No.61 (79-25)

A Residential Search Routine for A Metropolitan Residential Relocation Model*

by

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December 1979

* This paper is a part of the author's Ph.D dissertation (Oguri, 1978), which was supervised by Prof. B. Harris. The author would like to acknowledge Prof. H. Kaji and Dr. S. Harashina for their invaluable comments, and the Kajima Foundation who funded this research. This paper is released for limited circulation in order to facilitate discussions and invite criticism, and should not be quoted in publications without the permission of the author.

Abstract

A residential search routine is built for a Metropolitan Residential Relocation Model (MRRM). Using the Monte Carlo method, the routine simulates the housing and residential zone search process of households of different attributes which realize, or fail to realize, their housing preferences, or their potential demand, under prevailing economic constraints. The routine satisfies several requisites for a residential search routine, and its execution is well supported by the data available from a Metropolitan Residential Relocation Survey, which preceded the model development. The simulation results of the MRRM which incorporated the proposed routine were plausible.

1. Introduction

A Metropolitan Residential Relocation Model (MRRM) was developed by Oguri (1978) for the Tokyo region, with a purpose of projecting how the housing demand of the households at different stages of the family cycle is accomodated in the region under different sets of housing policies. This paper describes how the pocess of housing and residential zone search, or, in short, the residential search process, is simulated in the MRRM. Preceding the model development, the Metropolitan Residential Relocation Survey (MRRS) was undertaken to analyze the relocation demand and housing preference of the metropolitan residents of Tokyo, sampling 1,599 employees working at major centers of the region in 1977 (Oguri, 1979). The relationship of the survey results with the model development is discussed here. Also, after briefly describing how this routine is incorporated in the modeling framework, this paper shows a part of the simulation results.

2. Requisites for a Residential Search Routine

What are the essential requisites for a simulation routine of the residential search process in an urban residential model? The micro economic theories of housing and location choice (Alonso (1964), Muth (1969), etc.) explicitly state that a household determines the amount of housing services to be consumed under an income constraint to·maximize its utility level.[1/] The economic theories cannot easily be transformed into operational simulation routines, since, among many reasons, the specification of the utility

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1/ See also Oguri (1979), pp.2-5.

function is quite difficult, and the housing demand includes not only the demand for housing services but also for housing stock. The economic theories may, however, give us a rationale which requires that "a model routine of the residential search should be built in such a way that we can simulate the households' behavior of realizing their preference, or potential demand, for houses in the market under the economic constraints." This we call requisite 1.

Requisite 1 is the essential requirement for a residential search routine to include households' preference for houses, the expenditure for houses, and the housing prices in the market, and from this we derive some other requisites. First, households have to be disaggregated by their attributes (requisite 2), since the housing preference among households of different attributes are divergent, as was detected by the MRRS. The economic constraints, or the housing expenditure, are also dependent on the household attributes. Second, the disaggregation of houses by their attributes is necessary (requisite 3), since the housing preference of a household is stated in terms of the strength of the preference for houses of different attributes. The prices of the houses vary according to housing attributes.

Furthermore, in a metropolitan region, whose outerboundary is defined, relocation activity within the region composes a significant portion of the residential activity. Thus, we may require a residential search routine to include the relocation activity as its subject of simulation (requisite 4).

A residential search routine can be regarded as constituting the demand side of a model of housing market. Thus a routine of residential search is to be built as an integral part of a comprehensive model which simulates the performance of the housing market (requisite 5).

3. Review of Existing Models of Residential Search

A large amount of efforts have been devoted for constructing models which simulate the residential search activities of the household. To briefly review those models in the limited space, we may categorize them into several classes, i.e. : (1) micro-economic approach (Alonso, op. cit, Muth, op. cit., Solow (1973), Oron, Pines, and Sheshinski (1973), etc.); (2) linear programming approach (Herbert and Stevens (1960), Ingram et al. (1972), Wheaton (1974), etc.); (3) gravity, accessibility, and intervening opportunity approach (Hansen (1959), Lowry (1964), Lathrop and Hamburg (1965), Goldner et al. (1972), Christiansen (1975), etc.); (4) Markov chain approach (White (1971), Hiramoto (1974)); and (5) Monte Carlo simulation approach (Kumata et al. (1968), and Ito et al. (1973)).[1/] Among these, models of categories (3) and (4) are difficult to satisfy the essential requisite 1. Models of category (1) are built to meet requisites 1 and 5 elegantly, but are difficult to satisfy requisites 2, 3, and 4. Models of category (2) operationalize the models of micro-economic approach by taking account of requisites 2 and 3, and in the NBER model (Ingram et al., op. cit.), requisite 4 is also taken into consideration. Execution of these models, however, are hampered by such difficulties as the specification of utility functions, the determination of bid prices for houses, or the inclusion of the demand for owner-occupied

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1/ Review and evaluation of the models of entropy maximization approach (Wilson (1970), Anas (1974), etc.), which are regarded as powerful and promising for residential search simulation, is left for future studies.

houses. Models of category (5) are suitable for the disaggregation of households and houses and thus satisfy requisites 2 and 3, for replicating housing preferences to meet requisite 1, and can be built to describe the relocation activity (requisite 4) within the framework of housing market (requisite 5). Considering these, the residential search routine of the MRRM is built adopting the Monte Carlo methods.

We, however, observe some problems in the preceding works of Monte Carlo approach. In the Kumata model (Kumata et al., op. cit.), first house to be searched is identified as a result of the choice of desirable housing attributes, whose choice probabilities are assumed to be conditional to household attributes and given to the model exogenously. The existence of such a desirable house is examined in the model, and if it is found to be unavailable, some of the housing attributes are changed to less desirable levels, and the same examination of existence is undertaken. This procedure is repeated until a sample household find out an available house. In spite of its excellence in describing the preference structure for houses, the execution of the model cannot be easily supported by actual data since the preference for housing attributes perse is difficult to be identified in conformity with the modeling structure. As a result, the Kumata model was executed using hypothetical data. Ito model (Ito et al., op. cit.) adopts a much simpler routine of residential search with an assumption that preference order to the four types of houses (owner-occupied houses, public rental houses, private rental houses, and lodging houses) is common for all the households, and this may be regarded as oversimplifying the real world. In both models, the budget constraints of the households are implicitly included in the process of identifying the houses to be searched, and the final choice is dependent only on the existence of the house searched. The residential search routine of the MRRM tries to overcome these shortcomings of the preceding works.

4. Designing a Residential Search Routine

a. Outline

The Metropolitan Residential Relocation Model simulates the residential activities in a metropolitan region, which is subdivided into NZN[1/] zones, between the initial year J and the projected year K. The actors to be simulated in the model are the households who undertake residential search activity in the region within the period. These are designated as moving households. Moving households are composed of relocating households, which have intention to relocate within the region in the period, and new households which can be further decomposed into in-migrating households to the region and newly formed households within the region. A relocating household is characterized by:

JRZ (=1 ∿ NZN) = residential zone in the initial year J;

JHT (=1 ∿ NHT) = housing type in J;

KBZ (=1 ∿ NZN) = business zone in the projected year K;

KHL (=1 ∿ NHL) = household type[2/] in K; and

KYM (=1 ∿ NYM) = income class in K.

1/ Notations for the description of the model are in FORTRAN. From time to time, however, we use expressions in calculus for the sake of simplicity.

2/ A household type is defined as a combination of family size class, KFS (=1 ∿ NFS), and age class of household head, KAH (=1 ∿ NAH).

A new household, on the other hand, is characterized by KBZ, KHL, and KYM. The results of residential search of a moving household are stipulated as a choice of:

KHT (=1 ∿ NHT) = housing type in K; and

KRZ (=1 ∿ NZN) = residential zone in K.

The residential search routine of the MRRM takes a sample of the moving households, determines the attributes of each member of the sample, simulates its residential search activity, and aggregate the results of residential search of the moving households. Below we discuss how a sample household's behaviour is simulated after its attributes are determined.

b. Replication of Housing Preference

A residential search routine is to simulate the households' behavior of realizing their preference, or potential demand, for houses in the market subject to their economic constraints (requisite 1). To meet this requisite, we build the residential search routine of the MRRM in such a way that a moving household search for houses which are rank-ordered according to its preference, and consequently acquires the first house which meets its housing budgets.1/ The first task of this routine is to identify houses, which are

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1/ Suppose a household's utility level is dependent on the amounts of housing services and of other composite good to be consumed. The house acquired under the concept of the routine building provides the highest utility level to the household under the assumption that the housing budget, or the maximum expenditure for a house, is predetermined. The housing budget is, however, to be determined endogenously in the utility maximization process, and the routine proposed here does not replicate this.

the subjects of search, in the order of preference level.

In the MRRM, this procedure is carried out in two stages. First, housing groups are identified consecutively according to the preference level. A housing group, KHG (=1 $\sim$ NHG), is defined as a combination of a housing type KHT and a certain range of the commuting distance between the business zone of the sample household's head, KBZ, and the residential zones, KRZ's, in which such houses are located. The identification of a housing group KHG therefore implies that a household identifies houses of type KHT which are located in the residential zones whose commuting distances to the business zone KBZ are within the specified range as its subjects of search. Thus, in the second stage, residential zones within the housing group are identified in the order of commuting distance from the business zone, KBZ. Methods and significance of the housing group identification and zone search are discussed below.

c. Identification of Housing Groups

How are the housing groups identified consecutively in the model? A questionnaire on housing preference of the Metropolitan Residential Relocation Survey was designed such that it corresponds to the modeling method. In the MRRS, 27 housing groups were defined by dechotomizing 14 types of houses on the basis of short and long commuting distance (Table. 1). The order of preference was given to the housing groups by each of the respondents. An example of the preference order is ($1 \rightarrow 2 \rightarrow 3 \rightarrow 5 \rightarrow 7 \rightarrow$ end), which is read as housing group 1 is preferred to 2, 2 is preferred to 3, ..., and housing group 7 is chosen last.

Table 1.

Twenty Seven (27) Housing Groups

Housing types / Commuting distance	Owned					Rented								
	Single detached		Publicly constructed apartments	Privately constructed apartments		Single detached		Company-issued	Publicly constructed apartments		Privately constructed apartments		Lodging houses and dormitories	Multiple use structures
	f.a.* $100m^2$ or more	l.t.** $100m^2$		$50m^2$ or more	l.t. $50m^2$	$75m^2$ or more	l.t. $75m^2$		$25m^2$ or more	l.t. $25m^2$	$15m^2$ or more	$15m^2$ or more		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Short commuting distance	60 min. or less 1	60 min. or less 3	60 min. or less 5	45 min. or less 7	45 min. or less 9	60 min. or less 11	60 min. or less 13	60 min. or less 15	60 min. or less 17	60 min. or less 19	30 min. or less 21	30 min. or less 23	30 min. or less 25	27
Long commuting distance	m.t.*** 60 min. 2	m.t. 60 min. 4	m.t. 60 min. 6	m.t. 45 min. 8	m.t. 45 min. 10	m.t. 60 min. 12	m.t. 60 min. 14	m.t. 60 min. 16	m.t. 60 min. 18	m.t. 60 min. 20	m.t. 30 min. 22	m.t. 30 min. 24	m.t. 30 min. 26	

Note: (1) ~ (14) indicate housing type numbers, while 1 ~ 27 indicate housing group numbers.
*f.a. = floor area
**l.t. = less than
***m.t. = more than

The MRRM adopts the same definition of housing groups, excluding the 27th housing groups, i.e. multiple use structures, as a subject of search, and replicates the preference order regarding the housing groups expressed by the respondents. The method for this replication of the preference order for housing groups is shown in Fig. 1. First, the housing group which is selected as the first subject of search is identified, utilizing probability distributions which are estimated from the MRRS. The survey detected that the houses of first choice are divergent according to households' family cycle stage and also according to their previous housing types (Oguri, 1979, pp.19-20.). Thus, we define household groups, KST, by combining all the household attributes, and estimate the probability distributions of housing groups of first choice for different household groups, which we denote as PRHGS(KHG,KST), where $\sum_{KHG=1}^{NHG}$ PRHGS(KHG,KST) = 1.0 for all KST. Since sample household's attributes are already determined at this stage, the household group KST to which the sample belongs is determined, and the corresponding vector can be selected. Then, generating a random variable, XR, associated with a uniform probability distribution in the range [0, 1.0), or a random number, we determine the housing group of first choice, KHG. For this procedure, we adopt the following simple notation:

$$XR \rightarrow PRHGS(KHG,KST) \rightarrow KHG \qquad (1)$$

This is read as follows; KHG is determined by a random number with probability distribution PRHGS(KHG,KST) given KST. In the execution of the model, 13 housing groups were stipulated, and the vector of choice probabilities was estimated for each of the household groups.

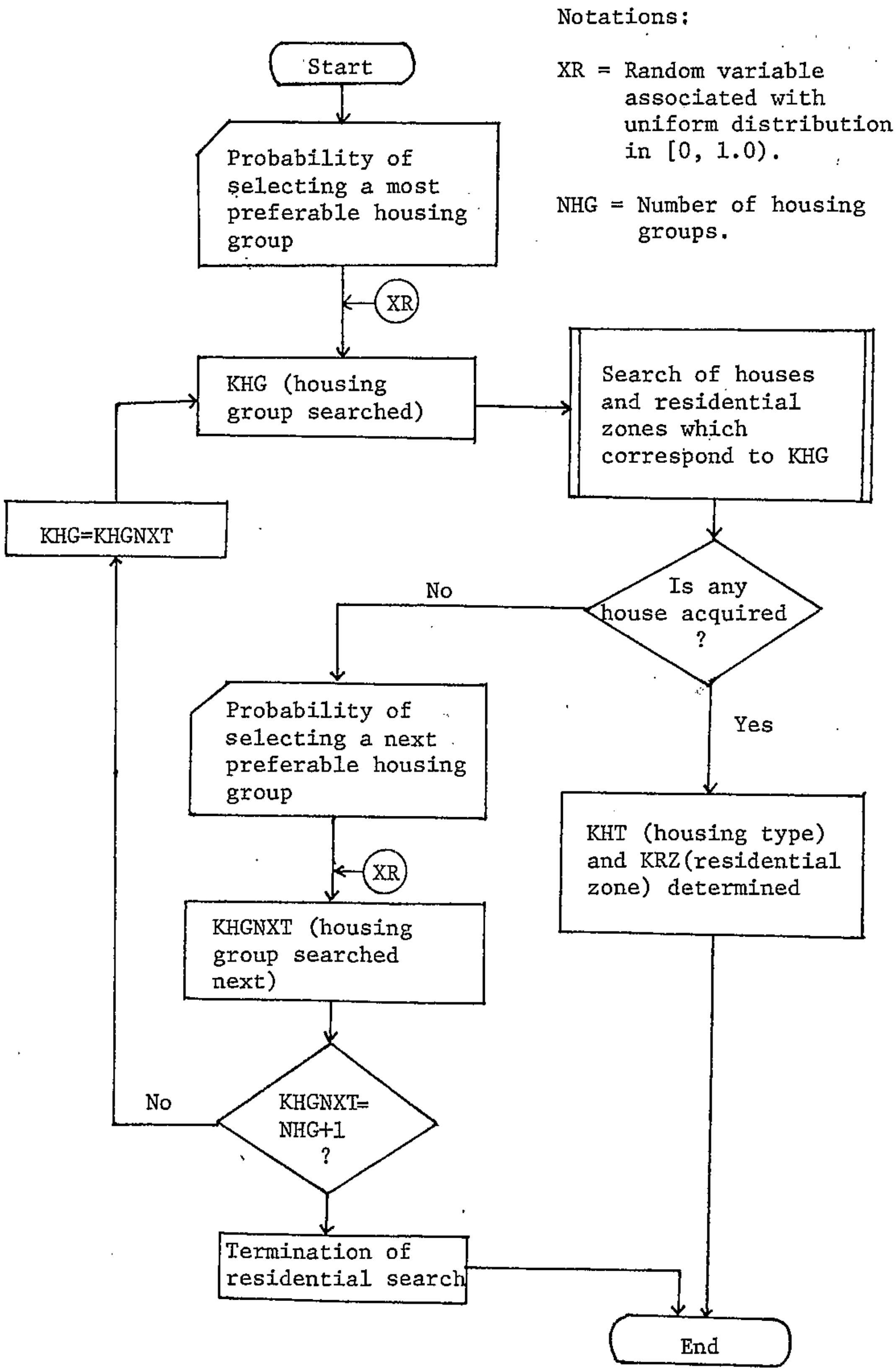


Fig. 1 Identification of Housing Groups

The sample household searches for houses of type KHT in different zones within the housing group KHG. We leave the discussion on how this procedure is undertaken for a later topic, and discuss how the next housing group, KHGNXT, is identified when no available house is found within KHG. Let us, for example, adopt the preference order regarding the housing groups (1 → 2 → 3 → 5 → 7 → end). Each pair of housing groups in this preference order, i.e. (1 → 2), (2 → 3), (3 → 5), (5 → 7), and (7 → end), indicates the transition of preference for housing groups. We construct a transition matrix of selecting housing groups, using these pairs as the element of the matrix. The matrix includes important information, i.e. at which housing group the moving households terminate housing search. The analysis of the survey results indicated that this decision depends on household attributes, including family cycle stage and previous housing (Oguri, 1979, pp.23-25). Considering this, we define household groups, KTP, by combining all the household attributes, and estimate the transition matrix for each of the household groups. The matrices for the housing groups are denoted, by PRHH(KHGNXT,KHG,KTP), where $\sum_{KHGNXT=1}^{NHG+1}$ PTHH(KHGNXT,KHG,KTP) = 1.0 for all KTP and KHG. Utilizing these matrices, the housing group of next search is determined as:

$$XR \rightarrow PRHH(KHGNXT,KHG,KTP) \rightarrow KHGNXT \quad (2)$$

For the execution of the model, 7 household groups were stipulated. Table 2 shows the transition matrix of the households whose heads are between 30 and 39 years old and whose previous houses are rental. The matrix also applies to the new households of the same age class. PRHH(NHG+1, KHG,KTP) indicates the probability of terminating the residential search with housing group KHG. Thus, if KHGNXT = NHG+1 the residential search is terminated.

Table 2.

Transition Matrix for Selecting Housing Groups to be Searched

Upper row - Number of sample. Lower row - Probability of transition from one housing group to the consecutive one in percentage.

Housing group of k-th selection \ Housing group of (k+1)-th selection					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	End	Total
Owned	Single detached	f.a.* 100m² or more	0-60 min.	1		41 37.2	35 31.8	4 3.6	4 3.6	2 1.8	5 4.5	1 0.9	2 1.8													1 0.9		1 0.9			14 12.7	110 100.0
			60 min.-	2			35 49.2	17 23.9	3 4.2		1 1.4	2 2.8			1 1.4		1 1.4		1 1.4							1 1.4					9 12.6	71 100.0
		l.t. 100m²	0-60 min.	3		19 15.5		31 25.4	23 18.8		9 7.3		2 1.6		1 0.8				2 1.6		1 0.8		1 0.8		1 0.8						32 26.2	122 100.0
			60 min.-	4					19 27.5	2 2.8	7 10.1	6 8.6	1 1.4		2 2.8							1 1.4			1 1.4						30 43.4	69 100.0
	Publicly constructed apartments		0-60 min.	5	1 1.2		1 1.2			23 29.4	19 24.3	6 7.6	2 2.5		1 1.2		2 2.5		2 2.5		7 8.9										14 17.9	78 100.0
			60 min.-	6	1 3.0	1 3.0	1 3.0	1 3.0			3 9.0	3 9.0	3 9.0		1 3.0				1 3.0	1 3.0	4 12.1	1 3.0									12 36.3	33 100.0
	Privately constructed apartments	f.a. 50m² or more	0-45 min.	7	2 3.4	1 1.7	2 3.4	3 5.1	2 3.4	1 1.7		14 24.1	8 13.7		2 3.4		2 3.4		1 1.7		3 5.1				1 1.7	1 1.7					15 25.8	58 100.0
			45 min.-	8		1 2.7		2 5.4	6 16.2	2 5.4			2 5.4	2 5.4	3 8.1	1 2.7						1 2.7									17 45.9	37 100.0
		l.t. 75m²	0-45 min.	9			1 4.7	1 4.7	4 19.0			1 4.7		6 28.5	2 9.5						1 4.7										5 23.8	21 100.0
			45 min.-	10				1 11.1	2 22.2						2 22.2						1 11.1										3 33.3	9 100.0
Rented	Single detached	f.a. 75m² or more	0-60 min.	11							1 5.2					6 31.5	8 42.1		2 10.5		1 5.2					1 5.2						19 100.0
			60 min.-	12													2 20.0	1 10.0			2 20.0										5 50.0	10 100.0
		l.t. 75m²	0-60 min.	13												2 7.1		2 7.1	2 7.1		4 14.2	1 3.5	1 3.5	1 3.5	4 14.2						11 39.2	28 100.0
			60 min.-	14					1 16.6																1 16.6						4 66.6	6 100.0
	Company issued		0-60 min.	15	1 4.3						2 8.6				1 4.3					4 17.3	3 13.0				2 8.6						10 43.4	23 100.0
			60 min.-	16													1 14.2		1 14.2			1 14.2									4 57.1	7 100.0
	Publicly constructed apartments	f.a. 25m² or more	0-60 min.	17	1 2.5												3 7.6						6 15.3		3 7.6	3 7.6		1 2.5			17 43.5	39 100.0
			60 min.-	18							1 6.2												1 6.2	2 12.5	1 6.2	2 12.5					9 56.2	16 100.0
		l.t. 25m²	0-60 min.	19					2 15.3						1 7.6			1 7.6				2 15.3			2 15.3	1 7.6	1 7.6	1 7.6			2 15.3	13 100.0
			60 min.-	20											1 33.3										1 33.3						1 33.3	3 100.0
	Privately constructed apartments	f.a. 15m² or more	0-30 min.	21						1 5.0									1 5.0							3 15.0	4 20.0				11 55.0	20 100.0
			30 min.-	22					1 5.8													1 5.8	1 5.8								15 88.2	17 100.0
		l.t. 15m²	0-30 min.	23																								1 11.1			8 88.8	9 100.0
			30 min.-	24															1 25.0												3 75.0	4 100.0
	Lodging houses and dormitories		0-30 min.	25																												
			30 min.-	26																												

Source: MRPS. * f.a.=floor area.

Note: The sample of the matrix is: (1) relocating households whose heads are between 30 and 39 years old, and whose previous houses are rental; and (2) new households whose heads are between 30 and 39 years old.

Otherwise a replacement is made as:

$$KHG = KHGNXT \tag{3}$$

The moving household searches for houses of the new housing group KHG. If it cannot find any house to acquire within this housing group, the next housing group KHGNXT is identified again by (2). This process is repeated until either the moving household finds a house to acquire or the next housing group is null, i.e. KHGNXT = NHG+1. A housing group should not appear twice or more times in the residential search of a moving household. Thus, for all KHGNXT's which have been already identified as the subject of search, PRHH(KHGNXT,KHG,KTP) is turned into zero. Other probabilities are readjusted under the condition that $\sum_{KHGNXT=1}^{NHG+1} PRHH(KHGNXT,KHG,KTP) = 1.0$.

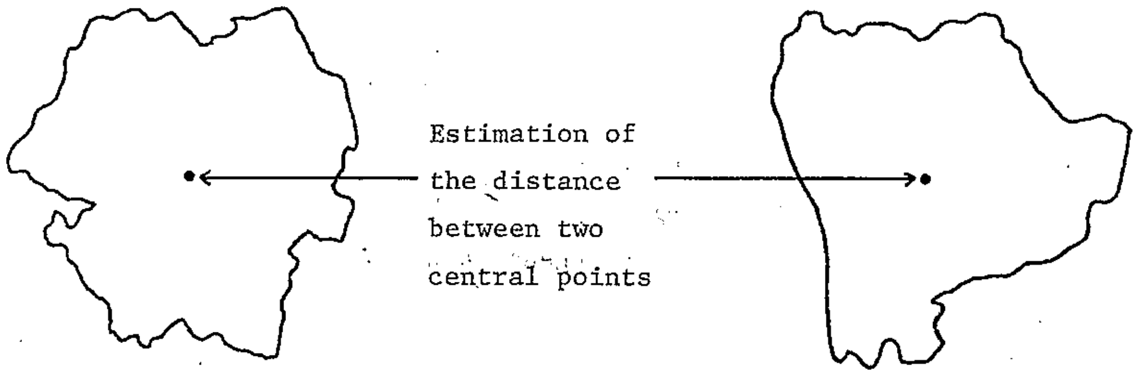
What are the advantages of this modeling? First, the routine expresses the preference for housing attributes and the trade-off among them stochastically. Assume that houses in group 1 are owner-occupied single detached houses with large floor areas and within short commuting distance; houses in group 2 are those with large floor areas and within long commuting distance; and houses in group 3 are those with small floor areas and within short commuting distance. Also assume that the housing group of first selection is 1, i.e., KHG=1. If the next housing group is 2, i.e. if KHGNXT=2, the sample household is said to have strong preference for floor space, i.e. floor-area-oriented. If, on the other hand, KHGNXT=3, the sample household is commuting-distance-oriented. Since the determination of KHGNXT is probabilistic, the routine of idenfifying housing groups of this model probabilistically expresses the trade-off between space and distance. Also, since the housing groups are characterized by many housing attributes, the routine is said to express the preference for these attributes stochastically. Second, the routine describes how the demand for relocation is realized, or not realized, in the market, and thus satisfies requisite 4. Third, households and houses of this routine are largely disaggregated and thus satisfies requisites 2 and 3.

d. Residential Zone Search

How, then, do the moving household search residential zones within a housing group? Let us denote the minimum commuting distance for housing group KHG by DSMN(KHG), and the maximum by DSMX(KHG). For the sample moving households, houses of housing group KHG are distributed among zones which are within the range between DSMN(KHG) and DSMX(KHG) from the business zone of the head of household KBZ. It is plausible to assume that, for any household, a house with shorter commuting distance is more preferable when other attributes are kept equal. Under this assumption, the moving household searches residential zones which are rank-ordered by the commuting distance from KBZ.

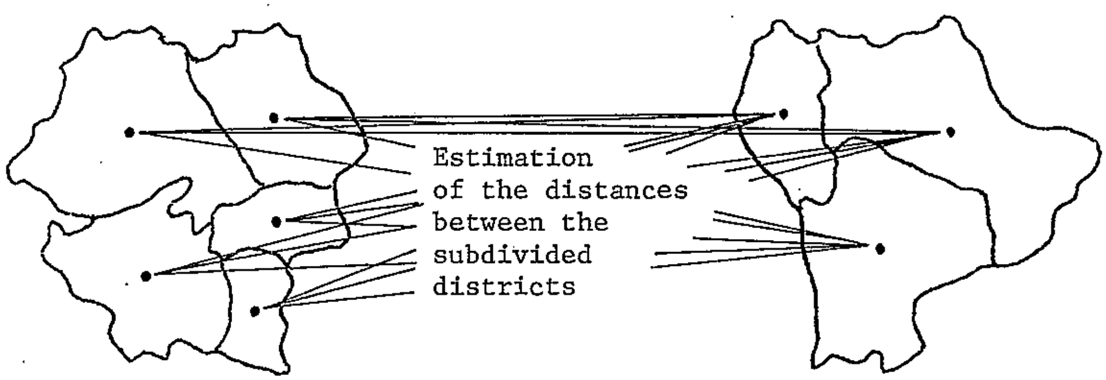
What is, then, the commuting distance between a business zone and a residential zone? In spatial models, conventionally, a central point is defined for each subdivided zone, and the distance between two central points, which is constant, is measured as the distance between two zones.(Fig. 2-a). If the zones are large, however, a constant distance may not well represent the real world, because the distance between a certain point in zone A and a certain point in zone B may differ from the distance between another point in A and another point in B. As a matter of fact, the distance between two zones is intrinsically a set of inifinite number of distances between the

a. Conventional Method



The distance between two zones is treated as a constant.

b. The Method adopted in the MRRM



The average and the standard deviation are estimated. Utilizing these as the parameters, the distance between two zones is determined stochastically for each household under the assumption that the distribution is normal.

Fig. 2 Determination of the Distance between Two Zones points in the two zones, which are also infinite in number. To represent this, we treat the distance between two zones as a random variable.

Both business zone KBZ and residential zone KRZ are subdivided into smaller districts and the distances between districts are measured. The average, DSAV(KRZ,KBZ), and the standard deviation, DSSD(KRZ,KBZ), of the distances are then estimated. Utilizing these, the distance between zones KBZ and KRZ, DS(KRZ,KBZ), is determined stochastically for each household, under the assumption that the distribution is normal,[1/] i.e.:

$$DS(KRZ,KBZ) = DNORM(AVDS,SDDS,XR) \quad (4)$$

where AVDS=DSAV(KRZ,KBZ), SDDS=DSSD(KRZ,KBZ), and DNORM(AVDS,SDDS,XR) is a function which generates a random variable whose associated distribution is normal with AVDS as its average and SDDS as its standard deviation (Fig. 2-b). Note that, with this procedure, the distance <u>within</u> a zone can also be estimated.

Residential zones are then sorted in ascending order with respect to the commuting distance from the business zone KBZ. DSRO(IZNPF,1) denotes the distance between KBZ and the residential zone whose preference order is IZNPF, while DSRO(IZNPF,2) denotes the IZNPF-th residential zone number.

The moving household, whose subject of search is housing group KHG, now searches houses of type KHT. The search begins in a residential zone of the shortest commuting distance, i.e. KRZ=DSRO(IZNPF,2), where IZNPF=1. Should it find itself unable to acquire a house in zone KRZ, whose criteria is shown later, or should the condition:

1/ Statistical examination of the distribution form is left for future research.

DSRO(IZNPF,1) ≥ DSMN(KHG) (5)

not be met, the household searches another residential zone whose commuting distance is the next shortest, i.e. KRZ=DSRO(IZNPF,2) where IZNPF=2. This procedure is repeated until either: (i) the household finds a residential zone in which it can locate; or (ii) no residential zone is left to be searched, i.e. IZNPF=NZN; or (iii) the condition:

DSRO(IZNPF,1) ≤ DSMX(KHG) (6)

is not met. In the case of (ii) or (iii), the next housing group is identified by (2). Note that, in this procedure, the rank-orders of the residential zones for different households are generally different even when their business zones are identical.

For a housing group of long commuting distance, the maximum distance, DSMX(KHG), is the maximum commuting distance tolerable for a household for the acquisition of a house of type KHT. The maximum commuting distance is likely to vary among individuals. Thus it is treated as a random variable of normal distribution, whose average and standard deviation are estimated from the MRRS.

e. Determination of Housing Type and Residential Zone

Thus far, we have discussed how the sample household's preference order for houses is replicated in this routine. The budget constraints need to be taken into consideration for the actual acquisition of a house.

We assume that a moving household acquires a house of type KHT in residential zone KRZ which first meets the following criterion:

$$ABPAY(KHT) \geq CSTH(KHT,KRZ) \quad (7)$$

where ABPAY(KHT) = the expenditure for a house of type KHT, and CSTH(KHT, KRZ) = the price of a house of type KHT in zone KRZ.

The procedure for the determination of the housing expenditure is shown as Fig. 3. Expenditures for rental houses are determined as rent payment, while those for owner-occupied houses are determined as the payment for housing stock. In both cases, annual expenditures are determined on the basis of (1) annual household income, and (2) the ratio of the annual housing expenditure/annual household income. We know that the household belongs to an income class KYM. Let us denote the lower- and upper-income margins of class KYM by YNCML(KYM) and YNCMH(KYM) respectively. Assuming that households are uniformly distributed within an income class, the income level of the sample is determined probabilistically as:

$$YMCM = YNCML(KYM) + (YNCMH(KYM) - YNCML(KYM)) * XR \quad (8)$$

where XR denotes a random number. The ratio of annual housing expenditure/annual household income is likely to vary according to the household attributes and the house to be acquired. Moreover, even among households of similar attributes, the ratio seems to vary. Thus, the ratio for a house of type KHT, ALFA(KHT), is determined stochastically under a normal assumption,

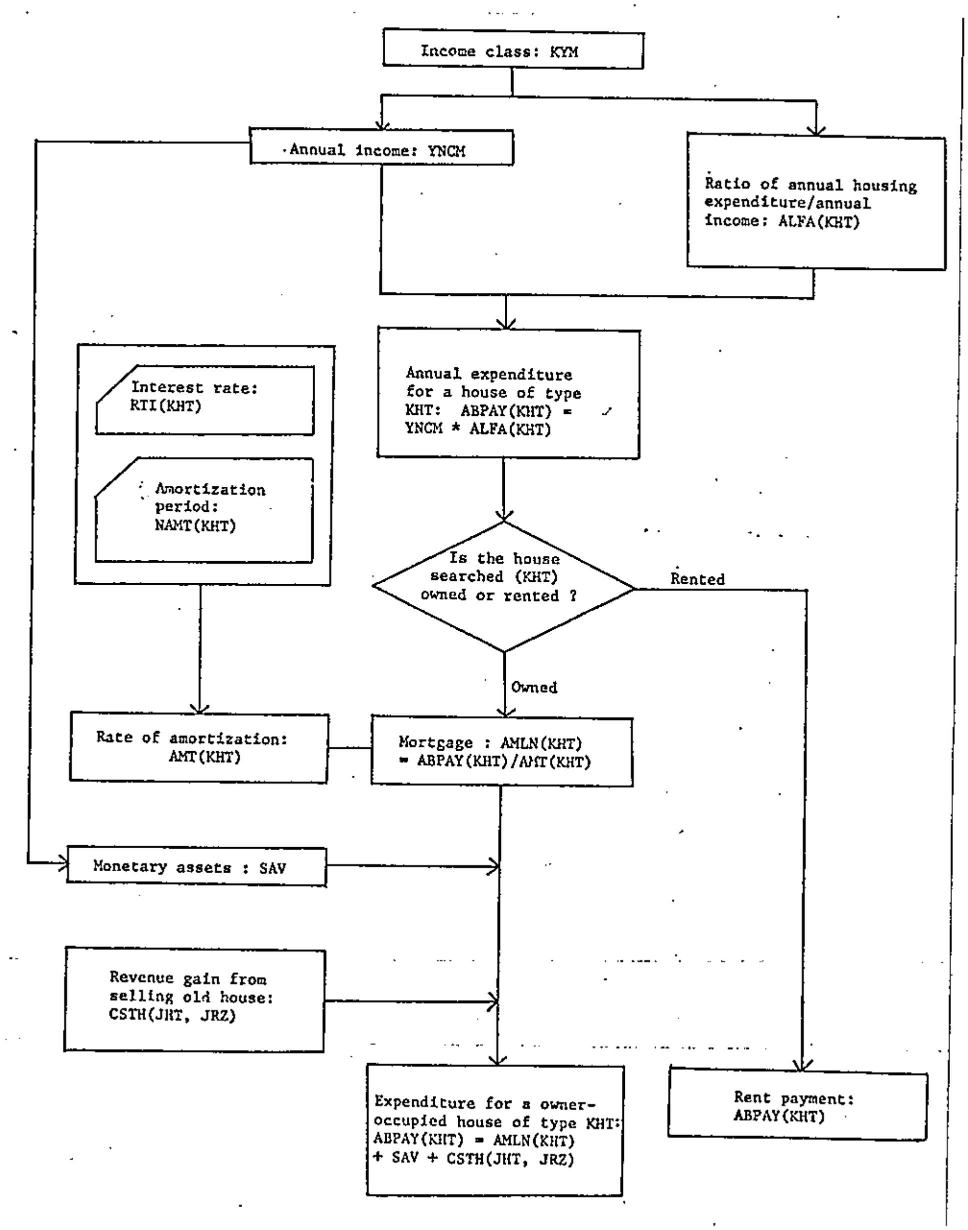


Fig. 3 Determination of Housing Expenditure

parameters for which are estimated for different income classes from the MRRS. The annual expenditure of the sample for a house of type KHT is, then, determined as:[1/]

```
ABPAY(KHT) = YNCM * ALFA(KHT)                                        (9)
```

For rented houses ABPAY(KHT) is rent payment, while for owner-occupied houses it is regarded as the mortgage payment. The amount of mortgage which the sample can borrow is:

```
AMLN(KHT) = ABPAY(KHT)/AMT(KHT)                                      (10)
```

where

```
AMT(KHT) = ((1.0 + RTI(KHT))**NAMT(KHT) * RTI(KHT))/
           ((1.0 + RTI(KHT))**NAMT(KHT) - 1.0))
         = the rate of amortization of the mortgage
           with interest rate RTI(KHT) and amortization
           period NAMT(KHT) for houses of type KHT.
```

In addition, monetary assets may be utilized for the acquisition of an owner-occupied house. The monetary assets of the sample household, SAV, is estimated as a function of income level. Moreover, if the sample is a relocating household and its housing at J is owner-occupied, it may utilize the revenue gains from selling its old house. Thus, the expenditure for owner-occupied houses of type JHT, if the sample household is a new

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1/ ABPAY(KHT) is assumed to be constant over different zones, and the commuting expenditure is neglected. This reflects the fact that, in Japan, households do not usually take commuting expenditure into account in locational decision, because firms usually supplement it.

household or if it is coming form a rental house in J, is:

ABPAY(KHT) = AMLN(KHT) + SAV (12)

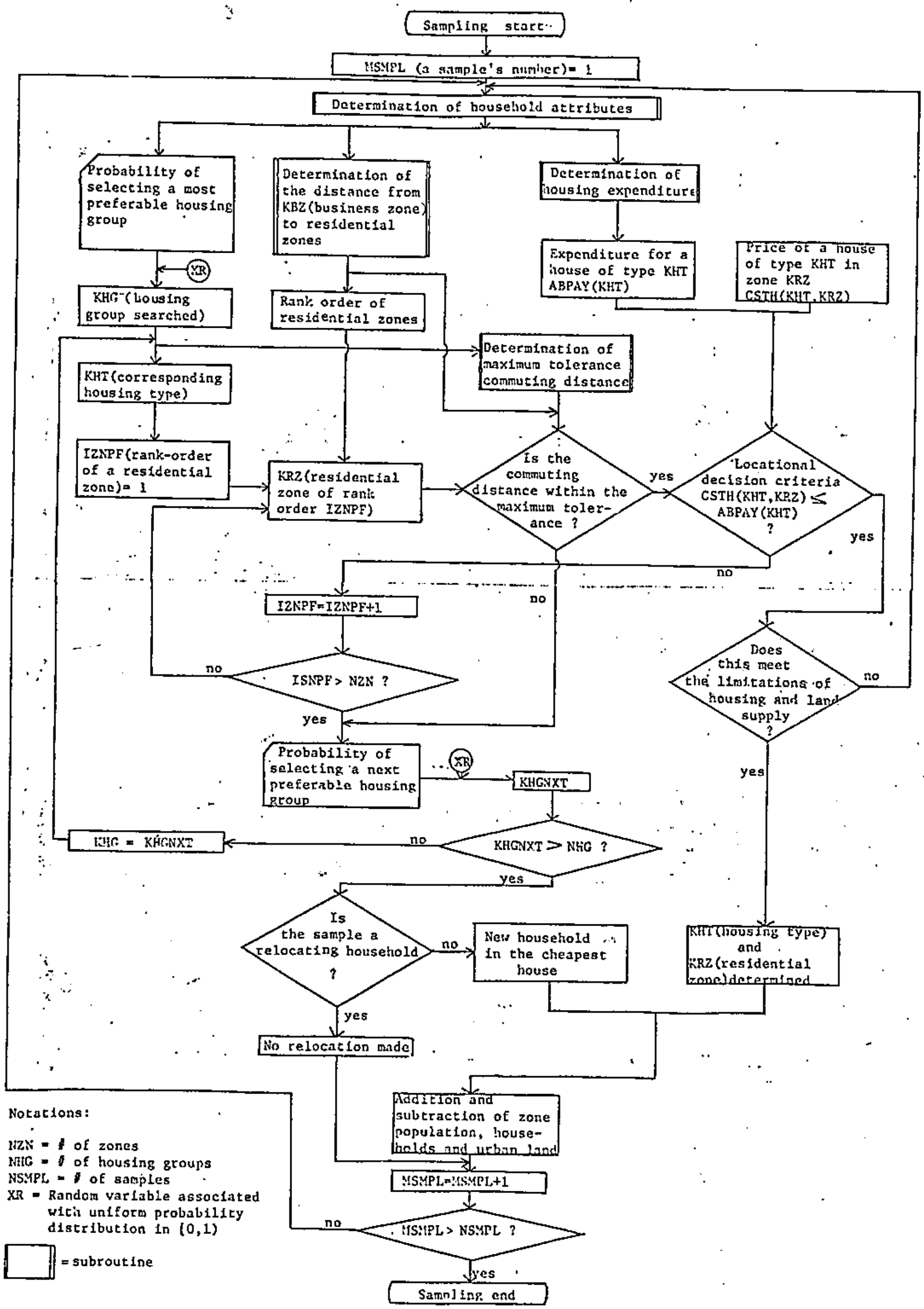
If the sample household is coming from an owner-occupied house of type JHT in zone JRZ, then the expenditure is:

ABPAY(KHT) = AMLN(KHT) + SAV + CSTH(JHT,JRZ) (13)

When the sample household is a relocating household, and if no house which meets the criterion of (7) is found, it gives up trying to acquire a new house. If the sample is a new household, it has to settle somewhere. It is often seen that households of low income reside in cheap rental houses rather close to their places of work. On the basis of this observation, we note that the sample household may settle in a rental house in a residential zone, i.e. KRZ=DSRO(IZNPF,2), where IZNPF=1.

The number of public houses in each zone is predetermined. Thus, even when the criterion (7) is met, the sample, which is looking for a public house, has to search the next zone if there is no vacancy in public houses in the present zone. Land for urban development in each zone is also limited. The feasibility of acquiring a house in a zone is examined under this limited availability of land.

Each time after a decision of housing acquisition is made by a sample household, addition and subtraction of zone values, i.e. number of households, population, and land area for urban activities, etc., are undertaken, and the information on relocation activities, i.e. change of housing type and residential zone, etc., is stored in the computer core. Detailed discussion on this procedure is not made here.



Notations:

NZN = # of zones
NHG = # of housing groups
NSMPL = # of samples
XR = Random variable associated with uniform probability distribution in (0,1)

[ ] = subroutine

Note: Housing prices are exogenouly given to this routine, but are endogenously determined in the model.

Fig. 4 Residential Search Routine of the MRRM

The structure of the residential search routine of the MRRM, which combines the procedures of the identification of the housing groups, identification of residential zones, determination of housing expenditures, and the decision criterion of housing type and residential zone, is shown in Fig. 4.

5. Outline of the Metropolitan Residential Relocation Model

The Metropolitan Residential Relocation Model is composed of three blocks, and the residential search routine discussed above constitutes block 2.
To block 1, the number of households by housing type in each zone in the initial year J is fed, and taking account of life cycle stage change in the period from year J to K and utilizing the probabilities of having a willingness to relocate of the households in different types of houses at different family cycle stages, which are estimated from the MRRS, the number of relocating households of different attributes is estimated. The number of newly formed households of different type is also estimated in the model, while the number of in-migrating households is given to the model exogenously. The estimation of the moving household in this block is proceeded by matrix algebra.
In this block, household disolution, out-migration, vacancy formation, and demolition of houses are also taken into account. Population, households by housing type, and land of urban use (public, business, and residential) in each zone before relocation and new location of moving households are estimated in this block.

Block 3 computes prices of houses of different types in each zone, CSTH(KHT,KRZ), on the basis of land prices and construction costs of structure. Stock prices are calculated for owner-occupied houses, while for rental houses rents are computed based on the payment on mortgages which are borrowed to finance the construction of the structures. Land prices provided to this block at first are those at initial year J, and the residential search of all the sample households is executed in block 2 under these prices. Certain amount of demand for residential land is associated with location of households in each zone, but this demand is regarded as only notional demand under the land prices of initial year J. Thus, in block 3, the urban land area after the simulation is compared with that of initial year J, in each zone, and the land price of the zone is revised according to the changes in urban land demand. The computation of block 2 is undertaken under these revised prices. Generally, the t-th revision of land prices is made according to the changes of urban land demand from (t-1)-th to t-th computation, and housing prices based on the land prices of t-th revision are provided for (t+1)-th computation of block 2. This procedure is continued until land prices of the zones converge to certain stable levels. The iterative structure of the model describes the mutual interaction between the micro behaviour of residential search of the households and the micro state of the housing market. The MRRM does not describe the behavior of housing and land suppliers and is essentially a demand-side model. We, however, may say that the residential search routine of the MRRM can be integrated within a comprehensive model which simulates the performance of housing market, and, thus, would satisfy requisite 5.

6. Model Execution and Some Simulation Results

The MRRM was executed for the period from 1970 (initial year J) to 1975 (projected year K). The Tokyo metropolitan region was stipulated as being composed of 184 wards, cities, towns, and villages, most of which are within a 60km radius from the Tokyo station, and was divided into 25 zones. As was indicated before, houses are divided into 13 types and, these are further dichotomized according to commuting distance into 26 groups. Households are disagregated into 16 types by the family members and the age class of head. Income classes of the households are 12.

Sampling 10,000 moving households in each computation, the model was computed 13 times iteratively. Through the iteration, the land values of the zones converged to stable levels, which were close to observations. The estimated values of zone population were also close to observed values. Among various outputs of the model, Table 3 compares a simulation result of Relocated Household Ratio, i.e. the ratio of the number of households which actually relocated to the total number of households which had willingness to relocate, which is 73.0%, with that of observation from the MRRS, which is 70.1%. Fig. 5 compares simulation result of MRRM and survey result of MRRS of Actual Acquisition Ratio of different categories of houses, i.e. the ratio of the number of the households which actually acquired houses of the category of first preference to the total number of households which attached the highest priority to that category of houses. Although there are some under-estimation of AAR's for publicly-constructed owner-occupied apartments and company-issued houses and over-estimation for privately-constructed owner-occupied apartments, the model may be said to have well described the divergence of housing demand realized in the market from the potential demand,which was detected by the MRRS.

Table 3

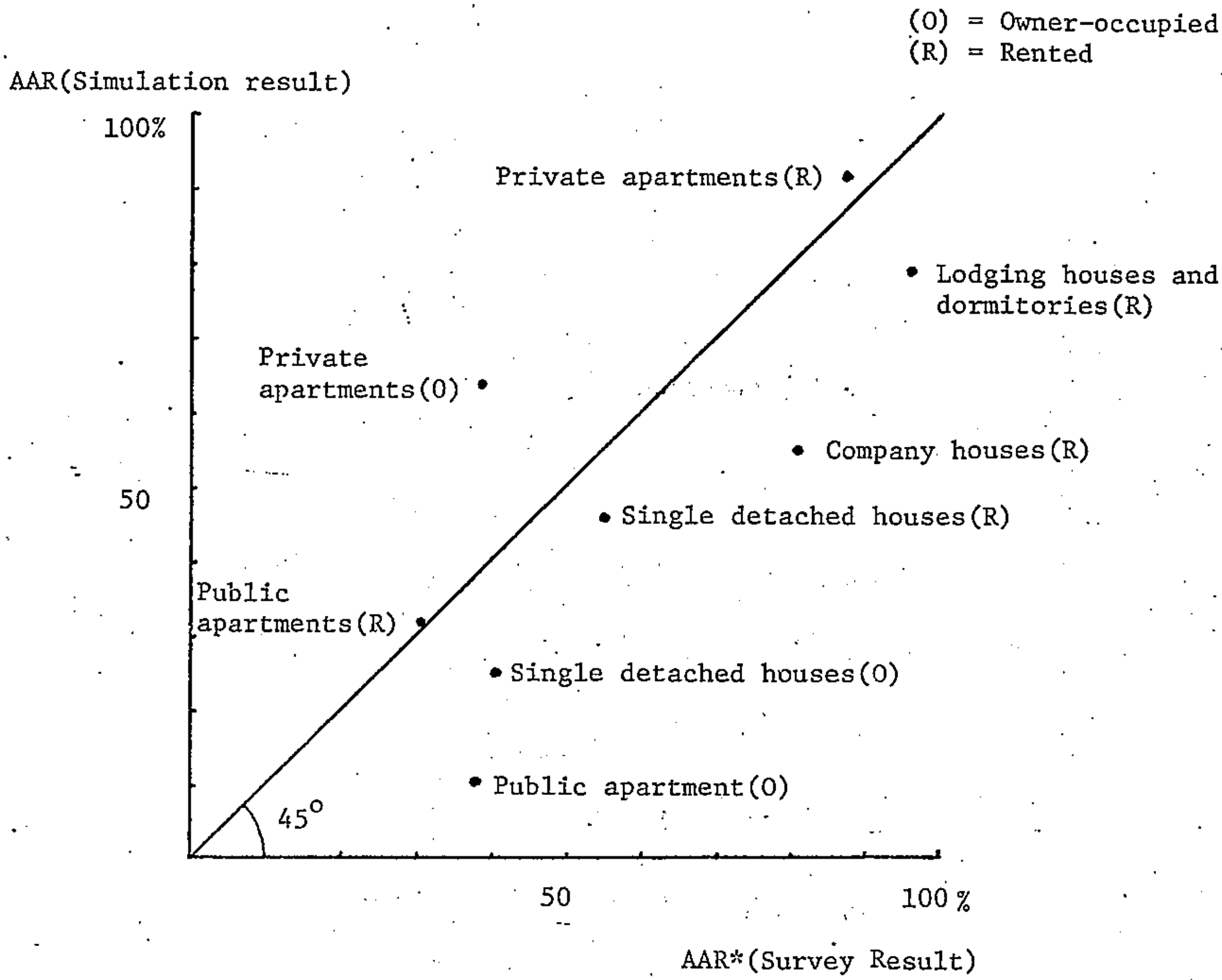
Comparison of Survey Result and Simulation Result: (1) Relocated Household Ratio

		Survey Result	Simulation result
Relocating households*	a	589 hhlds	2,393,000 hhlds
Relocated households**	b	413 hhlds	1,748,000 hhlds
Relocated household ratio	b/a	70.1%	73.0%

* Relocating households = households which had willingness to relocate.

** Relocated households = households which acutally relocated.

Note: The survey result is from the MRRS, while the simulation result is from the MRRM.



* AAR≡Actual Acquisition Ratio = (number of the households which actually acquired houses of the category of first preference/ total number of households which attached the highest priority to that category of houses)

Note: The survey result is from the MRRS, while the simulation result is from the MRRM.

Fig. 5 Comparison of Survey Result and Simulation Result: (2) Actual Aquisition Ratio of Different Categories of Houses

7. Conclusions

A residential search routine was built for the Metropolitan Residential Relocation Model. The routine, which was designed using the Monte Carlo method, satisfies several requisites for a residential search routine, and was well supported by the data available from the Metropolitan Residential Relocation Survey. The simulation results of the MRRM were plausible.

Some problems are left for future studies. First, the routine is designed with the data of housing preference as given factors. Preference for houses are, however, dependent on market condition, and the routine has to be extended to describe this. In the same line, the problems which are associated with the inclusion of housing expenditure as given factor[1/] has to be further examined. Second, only commuting distance was taken into account in the zone search process. Construction of indices of "attractiveness" of zones and inclusion of them into the zone search process has to be considered.

Further examination of these subjects is expected to elaborate the routine discussed in this paper, and, consequently, to make the MRRM a more powerful tool for policy examination.

1/ See the footnote of p.7.

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