SPATIAL MICROSIMULATION MODELLING FOR ESTIMATING MACHIYA DEMOLITIONS AND THE PRESERVATION POLICY EFFECTS

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ABSTRACT:

Machiya is a traditional wooden townhouse built during the period between the Meiji era (1868-) and World War II. It is a core element of the historical landscape of Kyoto City, Japan. However, the number of machiyas has been falling last fifty years and thus, protecting them is regarded as an urgent policy task. Thus, the purpose of this study is to use a dynamic spatial microsimulation model called *MachiyaSim* to estimate machiya demolitions in the next 15 years. The results of this study are summarized as follows: (1) a synthetic microdata set of machiya residents were constructed by combining multiple datasets in the manner which the sums of the synthetic microdata set agrees with those of the census datasets. (2) Decision making units such as individuals, households and machiyas can be modelled in the same way they exist and behave in the real world by using object-oriented modelling. (3) The results of simulations show that, in the next 15 years, only 67.3% of machiyas will be preserved and aging of the residents will continue. On the other hand, when a comprehensive preservation policy is implemented, 82.5% of machiyas can be protected. The application of MachiyaSim is useful for understanding the process of machiya demolitions and run what-if simulations based on the preservation policies. (4) The results of the simulations are displayed in the forms of maps and charts in real-time via a graphical user interface.

1. INTRODUCTION

Machiya is a traditional wooden townhouse mainly built during the period between the Meiji era (1868-) and World War II. These wooden houses characterize the historical landscape of Kyoto City, Japan. However, the number of machiyas has been falling last fifty years. According to the recent surveys conducted by Yano et al. (2006), the number of machiyas decreased from 28,000 in 1998 to 24,000 in 2004 in the central part of Kyoto City. Therefore, protecting machiyas is an urgent policy task.

To estimate machiya demolitions, using a spatial microsimulation is beneficial in two ways:

First, individual-based simulation approaches including microsimulation model are useful to understand complex and dynamic socio-economic phenomena (Gilbert and Troitzsch, 1999). For example, Ballas et al. (2006) estimate job losses and analyse the related or multiplier effects on socio-economic status of population by using a spatial microsimulation. It is reported that machiya demolitions were occurred in relation with (1) deterioration of the exterior conditions of machiyas, (2) demands for high-rise buildings, (3) deterioration of neighbourhood environments for living in a machiya along with the demolitions, and (4) change of generation because most of machiyas are reaching a time of replacement and the structure and interior are less favourable for younger generations (Hashimoto et al., 2001; Hanaoka et al., 2009). These factors contribute to machiya demolitions individually while they are interacting with each other. Therefore, using a spatial microsimulation approach allows us to model behaviour and interactions of each of machiyas, persons and households more specifically.

Second, a spatial microsimulation is able to generate a synthetic microdata set by combining multiple aggregated datasets (Williamson et al., 1998). Since there is no microdata set of machiya residents available, a synthetic microdata generation allows understanding both their demographic attributes and locations in details.

Therefore, the purpose of this study is to construct a dynamic spatial microsimulation model called MachiyaSim to predict machiya demolitions in the next 15 years in order to provide quantitative information about the number of machiya surviving and socio-economic impacts on machiya residents by introducing machiya conservation policy.

2. SPECIFICATION OF MACHIYASIM

2.1 Datasets

The Machiya Survey in 1995-98 and 2003-04 are used to understand machiyas and the residents. This survey consists of an exterior survey and the resident survey. In the exterior survey, location, type, traditional elements, physical condition and façade condition were examined. In the resident survey, both face data (# of household members, age of household head, and household type) and attitude toward machiya preservation (wants of rebuild, # of repairs in the last 5 years, a type of building after demolition) were surveyed. The Population

Census of Japan in 2000 and Samples of the Person-Trip Survey (PT) in 2000 are used to create a baseline microdata set of machiya residents.

The procedure to construct MachiyaSim consists of four major steps as follows: (1) generation of a synthetic microdata set of households living in machiyas, (2) design of simulation components, (3) model validation, and (4) simulations for evaluating alternatives of machiya conservation policies.

2.2 Generation of a synthetic microdata set

A synthetic microdata set is generated by combining multiple tables and an available microdata set when an suitable microdata set is not surveyed. In MachiyaSim, a procedure of generating a synthetic microdata set consists of three major steps: (a) generation of a synthetic microdata set of households living in Kyoto City, (b) estimation of a household head from household members, and (c) determination of whether they live in a machiya (Figure 1).

First, a simulated annealing algorithms is used to construct a synthetic microdata set of all households living in Kyoto City. This method allows finding the most fitted set of samples from the PT survey against census table at a small area level. Three census tables: (a) households by family type, (b) households by household size, and (c) population by age group and industry at the small area level are included as a constraint.

Second, a household head is chosen from members of a household by using a Monte-Carlo simulation. Conditional probabilities of being a household head for each member are estimated from a census table of households (household head and family type).

Third, to determine whether a household lives in a machiya or not, probabilities of living in machiyas are calculated by age group of household heads. Thereafter, a Monte-Carlo simulation is applied to decide machiya living and allocate households to machiyas.

2.3 Design of simulation components

MachiyaSim is coded based on AnyLogic5.5, which is an integrated development environment for an agent-based modelling developed by XJ Technologies Company LTD. In MachiyaSim, persons, households and machiyas are defined as objects. Properties and methods of the objects are presented along with a relationship among the objects in Figure 2.

Demographic events such as aging, birth, death, leaving home and marriage for a person object, move-out/in and separation of members for a household object are considered. The parameters of the demographic changes are estimated from Vital Statistic in Japan. Transitions of physical and façade conditions of machiyas depend on time since the last repair and/or vacancy. Machiya demolitions are estimated by a logistic regression model which includes a physical condition, traditional façade condition, height zoning, distance from the nearest road, total area of machiyas within 50m radius as independent variables. Total area of machiya within 50m is included to consider neighbourhood effects of machiya demolitions identified in Hanaoka et al. (2009). Details of the simulation components are discussed in Hanaoka (2009).

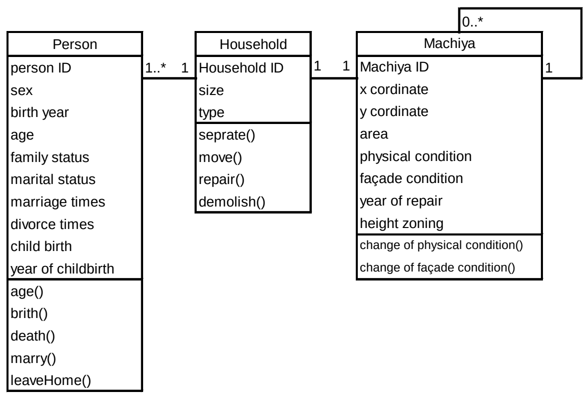

Figure 2. Class diagram of MachiyaSim

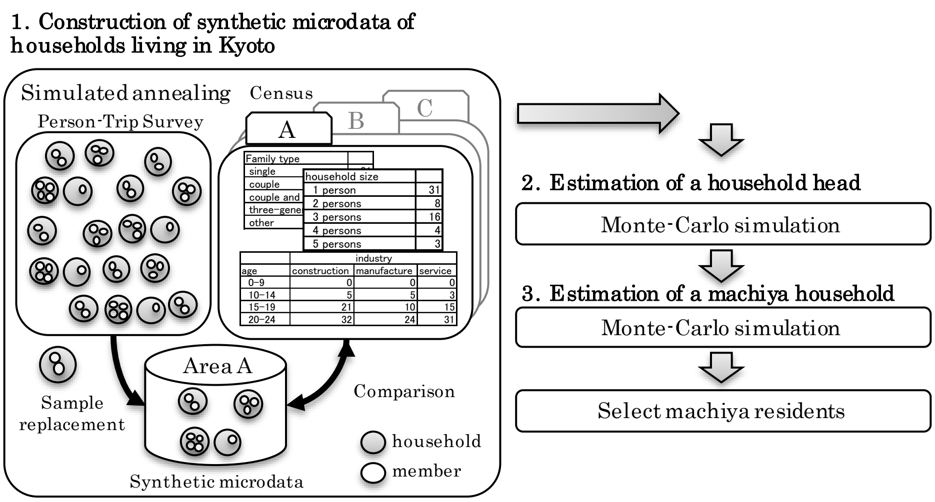

Figure 1. Procedure of constructing a synthetic microdata set

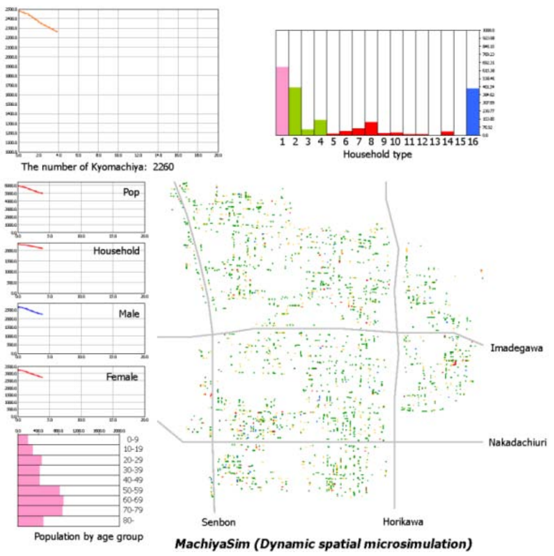

Figure 3. GUI for MachiyaSim

A graphical user interface shown in Figure 3 is incorporated in MachiyaSim to display simulations in real time. A spatial distribution of machiyas painted according to a physical condition is shown in a map at the centre. Bar and line graphs display population transitions and compositions.

3. SIMULATIONS

3.1 Study area (Nishijin district)

Nishijin district is selected as study area (Figure 4) since it is one of the historical centres of Kyoto City and transformations from machiyas to high-rise accommodation were observed (Fujitsuka, 2004). It is reported that there were 2,400 machiyas surviving in 2004.

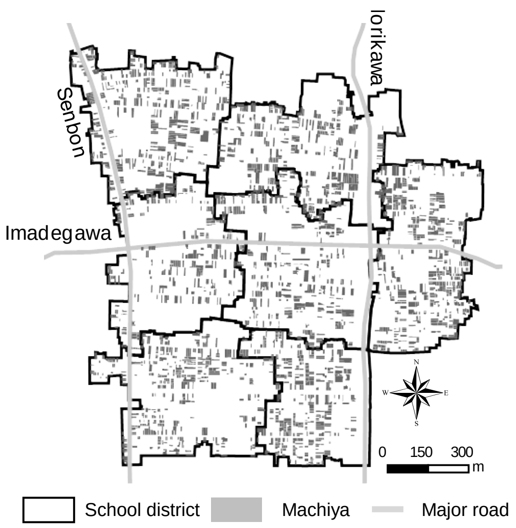

Figure 4. Study area (the spatial distribution of machiyas in 2004)

3.2 Model validation

Using a dataset of machiyas identified in the first survey and the same parameter setting mentioned in Section 2.2, the demolitions of machiyas from 1998 to 2004 are simulated for a model validation. The average numbers of surviving machiyas by school district are estimated based on 100 simulation runs of MachiyaSim. Table 1 shows the average of absolute values of error ratios are 2.3% and the observed and estimated frequencies of the machiyas by school district are highly correlated. Therefore, MachiyaSim can reproduce a similar spatial pattern as an observed one.

3.3 Scenario Analysis

Under Scenario A, the current status of demolition ratio is preserved. Under Scenario B and C, more financial supports for repair are introduced. Thus, probabilities of being machiya exterior conditions improved within 5 years increase. These probabilities are decided based on a question about willingness to repair in the machiya resident survey. They are 20.2% for Scenario C and 38.9% for Scenario D, respectively. Assumption of Scenario D and E is based on a new policy which supports for searching new residents. These policies increase the probabilities of move-in after a machiya is vacant within 5 years. These parameters are estimated based on the results of machiya resident survey. They are 43.3% for Scenario D and 59.4% for Scenario E. Under Scenario F, the tightest height zoning in status quo applies to whole study area. All parameters of height zoning in a logistic regression model are changed to one of the tightest zoning. Under Scenario G, all assumptions of Scenario C, E and F are simply applied.

Table 2 shows the average numbers of surviving machiyas in 100 simulation runs along with ratio of surviving machiyas and ratio against Scenario A (the status quo). Under the condition of scenario A. MachiyaSim estimates that, in the next 15 years, 67.3% of machiyas survives and the number of machiyas decreased from 2478 to 1667. On the contrary, with a financial support for repair, ratios of surviving machiyas are increased to 70.1% (Scenario B) and 74.4% (Scenario C) respectively. Further, with a support for searching new residents, the ratios slightly improves to 67.7% (Scenario D) and 68.1% (Scenario E). Tighter height zoning has also reduced the number of machiya demolitions and the ratio of surviving machiyas is 76.1%. Finally, under Scenario G, demolitions of machiyas are the most strongly restricted and the ratio of surviving machiyas is 76.1%. Comparing with the number of machiyas (2,478) in 2004, if the comprehensive policy will be implemented, 82.5% of machiyas can be protected on the contrary to 67.3% if the status quo will be preserved.

Furthermore, MachiyaSim can provide details of machiyas and population transitions by re-aggregating the output of the microdata set. Figure 5 shows the number of surviving machiyas decreased at the same time conditions of machiya and neighbourhood machiya (a ratio of machiyas' area within 50m radius) changed. The figure also shows the changes of a physical condition are slower under Scenario G compared with Scenario A. Figure 6 displays a population transition under Scenario A. The result indicates that aging of machiya resident continues and the population composition is changed drastically in coming 15 years. As such, MachiyaSim can provide useful information flexibly.

school district	observed (year 2004) [a]	estimated [b]	error ratio
Karaku	252 (89.0%)	251	0.00
Kenryu	444 (88.8%)	439	-0.01
Ogawa	350 (88.4%)	350	0.00
Seishin	425 (86.7%)	425	0.00
Nishiiin	351 (91.9%)	334	-0.05
Touen	295 (81.3%)	316	0.07
Juraku	362 (90.5%)	357	-0.01
			average of |error ratio|
total	2478(88.1%)	2,471	0.02

values in brackets: # of machiyas in 2004 / # of machiyas in 1998 * 100
error ratio = (b - a) / a

Table 1. The observed and estimated number of the surviving machiyas by school district

scenario	# of machiya	ratio of survived machiya	ratio against scenario A
A: keeping status quo	1,667	67.3%	100.0%
B: increase of repair ratio (low ratio)	1,738	70.1%	104.2%
C: increase of repair ratio (high ratio)	1,845	74.4%	110.7%
D: increase of move-in ratio (low ratio)	1,679	67.7%	100.7%
E: increase of move-in ratio (high ratio)	1,687	68.1%	101.2%
F: tighter height zoning	1,886	76.1%	113.1%
G: combination of C, E and F	2,045	82.5%	122.7%

ratio of survived machiya= # of machiya in 15 years / # of machiya in 2004 * 100

Table 2. Comparison of simulation results by scenario

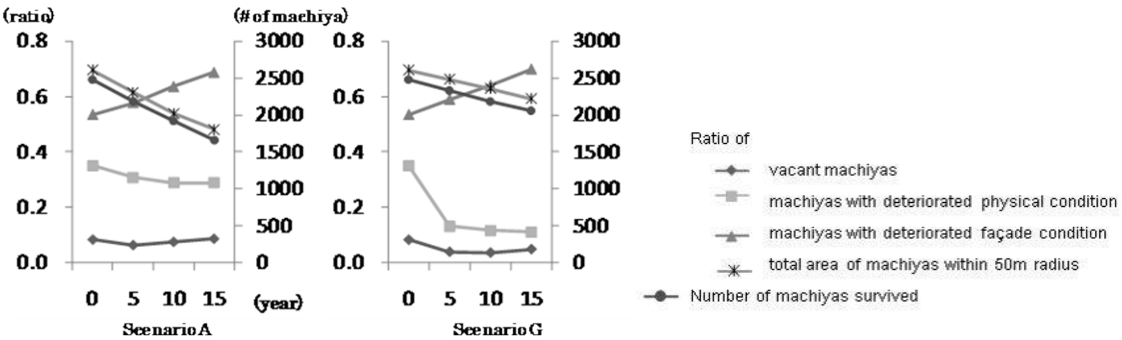

Figure 5. Machiya transition by condition (Scenario A & G)

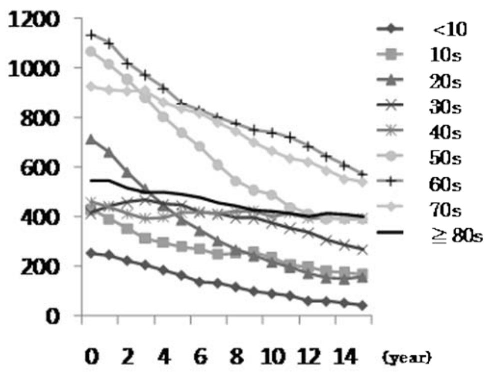

Figure 6. Population change by age group (Scenario A)

4. CONCLUSIONS

The results of this study are summarized as follows:

(1) A synthetic microdata set of machiya residents were generated by combining multiple existing datasets in the manner which the sums of the synthetic microdata set agree with those of the census datasets. The use of the synthetic microdata allows us to analyse detailed household demographics and the process of machiya demolitions both at individual level and at the small area level.

(2) Decision making units such as individuals, households and machiyas can be modelled in the same way they exist and behave in the real world by using object-oriented modelling. A merit of this approach is that objects are able to be updated dynamically in a relation with other agents.

(3) The results of simulations show that, in the next 15 years, only 67.3% of machiyas will be preserved and aging of the residents will continue. On the other hand, when a comprehensive preservation policy is implemented, 82.5% of machiyas can be protected. The application of MachiyaSim is useful to understand the process of machiya demolitions. Furthermore, what-if simulations based on machiya preservation policies help evaluating the effectiveness of policies quantitatively.

(4) The results of simulations such as changes of machiyas and residents are displayed in the forms of maps and charts in real-time via a graphical user interface. Such visual presentations would allow city planners and citizens to understand the results easily so as to encourage them to participate in forming preservation policies of machiyas.

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