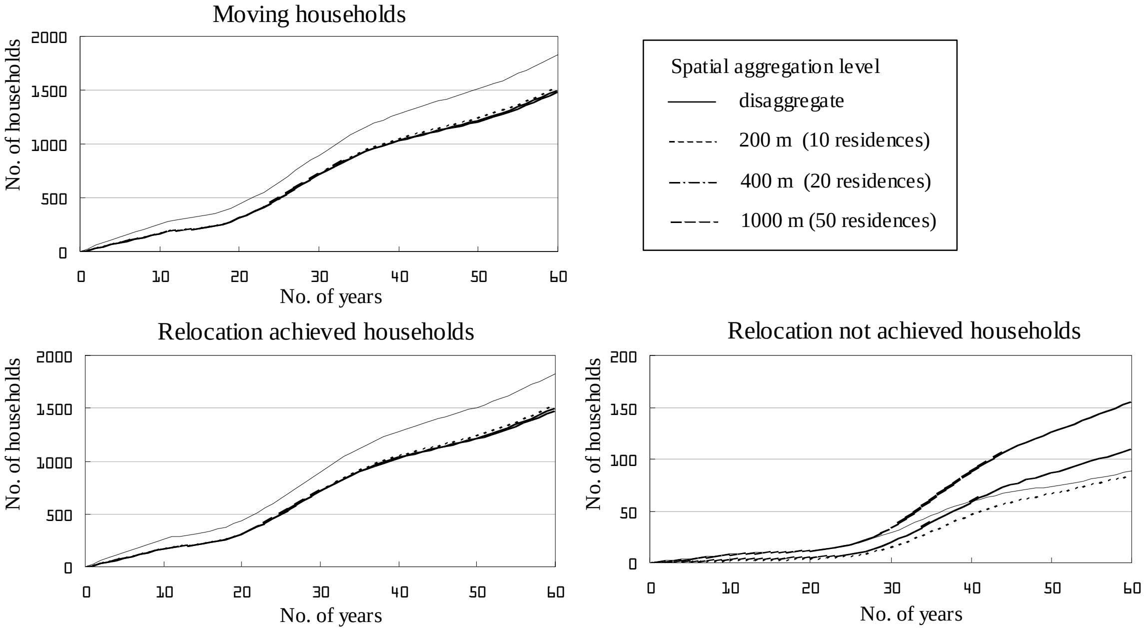

Figure 7. Effect of spatial aggregation on moving and relocation

4.4 Simulation performance

The stability of the simulation results over the iteration is examined using the error by number of simulations n, σ_n, which is defined by equation (22).

$$\sigma_n = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X_i - \overline{X}_n)^2} \qquad (22)$$

where, X is the examined variable, and $\overline{X}_n$ is the average of the examined variables in n simulations. Figure 8 shows the error of own-detached dwelling utility for temporal and spatial aggregation, which is averaged in the virtual city at the end of the simulation. It appears that the result becomes stable after about 80 iterations, though there is a tendency that a large number of simulations are needed for stabilization as the simulation time step is longer. In terms of spatial aggregation, the result becomes stable after about 50 iterations.

The calculation time for each simulation case, which is taken as 100 simulations spanning 60 years, is listed in Table 5. Although the calculation time is greatly reduced as the simulation time step length increases, it does not affect any spatial aggregation level. These simulations were executed in a relatively short time, even in the disaggregation case, it was approximately 40 minutes. However, if these simulations are extended to a real city in the future, it is predicted that the calculation time will increase exponentially with an increase in the concerned activities. Therefore, there are some future tasks involving the execution of a realistic simulation, such as the development of a simulation system in a distributed computer network environment.

5. Conclusions

In this study, a residential micro-simulation model, which considers the flexibility of the simulation time step length and spatial disaggregation, was developed in order to investigate the effect of the temporal and spatial aggregation. In this model, the event occurrence probability was defined by introducing a survival duration analysis. Moreover, a sensitive analysis of temporal and spatial aggregation was executed in the linear virtual city that was used as a model application. The results demonstrate the usefulness of our micro-simulation model for flexibility of the time element, and indicate the incidence of distortion in the existing quasi-dynamic approach. Furthermore, a potential problem of spatial aggregation, that is location competition is not evaluated consistently in the expression of residential location choice, was pointed out.

The future course of this study will involve the development of a dynamic micro-simulation model, which exploits the potential of the micro-simulation model, with additional functions such as a detailed description of interaction during the activities or the expression of the price determination mechanism. The meaning and applicability of the various prediction results, which are expressed under the path-dependability of locators, should also be examined for project evaluation. Moreover, long-term research should also include methods of building a real-size model from the viewpoint of data availability, database manageability, and computation capability of a large micro-simulation.

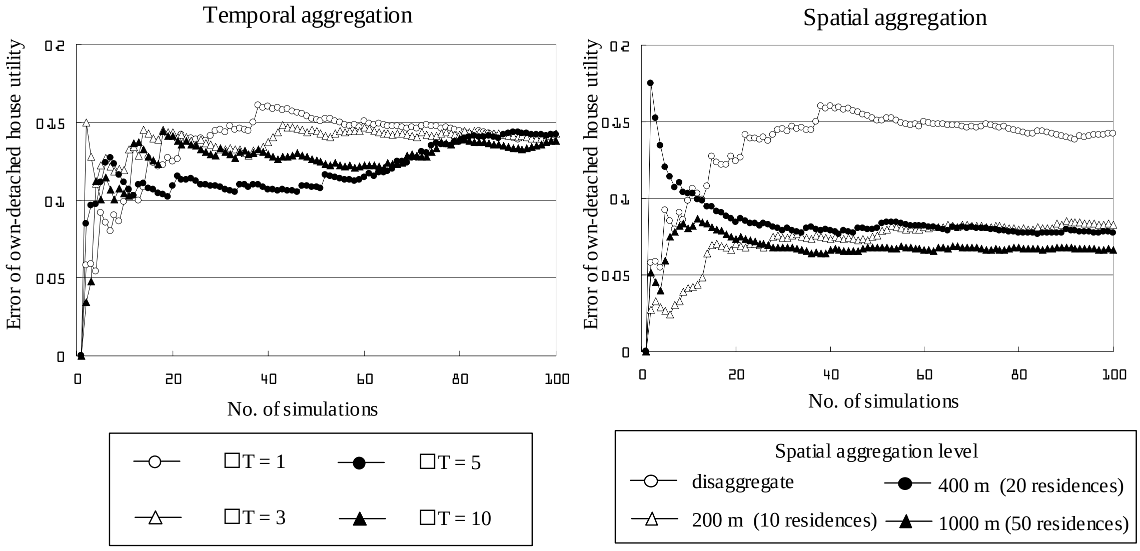

Figure 8. Stability of own-detached house utility error

Table 5. Calculation time

Time step	Spatial aggregation	Calculation time (sec)
$\Delta T = 1$	disaggregate	2383
$\Delta T = 3$	disaggregate	939
$\Delta T = 5$	disaggregate	728
$\Delta T = 10$	disaggregate	482
$\Delta T = 1$	200 m	2134
$\Delta T = 1$	400 m	2123
$\Delta T = 1$	1000 m	2183

Specs : Gateway G7-500, CPU/Intel Pentium 500MHz, RAM/255MB, HD/40GB

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