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Household projection 2006/07 in Japan using a micro-simulation model

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By using a micro-simulation model named INAHSIM, we conducted household projection 2006/07 in Japan for the period of 2005-2050. Concerning the elderly, the model produces such outputs as a) the number of the elderly according to different living situation, b) the number of the elderly by physical condition x living situations, and c) the relative number of parents weighted by the number of brothers and sisters of children. Distribution of the elderly by physical condition and living arrangement is important in considering social support for the elderly, especially long-term care.

1. Introduction

The household is one of the most important statistical bases for policy formulation on health and welfare. Statistical information on households and families is still inadequate, although expanding recently, to understand the dynamic process of formation and dissolution of households and families in a systematic and coordinated way.

Dynamic micro-simulation is one method for household projections, in which the state of individuals is to change stochastically through vital and other events. Quite contrary to macro simulation, in which population is distributed deterministically and vital events occur to the population as a whole, occurrence and timing of various events in micro simulation are decided stochastically at the individual level. Static micro-simulation models are most frequently used to provide estimates of the immediate distributional impact of policy changes. Dynamic micro-simulation models often start from exactly the same cross-section sample surveys as static models. However, the individuals within the original microdata are then progressively moved forward through time; this is achieved by making major life events- such as death, marriage, divorce, fertility, education, labour force participation etc- happen to each individual, in accord with the probabilities of such events happening to real people within a particular country (Harding, 1996).

Dynamic micro-simulation models are widely used in Europe, Australia and North America for the evaluation and planning of many social policies (Inagaki, 2007). Information on each category of population can be tabulated flexibly without changing the main framework of the simulation. Dynamic micro-simulation method does have some drawbacks, including difficulties in obtaining the initial population and estimating the transition probabilities, and existence of sampling errors owing to the use of random numbers. Because of the consistency and flexibility, however, dynamic micro simulation is considered to be the most suitable method to observe dynamic evolution of households and families and to forecast their future trends (Fukawa, 1995). While most micro-simulation models developed to date have focused on the household sector, a number have been created which simulate the behaviour of business firms, rather than individuals or households (Harding, 1996).

INAHSIM (Integrated Analytical Model for Household Simulation) is a dynamic micro simulation model, which was first developed in 1984-85 in Japan by using actual initial population derived from a household survey and a set of transition probabilities derived from population census, vital statistics and several national sample surveys (Aoi et al, 1986). Among several attempts to improve the simulation model since 1985, a new application of the model has been made in 1993-94, which we call as 1994 Simulations. Characteristic features of 1994 Simulation were: a) the initial population was formed by using the INAHSIM model itself; and b) the dynamic transition of household types was particularly focused upon. The 2004 Simulation improved the creation of the Initial Population further and added the physical condition of the elderly in the model. The main purpose of INAHSIM was to prepare projections to get information on the future number and composition of households, and to analyze households and families in terms of dynamic transition of household types, family systems, etc.

Events contained in this model include not only such vital events as birth, death, marriage, divorce, and changes of household situations generated by them, but also separation from and return to original household, reuniting of widowed or divorced persons to the parent's household, and merger of aged parent(s) to the child's household (Note 1). The death rate is given by age and sex for those who are less than 65 years old, but it is determined by transition probability which is given by age, sex, and physical condition for those who are 65 years old or over. Separation from original household means here that the married or unmarried individual separates from his/her original household temporarily and newly forms a one-person household. Return to original household means just the opposite process of separation. We employ four kinds of household merger: (a) Co-resident rate of adult child with parents upon marriage, (b) Reuniting rate of adult child to the parent's household upon becoming widowed, (c) Reuniting rate of adult child to the parent's household upon divorce, and (d) merger rate of aged parent(s) with child generation by marital status, average age and physical condition of aged parent(s). The operation of each event is done once a year, and the order of the operation is as follows: marriage, birth, death, divorce, separation, return, and merger of aged parents. Reuniting of widowed or divorced to the parent's household is included in the operation of death or divorce respectively.

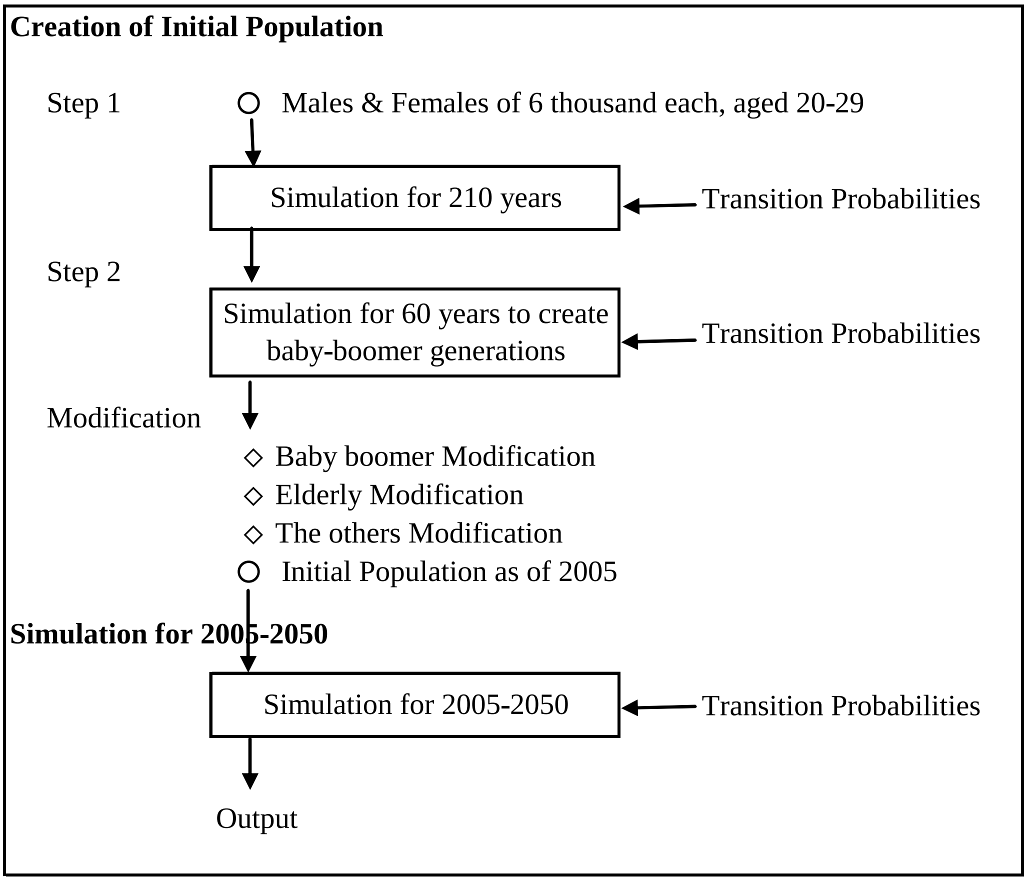
2. Framework of the 2006/07 Simulation

Observing the basic framework of 2004 Simulation, this 2006/07 Simulation has the following characteristics: a) the initial population was formed by using INAHSIM model itself; b) the physical condition of the elderly is related to the data of the Long-term Care Insurance (LCI); c) institutions are included in the model as a possible option for the elderly to move to. Whether a person moves to an institution or not depends on age, marital status, and physical condition of the elderly.

(1) Initial Population

Preparation of initial population was done by three steps as shown in **Fig. 1**. First, a group of males and females of 6,000 each, aged 20-29 according to age distribution in 2005, was created and thrown into the model. A simulation was executed for 210 years in order to obtain a stable state, using a set of transition probabilities prepared for this process. Next in

Fig. 1 Flow chart of INAHSIM 2006/07 Simulation



Step 2, baby-boomer generations were created using a specific set of transition probabilities. The final state of this second step, which was shown at the "Step 2" column of **Table**

1, was subject to modifications. Three modifications were done at this step in order to obtain such an initial population as reflected the age and household structure of the actual population in 2005. Baby-boomer modification was still necessary to create baby-boom cohorts in the model. The other two modifications were done to produce more suitable initial population in terms of age structure and household composition. Through these modifications, the initial population consisted of 85,415 individuals in 29,683 households. Obtained initial population was fairly good in general (Table 1). However, there was still a considerable discrepancy in the living situation of the elderly between the initial population and actual data in 2005. Throughout the simulation, the initial population was fixed.

Table 1 Creation of Initial Population for 2005

(In %)

			Modification			2005
	Step 1	Step 2	Baby Boomer	Elderly	The others	Actual Data
Population by age group						
0-14	18.1	13.1	12.7	13.2	13.5	13.8
15-64	59.8	63.4	64.4	66.8	66.8	66.1
65+	22.2	23.5	22.9	20.0	19.7	20.2
Household structure						
One-person (1P)	22.6	27.4	26.6	25.8	26.2	24.6
Couple only (Co)	16.6	13.3	13.9	15.1	16.2	21.9
Couple and child(ren) (CC)	29.7	24.2	25.7	26.8	27.2	31.1
Single parent and child(ren) (SC)	4.4	6.4	6.2	6.8	6.9	6.3
Three generation (3G)	13.6	12.2	11.8	12.3	12.4	9.7
The others (Oth)	13.1	16.4	15.9	13.3	11.1	6.4
Living situation of 65+						
One-person	16.4	18.1	18.0	16.9	17.5	14.1
Couple only	25.4	18.5	18.6	22.6	24.3	33.1
Co-resident with child (Couple)	21.3	16.7	16.6	17.8	17.3	29.4
Co-resident with child (Single)	15.2	22.1	22.3	23.2	22.1	19.7
The others	20.2	22.1	22.0	17.4	16.5	3.7
Households with 65+						
One-person	26.0	29.2	29.0	26.1	27.2	22.0
Couple only	21.1	15.0	15.2	18.1	19.5	29.2
Couple and child(ren)	5.6	6.9	7.2	8.4	8.7	16.2
Single parent and child(ren)	4.5	6.3	6.3	7.7	8.0	
Three generation	24.0	21.4	21.2	24.6	25.6	21.3
The others	18.8	21.3	21.1	15.1	11.0	11.3

(2) Transition Probabilities

Various transition probabilities are used in the model (Note 2). The total fertility rate was assumed to remain around 1.28 for S1 and around 1.44 for S2 throughout the simulation period, and results from S1 are used in the next section. Contrary to the fertility rate, the death rate is assumed to decline gradually, and life expectancy at birth will be 81.8 years for males and 88.4 years for females in 2050. Although we did not apply it this time, the family system can be expressed by a set of three probabilities in this model: co-resident rate of adult child with parent upon marriage, reuniting rate of divorced or widowed persons to his/her parent's household, and merger rate of aged parent(s) to the child's households.

The physical condition of the elderly aged 65 or over is classified into 4 levels as follows:

Level 0: No disability and completely independent;
Level 1: With some disability but basically independent;
Level 2: Slightly or moderately dependent; and
Level 3: Heavily dependent.

Levels 2 and 3 correspond to the eligible persons of the LCI, and Level 3 corresponds to care need levels 4 and 5 in particular. The merger rate of aged parent(s) changes according to age, marital status and physical conditions (Note 3). As institutions are incorporated in the model this time, we assume that an aged person tends to move to an institution as his/her physical condition deteriorates (Note 4).

3. Results of the 2006/07 Simulation

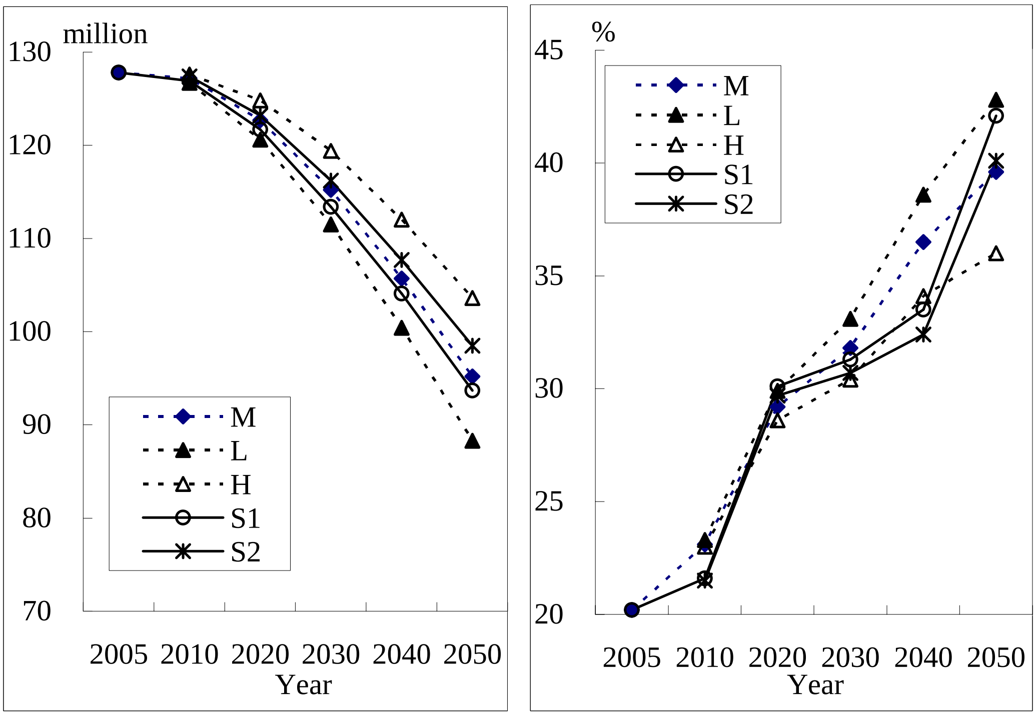
3.1 Basic Results

According to the 2006/07 simulations, the Japanese total population started decreasing from 2005, while aging of the population will continue until 2050 (**Fig. 2**). Total population and aging rate (the proportion of those who are 65 years old or over to the total population) in future years are in line with the result of the latest population projection published in December 2006.

Although the number of total households will start decreasing from 2005 same as the total population, the numbers of both households headed by the elderly (65+) and households with the elderly (65+) will increase until 2020 (**Table 2**). Table 2 also shows the distribution of children aged 0-14 by household type. The number of three-generation households is anticipated to decrease in future, and the number of children living in the three-generation households will decrease accordingly.

Fig. 2 Total population and aging rate

(a) Total population (b) Aging rate



Note: M, L, H mean middle, low, and high scenario of the Population Projection as of December 2006 respectively.

Table 2 Future Population and Households

(In million, %)

	Population						Number of Households			Distri. of children (0-14) by household type (%)		
	Total	Age Structure (%)				Elderly	Total	Headed by the Elderly	With the Elderly			
		0-14	15-64	65+	75+					CC	SC	3G
2000	126.9	14.6	68.1	17.4	7.1	22.0	45.5		15.6			
2005	127.8	13.8	66.1	20.2	9.1	25.7	48.0	13.8 a	18.5			
2010	126.9	13.7	64.7	21.6	11.2	27.5	46.7	17.6	20.9	53.7	4.2	29.7
2020	121.7	11.5	58.4	30.1	13.6	36.6	45.7	22.5	25.4	53.0	4.1	30.7
2030	113.4	9.6	59.1	31.3	20.7	35.5	43.6	22.0	24.8	51.9	3.9	31.6
2040	104.1	10.1	56.4	33.5	20.6	34.9	40.5	21.0	23.8	49.4	4.6	31.5
2050	93.7	9.1	48.8	42.1	22.6	39.4	37.3	23.1	25.3	49.5	4.6	30.7

a 2004

Elderly in this table means those who are 65 years old or over.

3.2 Projections on the elderly

Table 3 shows the living situation of the elderly (65+). In 2004, among the elderly population, 14.7 percent live in one-person households, 36.0 percent in couple-only households and 45.5 percent live with the child generation. According to the simulation, the proportion of one-person households will increase and the proportions of both couple-only households and co-resident households will decrease. The proportion of those elderly who stay in institutions will steadily increase until 2040.

Table 3 Living situation of the elderly (65+)

(In %)

Year	Total							Male						Female					
	1P	Co	Co-resident with child				Insti-tution	1P	Co	Co-resident with child				1P	Co	Co-resident with child			
			a	b	c	d				a	b	c	d			a	b	c	d
2004	14.7	36.0	23.6		21.9			8.2	46.5	18.4		23.2		19.6	28.0	27.5		21.0	
2010	18.4	21.9	6.3	8.5	15.1	9.0	2.6	14.7	28.0	7.8	3.8	20.9	4.3	21.4	17.0	5.1	12.2	10.4	12.7
2020	16.7	19.8	6.3	6.1	17.3	8.9	2.9	13.7	24.2	7.6	2.9	21.7	4.5	19.1	16.2	5.4	8.8	13.8	12.4
2030	17.6	16.4	6.1	6.5	14.6	10.5	4.4	15.2	20.9	7.4	3.3	18.9	5.4	19.5	12.9	5.0	9.0	11.3	14.5
2040	17.2	14.6	5.4	6.5	12.5	11.3	5.6	14.9	18.8	6.8	3.1	16.8	6.0	19.0	11.3	4.3	9.2	9.2	15.4
2050	17.5	16.3	5.0	5.5	12.5	8.9	4.9	15.8	19.2	5.9	2.8	16.4	4.9	18.9	14.0	4.4	7.6	9.3	12.2

Note: Co-resident with child

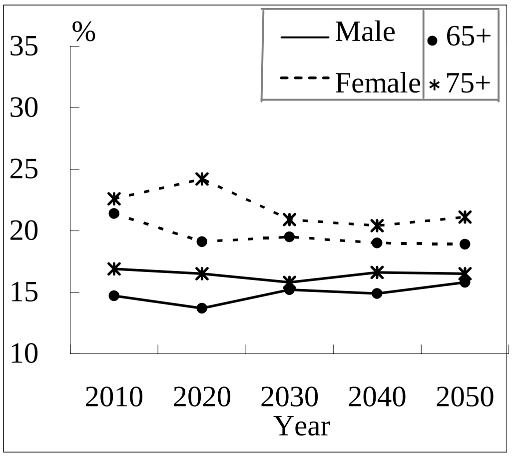
Elderly	Child	
	Couple	Single
Couple	a	c
Single	b	d

The living situation of the elderly is rather different between males and females as shown in **Fig. 3**. Reflecting the difference in death rates, the proportion of one-person households is higher and that of couple-only households is lower for females than males. The number of female elderly staying in institutions is higher than that of male elderly. However the proportion of those who stay in institutions is rather similar between males and females.

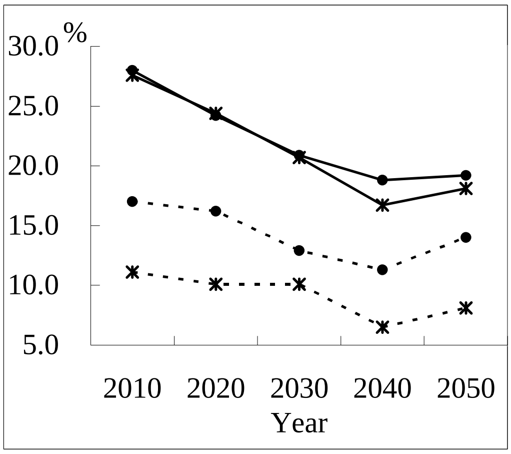
Baseline data for the physical condition of the elderly in 2004 are obtained from the national sample survey conducted by the Ministry of Health, Labour and Welfare as shown in **Table 4**. The proportion of those elderly whose physical condition is in level 3 will steadily increase especially among females.

Fig. 3 Living situation of the elderly by age group and sex

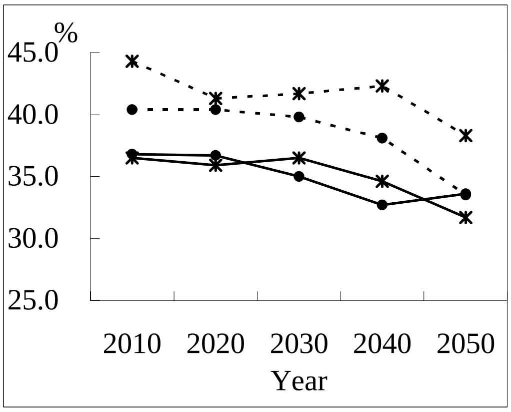
a) One-person



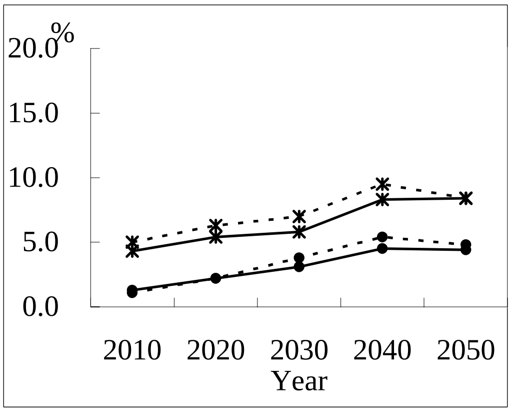
b) Couple-only



c) Co-resident with child generation



d) Institution



Relative number of parents weighted by the number of brothers and sisters of children is obtained from the model as follows (Fukawa, 2005):

$R(y)$ = Relative number of parents according to age group of children (y);

n = number of brothers and sisters of children;

$F(y) = \sum_n F(y, n)$, where $F(y, n)$ = Number of children at age group of y with n brothers and/or sisters;

$G(y) = \sum_n G(y, n)/ n$, where $G(y, n)$ = Number of parents with children at age group of y and n brothers and/or sisters;

$R(y) = G(y) / F(y)$

Table 4 Distribution of the elderly (65+) by physical condition level

（In %）

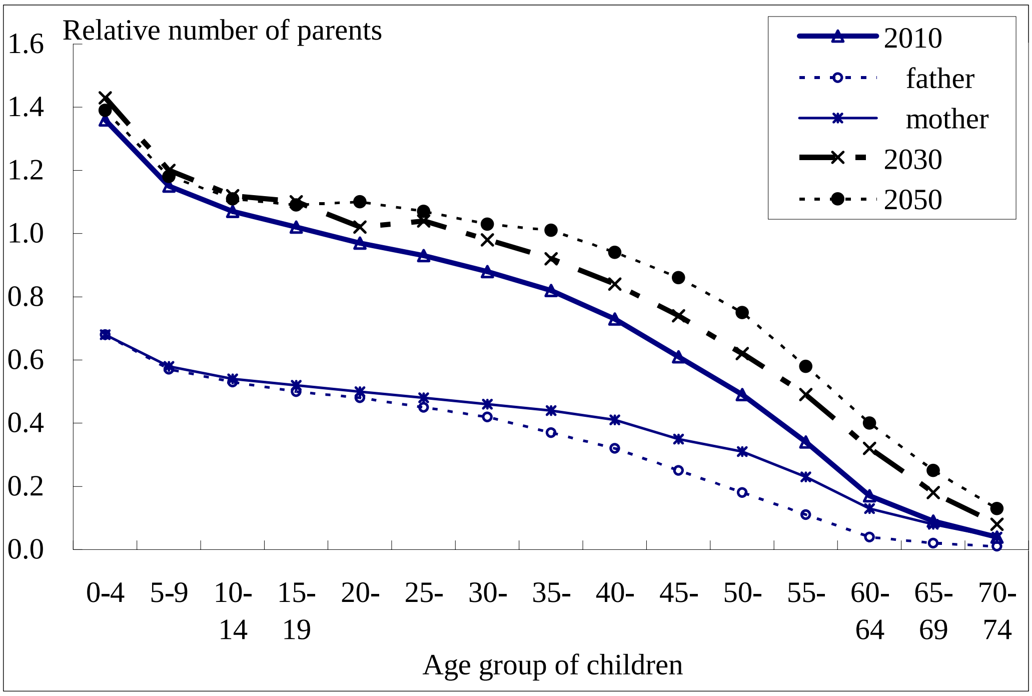
Year	Total				Male				Female			
	Level				Level				Level			
	0	1	2	3	0	1	2	3	0	1	2	3
2004	91.4		5.0	3.6	93.0		3.8	3.2	90.2		5.9	3.9
2010	72.5	13.9	9.4	4.2	70.9	17.8	8.3	3.0	73.7	10.7	10.3	5.2
2020	72.4	14.2	9.0	4.5	69.9	18.5	7.9	3.6	74.4	10.6	9.8	5.2
2030	65.5	16.4	11.4	6.7	61.9	22.1	10.6	5.3	68.4	11.9	12.1	7.7
2040	62.3	15.5	13.2	9.0	60.0	21.5	12.0	6.5	64.1	10.9	14.1	10.9
2050	65.5	14.9	11.1	8.4	63.6	20.3	10.0	6.1	67.1	10.6	12.0	10.3

Note: Physical condition level

- 0: No disability and completely independent
- 1: With some disability but independent
- 2: Slightly or moderately dependent
- 3: Heavily dependent

Fig. 4 shows the results for the years 2010, 2030, and 2050. As low fertility continues and life expectancy prolongs, the relative weight of parents to adult children will increase remarkably in the future. The relative weight of mothers is higher than that of fathers reflecting the difference of death rate by sex.

Fig. 4 Relative number of parents according to age group of children



3.3 Dynamic Transition of Households

Table 5 shows one-year transition matrix by household type for the years 2009-2010 and 2049-2050. As the net increase/decrease in the number of total households is the difference between newly formed households and dissolved households during a year, the number of households with structural change can be greater even if the net increase/decrease is small. From 2009 to 2010, 2,092,000 households are estimated to be newly formed and 2,148,000 dissolved, resulting in 56,000 as net decrease. During 2009-2010, 41,396,000 households will remain in the same household structure, and 3,236,000 households will change their household structure. Therefore, the total number of households changed (i.e. newly formed, dissolved or transformed the household structure) will be 7,476,000, which is more than 130 times the net decrease.

Table 5 One-year transition matrix by household type

2009-2010（46,780→46,723） (In thousand)

Household type	Number in 2009	Number in 2010						Disso-lved
		1P	Co	CC	SC	3G	Oth	
Total	46,780	10,887	7,908	12,385	3,141	5,606	6,797	2,148
One-person (IP)	10,960	8,664	86	34	136	3	53	1,983
Couple-only (Co)	7,851	236	7,022	451	15	0	61	66
Couple and child (ren) (CC)	12,534	5	462	11,606	178	95	175	13
Single parent and child (ren) (SC)	3,218	257	0	27	2,745	15	110	65
Three-generation (3G)	5,643	0	6	92	16	5,270	259	0
The others (Oth)	6,574	118	44	40	39	223	6,089	21
Newly formed	-	1,607	288	134	13	0	50	-

2049-2050（37,616→37,280） (In thousand)

Household type	Number in 2049	Number in 2050						Disso-lved
		1P	Co	CC	SC	3G	Oth	
Total	37,616	10,423	5,916	6,345	2,541	3,550	8,506	1,455
One-person (IP)	10,415	8,924	40	13	84	2	27	1,324
Couple-only (Co)	5,979	192	5,457	223	10	2	44	52
Couple and child (ren) (CC)	6,438	6	221	5,957	99	57	79	19
Single parent and child (ren) (SC)	2,619	228	0	18	2,292	2	39	40
Three-generation (3G)	3,643	2	3	47	15	3,357	220	2
The others (Oth)	8,522	157	92	21	32	131	8,069	19
Newly formed	-	913	102	66	10	0	27	-

As shown in Table 5**,** one-person households will increase from 10,960,000 in 2009 to 10,887,000 in 2010: 1,607,000 will be newly formed, 1,983,000 will be dissolved by death, return, merger of the aged, etc., 236,000 will change from couple-only households to one-person households by divorce or death of the spouse, and 257,000 will change from "single parent and child(ren)" households. Couple-only households are also relatively unstable. Out of 7,851,000 of couple-only households, 7,022,000 will remain, 462,000 will change from couple and child(ren) households to couple-only households, and 288,000 will be newly formed by marriage during the year 2009-2010.

There are some frequent patterns in streams of change according to Table 5. One-person households have a strong tendency to change: to be dissolved, to be newly formed, to change from couple-only households or single parent and child(ren) households. Couple-only households are newly formed by marriage, change to and from couple and child(ren) households, etc. Single parent and child(ren) households tend to change to one-person households by their children's marriage or independence, and some transfer to the other categories of household by co-residence with their married children.

The stability of each household type is measured by the yearly transition rate, which is calculated by 1 – (Number of continued households) / (Average number of households). The average number of total households during 2009-2010 will be 46,752,000, and the number of continued households will be 41,396,000. Therefore, annual rate of transfer for the total households during 2009-2010 will be 11.5 percent, and this means that the expected duration of household newly formed during 2009-2010 will be 8.7 years (**Table 6**). The expected duration of one-person households and couple-only households has a tendency to increase over time, but three-generation households have the opposite tendency in expected duration. However, we need a careful examination of all transition probabilities employed to lead any concrete interpretation out of this table.

Table 6 Yearly transition rate and expected duration by household type

Household type	From 2009 to 2010			From 2049 to 2050		
	Average N. of households (Thousand)	Yearly transition rate (%)	Expected duration (Year)	Average N. of households (Thousand)	Yearly transition rate (%)	Expected duration (Year)
Total	46,752	11.5	8.7	40,230	9.1	11.0
One-person	10,924	20.7	4.8	11,799	14.3	7.0
Couple-only	7,880	10.9	9.2	6,903	8.2	12.1
Couple and child (ren)	12,460	6.9	14.6	7,559	6.8	14.7
Single parent and child (ren)	3,180	13.7	7.3	2,888	11.2	9.0
Three-generation	5,625	6.3	15.9	2,370	6.7	15.0
The others	6,686	8.9	11.2	8,712	5.2	19.1

4. Discussion

INAHSIM was first developed in 1984-85 by a multi-disciplinary research group. In 1994 Simulation, the initial population of the model was prepared by using the simulation model itself. It has been confirmed that INAHSIM is applicable when the initial population is not available from census or national household surveys, and all problems caused by the initial population without the information about family members residing outside of the household will be avoided though creating an initial population by using the simulation model itself (Fukawa, 1995). In 2004 Simulation, the creation process of the initial population was improved and physical condition of the elderly was introduced in the model. In this paper, based on the 2004 Simulation, the physical condition of the elderly is related to the data of the Long-term Care Insurance and we incorporated institutions in the model for the first time.

The INAHSIM provides us, among others, with information on the dynamic transition of household types, the effects of family systems on the number and structure of households, and household situations of individuals with specific attributes. The household situation of the children is basic information for a well-defined child care support policy. The dynamic transition of households is always a good example of the predominant features of micro-simulation model. By changing the starting year of the simulation, INAHSIM is useful for both historical analysis and future projection of households and families (Fukawa, 1995). While dynamic models typically do capture some types of behavioural change, they face problems (like static models) when attempting to incorporate either behavioural change in response to government policy changes or second round effects because they do not necessarily allow changes in behaviour initiated by government policy change (Harding, 1996).

It turned out to be very important to connect the living situation and physical condition of the elderly. Expenditure of the LCI in 2004 was 6.0 trillion yen, 1.2 percent of GDP, providing benefits to 3.1 million people equivalent to 12.3 percent of the elderly. Due to aging of the population, the dependent elderly will increase rapidly in the future as shown in Table 4, and the distribution of the elderly by living situation and physical condition has a direct implication on the future expenditure of the LCI. A weighted parent-child ratio is an index of elderly care, and the usefulness of such an index increases through incorporating the physical condition of the elderly.

From the INAHSIM, we can obtain a population-household projection in a coherent manner as well as dynamic statistics which are difficult to obtain from static surveys or macro simulation. If we construct a pertinent initial population and improve accuracy of transition probabilities, then we can extract useful information from the INAHSIM which is only available from micro-simulation. The structure of INAHSIM is flexible enough to change output tables without changing main framework of the simulation, and to improve output information by putting additional simulation variables (Fukawa, 1995). Transition probabilities are able to be changed annually. In this model, the family system is expressed by a set of probabilities, and by changing these variables, the model can express different family systems. In order to analyze the family lifecycle, it is necessary to improve the accuracy of various transition probabilities on household mergers. By adding place of dwelling, housing and employment situation in the model, we can improve the usefulness of the model remarkably. Inagaki (2005) added employment situation in the model, and analyzed the effects of recent increase in non-regular workers to the future fertility and household situation.

Notes:

(Note 1) Occurrence of each event is based on the Monte-Carlo method: that is if and only if a random number generated by the computer for each event is equal to or smaller than the probability given, the event is allowed to occur. When an event is decided to occur, all necessary procedures will be done step by step to simulate the changing actual society.

(Note 2) Transition Probabilities

Birth: Birth rate: age of mother and birth order
Sex ratio at Birth: 105.5 males for 100 females

Death: Death rate: age and sex for 0-64 years old
Transition probability: age, sex and physical condition for 65+

Marriage: First marriage rate: age and sex
Re-marriage rate: age and sex

Divorce: Divorce rate by duration of marriage
Probability of husband leaving household upon divorce: 0.6939

Separation & Return: Separation rate: age, sex and marital status
Return rate: age, sex and marital status

Household Merger:

Co-resident rate of adult child with parents upon marriage
bridegroom's = 0.40901, bride's = 0.17647 (no brothers), 0.02373 (otherwise)

Reuniting rate of adult child to the parent's household upon becoming widowed: 0.3

Reuniting rate of adult child to the parent's household upon divorce: 0.43 (male), 0.35 (female)

Merger rate of aged parent(s) with child generation: marital status, average age of aged parent(s), and physical condition

(Note 3) Standard merger rate of aged parent(s), U, changes according to age and marital status: Single male 65: 0.015, 100: 0.207; Single female 65: 0.015, 100: 0.123; Couple 65: 0, 100: 0.05. Standard rate U is modified according to physical conditions as follows:

	Physical condition			
	0	1	2	3
Single	×0.8	×1.0	×1.5	Always 1.0

Couple	×0.5	×0.5	×0.7	×1.0

(Note 4) The following patterns are assumed concerning the probability of the elderly to move into institutions (number shows physical condition level):

Single 2: Merge to child generation, or move to institution

Single 3: Always move to institution

Couple:

	0	1	2	3
0	*	*	*	b)
1	*	*	a)	b)
2	*	a)	+	+
3	b)	b)	+	+

*: Do not move to institution

a): merge to child generation, otherwise [2] moves to institution

b): [3] always moves to institution

+: Both move to institution

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