SERIE RESEARCH MEMORANDA

A HOUSEHOLD LIFE CYCLE MODEL

FOR THE HOUSING MARKET

P. Nijkamp
L. van Wissen
A. Rima

Researchmemorandum 1988-25 augustus 1988

VRIJE UNIVERSITEIT
FACULTEIT DER ECONOMISCHE WETENSCHAPPEN
EN ECONOMETRIE
AMSTERDAM

A HOUSEHOLD LIFE CYCLE MODEL
FOR THE HOUSING MARKET

Peter Nijkamp*, Leo van Wissen*, Annemarie Rima**

Amsterdam, July 20, 1988

* Free University
Dept. of Spatial Economics
De Boelelaan 1105
1085 HV Amsterdam

** Tinbergen Institute
University of Amsterdam
Jodenbreestraat 23
1011 NH Amsterdam

1. Introduction

Dynamic spatial (urban and regional) economic models have increasingly become popular in the past years (see among others Andersson and Kuenne, 1986; Bahrenberg et al., 1984; Dendrinos and Mullally, 1985; Fischer and Nijkamp, 1987). Such models aim at describing and predicting the multidimensional compound and sometimes nested development of a dynamic spatial economic system composed of various sub-systems (housing, transportation, migration, etc.), so that its evolution can be replicated by means of plausible system's trajectories. In this context, various modeling approaches have been developed, such as:

- dynamic Lowry models (e.g. in the area of urban shopping and urban facilities analysis; cf. Wilson, 1981);
- urban ecology models (e.g. in the area of macro urban systems analysis; cf. Dendrinos and Mullally, 1983);
- micro simulation models (e.g. in the area of residential choice analysis; cf. Wegener, 1983);
- dynamic discrete choice models (e.g. in the area of locational and transportation analysis; cf. Dunn and Wrigley, 1985; Heckman, 1981); and
- master-equation models (e.g. in the area of non-linear migration analysis; cf. Barentsen and Nijkamp, 1988; Haag and Weidlich, 1984).

Despite the variety in modeling approaches there are also many striking similarities due to common theoretical or methodological underpinnings of such models (see Nijkamp and Reggiani, 1988; Rima and Van Wissen, 1987).

A consistent treatment of dynamic economic models for the various components of a compound spatial system characterized by various submodules, various aggregation levels, and various levels of precision of available data requires the use of an 'accounting framework' (Clarke and Wilson, 1985). This accounting framework is necessary for two reasons: (1) it ensures a coherent and consistent representation of a compound dynamic spatial system, and (2) it ensures a comprehensive and valid treatment of actors operating in varying socio-economic configurations (e.g. individuals, households, socio-economic groups, population as a whole).

Especially the latter point is extremely important in case of dynamic housing market research, where the demand for a dwelling exerted by a specific household is largely determined by the household composition. However, household composition is not a stable variable but subject to discrete changes (births, deaths, children becoming independent, etc.) depending on the household's position in a so-called household life cycle. Thus the macro development of an urban or regional housing market is to a large extent determined by structural changes at the micro level of households and individuals.

The present paper shows the modeling efforts and empirical estimation concerning the dynamics on an urban housing market -particularly the changes in household compositions- caused by the household life cycle phenomenon. The paper is organized as follows. Section 2 presents the position of a household model in the overall framework of a dynamic urban housing market model. In section 3 a household transition model for analyzing the effects of household life cycles is presented, followed by a presentation of empirical results for the city of Amsterdam in section 4. The paper is concluded with a discussion of feasible future research in the field of dynamic housing market research (section 5).

2. Dynamics of Households on a Housing Market: An Accounting Framework

The housing market is characterized by a variety of objects (i.e., dwellings with different size, age and quality categories) and actors (i.e., households with different size, composition and life cycle features). In the present paper the attention will be focused on the choices at the demand side of the housing market; especially in the Dutch context the supply side is an institutionally regulated market in which supply and allocation are mainly determined by complicated, rationing schemes (see also Anas and Cho, 1986). For the submodels modeling these elements of the housing market model the interested reader is referred to Van Wissen and Rima, 1988.

The demand side of our urban housing market model incorporates a detailed zonal distinction of an urban system, so that the demand effects of household dynamics can be assessed at a zonal level. Furthermore, an extensive set of different dwelling types will be distinguished in order to allow also a detailed assessment of the demand for each dwelling type in each zone. In addition to internal household dynamics caused by life cycle aspects also in- and outmigration may have a significant impact on the size and composition of actors at the demand side of the housing market. All these elements have to be incorporated in a dynamic accounting framework in order to achieve a consistent classification of models, variables and data in an organized series (vectors and matrices).

The specific position of the household dynamics model in our comprehensive urban housing market model is presented in figure 1 by means of the dashed box. Rectangles represent state matrices, double-line rectangles represent transition matrices, and the specific models to be used for estimating the transition matrices are marked with stars (see for more details on these models Van Wissen and Rima, 1988). In the present paper we will exclusively focus attention on the household submodule (including demographic changes caused by birth, death or ageing, and changes in household membership states of individuals) and its relation to the housing demand.

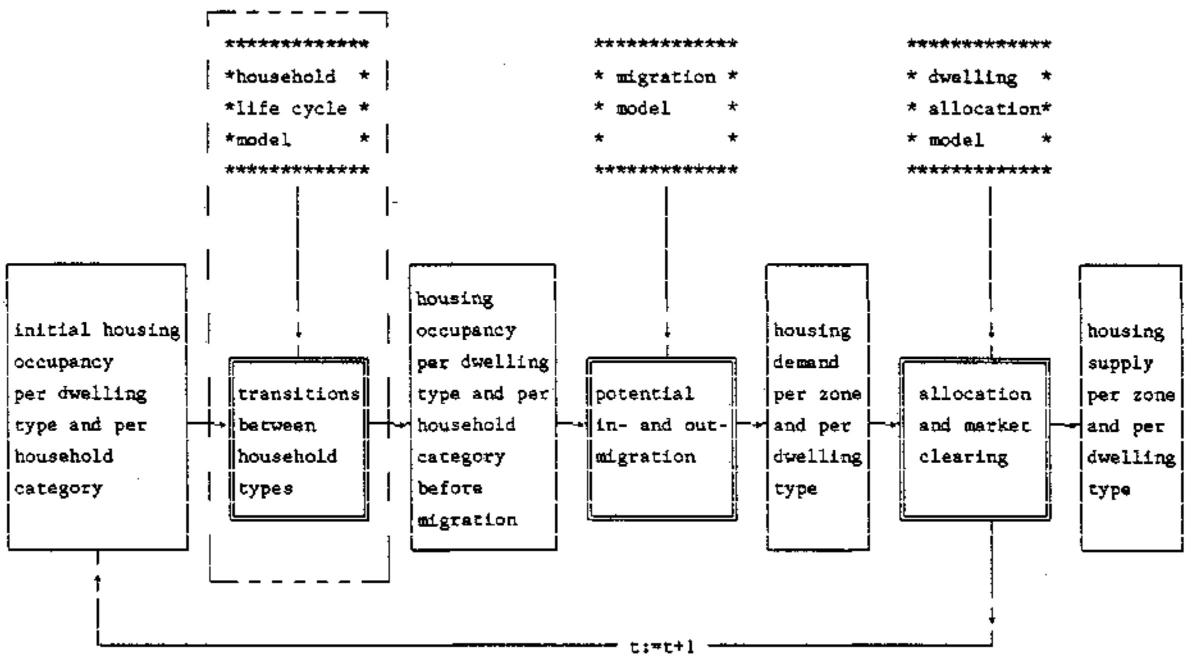

Figure 1. Accounting framework for household module as part of a dynamic housing market model

3. The Household Life Cycle Model

Household dynamics is a complex process, not only because of birth, death and ageing, but also because of household formation processes: households may split and rejoin in many ways thus affecting the total number of households. The estimation of the transition matrix for different household categories (according to size, age and composition) may be based on two approaches (see Keilman, 1984a,b):

- individual transition probabilities for a membership of household class i in period t to i' in t+1 (i,i'=1,..,I) (cf. Möller, 1982)
- household transition probabilities for different household classes (cf. Webber, 1983)

The first approach is straightforward and in agreement with many demographic data bases (e.g. on birth, death, marital status, household membership, etc.), but a drawback of this approach stems from its inherent consistency problems (e.g., the two-sex problem in the marital status table; see Keilman, 1984b). The second approach corresponds to the needs for assessing housing demand at a household level, but faces the problem of defining and measuring households. In this context the headship rate method is sometimes used (see Keilman, 1984a), but this method is unable to incorporate household dynamics. In our approach we will combine the individual and household level in one model to overcome the consistency problem (cf. Hårsman and Snickars, 1983; Willekens, 1984).

As such, our dynamic household model contains various components, like the assessment of individual transition probabilities for discrete changes in positions in a given household by means of multistate demography (cf. Rogers, 1973, 1975; Rogers and Ledent, 1975; Ledent, 1980; Willekens, 1980; Willekens and Drewe, 1984). Explicit continuity rules (McMillan and Herriot, 1985) for deriving household events from individual events are given as well. This implies that the existence of a given household is tied to a given member of the household (usually the head), so that continuation of the household unit is also guaranteed when two or more household members are splitting up. The household composition matrix provides a consistent link between the household distribution and the population by age (Akkerman, 1980, 1982, 1985), while the occupancy table links the housing market situation of each household to dynamic household events. The main ingredients of our specific household model will now briefly be described below.

The heart of the household model is the household transition table R, with elements $\{r_{gg'}; g=1,..,G,G+1; g'=1,..,G',G'+1\}$. The index g refers to household categories at the beginning of the time interval, while g=G+1 denotes new household formations. Likewise, index g' denotes household categories at the end of the time interval, while g'=G'+1 denotes household dissolutions. In our model one-year intervals are used. So the last row of R gives the household formations by type g' and the last column of R denotes household dissolutions by type g (see also Table 1). R is derived from the table T of individual transitions by position in the household, with elements $\{t_{hh'}; h=1,..,H, H+1; h'=1,..,H', H'+1\}$. h denotes individual positions in the household at the beginning of the one-year interval, while h' indexes the positions in the household at the end of the one-year interval. Index h=H+1 denotes inflows into household positions (births, change from a non-household to a household position), while h'=H'+1 denotes deaths. The household positions distinguished are: child, single, head (by size of the respective household: 2, 3, 4+) and partner (see also Table 1). Births and deaths are included as well, so that T represents a complete individual population projection matrix of household positions.

The transition probabilities $t_{hh'}$ are estimated from longitudinal data using the methodology of multistate demography. This involves the empirical estimation of individual age-specific transition rates $\mu_{hh'}(x)$, where x denotes age of the person. This empirical estimation is established by fitting a number of transition rate functions with the use of observed age-specific transition rates. Two types of functions were used, viz. the log-normal and the negative-exponential form. Next, these transition rates are organized in matrices μ (x) of the form (Ledent, 1980):

$$\mu(x) = \begin{bmatrix} \mu^*_{11}(x) & -\mu_{12}(x) & .. & .. & .. & -\mu_{1H'}(x) \\ -\mu_{21}(x) & \mu^*_{22}(x) & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & \mu^*_{ii}(x) & .. & .. \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. \\ -\mu_{H1}(x) & .. & .. & .. & .. & \mu^*_{HH'}(x) \end{bmatrix} \qquad (1)$$

The diagonal elements $\mu^*_{hh'}(x)$ denote the total force of mobility in the household h to a non-household position, whereas the off-diagonal elements contain minus the force of mobility from position h to h', i.e. $-\mu_{hh'}(x)$. The diagonal elements are defined as:

$$\mu^*_{hh'}(x) = \Sigma_{h' \neq h} \mu_{hh'}(x) + \mu_{hd}(x) \qquad (2)$$

where $\mu_{hd}(x)$ is the death rate. The matrix of individual age-specific transition rates can be used to estimate the matrix T(x) of individual transition probabilities between the positions in the household (see also Ledent, 1980; Willekens, 1980):

$$T(x) = \left[I + \frac{1}{2} \mu(x) \right]^{-1} \left[I - \frac{1}{2} \mu(x) \right] \qquad (3)$$

Through aggregation of T to R, the number of household events (viz. changes in composition of existing households, household formations and dissolutions) can be derived. In general, an individual transition from a non-head or single person to a head or single person is a household formation event, whereas a change from a head or single person to partner or child is a household dissolution. Changes within the positions of single person or head reflect changes in household size of existing households. In our model households are further typified by means of age of the head, while in our empirical study the total number of household categories is 24 (see also Table 2). In the next section an empirical example of analyzing such household transitions is given.

Given table R, it is possible to relate the abovementioned events to residential mobility of households. Various authors (e.g. Rossi, 1955; Gleave and Cordey-Hayes, 1977; Clark and van Lierop, 1987) have pointed out that changes in the household life cycle together with the current housing market situation provides the basic stimulus for the residential moving process. This can be incorporated in an accounting framework if we relate the household transition table R to the occupancy status of the household, represented by the occupancy table C, where $C = \{c_{kg};\ k=1,..,K;\ g=1,..,G\}$ is the complete cross-classification of households by household type g and by housing submarket k at the beginning of a given one-year time interval. Table 2 provides a complete overview of the household (table 2A) and housing submarket (table 2B) categories used within each zone in the system under consideration.

It should be noted that household category G+1 (i.e., the class of new household formations) is not included here since these households do not yet occupy a dwelling unit. The information related to the housing submarket index k can include all relevant explanatory factors for residential mobility, e.g. housing size, type and tenure, price quality etc. The information in C and R can be combined in the following way:

$$o_{kgg'} = c^*_{kg} \cdot r_{gg'} \qquad (4)$$
$$(k=1,..,K;\ g,\ g'=1,..,G)$$

where $O = \{o_{kgg'}\}$ denotes the <u>extended occupancy table</u> including household transitions and where c^* is a scale factor for the original value of c:

$$c^*_{kg} = c_{kg} \,/\, c_{+g} \qquad (5)$$

where '+' is the summation sign, so that

$$\Sigma_k c^*_{kg} = 1 \qquad (6)$$

Table O represents thus the complete breakdown of all households in terms of housing market characteristics and household transitions. Now a model of residential mobility can be formulated that incorporates all the information contained in O. We can construct a <u>movers table</u> M with the same dimensions as the extended occupancy table and elements $\{m_{kgg'}\}$ derived from O by means of a standard multiplicative model:

$$m_{kgg'} = \alpha_k \beta_{gg'} \tau_{kg'} o_{kgg'} \qquad (7)$$

where $m_{kgg'}$ represents the number of movers in housing submarket k with a transition from household category g to g'.

The set of coefficients α_k relates to characteristics of the current housing submarket k, $\beta_{gg'}$ relates to the event of a household transition from category g to g' (life cycle dynamics) and $\tau_{kg'}$ relates to the combined effect of household characteristics in relation to dwelling type (e.g. room stress). In our model a logit formulation was used to estimate α, β and τ. Now it is clear that

$$p_{kgg'} = \alpha_k \beta_{gg'} \tau_{kg'} \quad (8)$$

is the probability that a household in dwelling type k and with a household transition from category g to g' will change residence in the given one-year time interval, i.e.:

$$m_{kgg'} = p_{kgg'} \cdot o_{kgg'} \quad (9)$$

Figure 2 shows the relation between the tables **T**, **R**, **C**, **O** and **M**. In the next section the variables and coefficient values used in our model will be discussed in more detail.

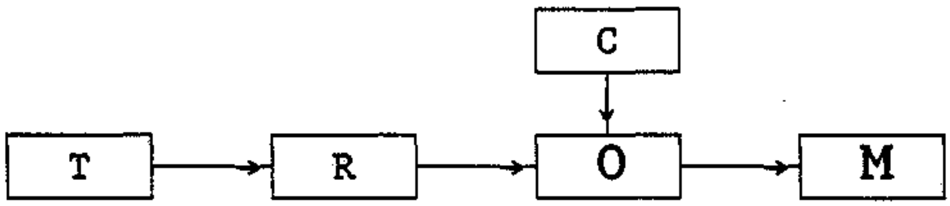

Figure 2. Linkages between the household tables T, R, C, O and M. (see text for explanation)

4. <u>Empirical Results</u>

The empirical estimation of the individual transition table T from equations (1) to (3) and the consistent linking of dynamic household events to the housing market situation in an accounting framework for Amsterdam (equations (4) to (6)) appeared to be a formidable and time consuming task, especially because data from different sources and years had to be integrated (viz. the population census 1971 (CBS, 1971), demographic data from Amsterdam (Amsterdam, 1971-1986) and data from the National Housing Needs Survey from 1981 (WBO, 1983)).

The urban region of Amsterdam was subdivided into 20 zones (see Figure 3) and the household model was run separately for each of these zones. In the present paper results of the household model and the housing demand model will only be shown for the year 1984 for the city of Amsterdam (zones 1 through 11). Table 1 shows the individual transitions between positions in the household and the aggregated household transition table for the total city of Amsterdam as estimated by the household model.

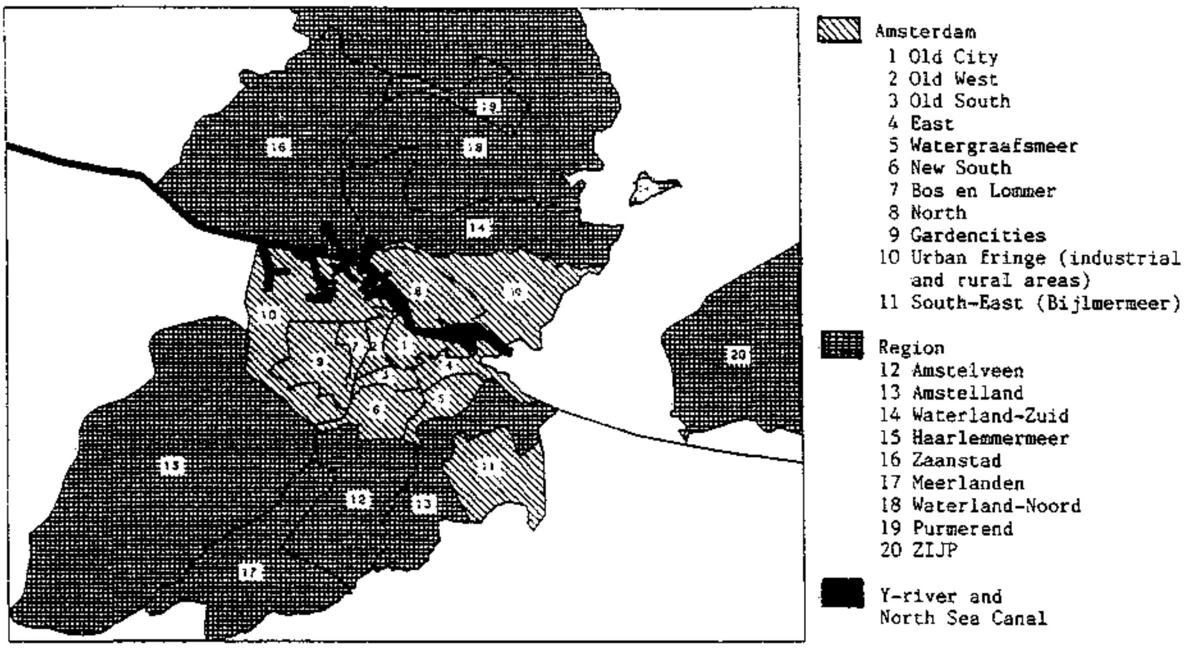

Figure 3. The study area divided in 20 zones

	Individual transitions								
	t=2								
t=1	child	single	hd 2p	hd 3p	hd 4+p	part.	non-h	dead	total
child	129927	5826	1984	121	20	2316	3	112	140309
single	0	137786	2277	1139	38	2025	759	2668	146692
head 2p	0	1590	86979	2413	158	199	1119	1797	94255
head 3p	0	221	2581	42234	1741	101	102	372	47352
head 4+	0	74	112	1473	34620	77	126	397	36879
partner	0	4039	215	140	84	165052	226	682	170438
non-hh	6241*	28	27	26	26	27	23381	1174	30930
total	136168	149564	94175	47546	36687	169797	25716	7202	666855

	Household transitions					
	t=2					
t=1	single	2 pp	3 pp	4+pp	diss.	tot
1	137786	2277	1139	38	694	141240
2	3616	86979	2423	158	745	93176
3	221	3021	42243	1741	204	47226
4	74	112	1760	34810	204	36756
new	7867	1786	29	0	0	9682
tot	141697	92389	47565	36747	1847	318398

Table 1. Estimated individual transitions in position in the household and aggregated household transitions in 1984 in Amsterdam
* births
Legend: hd=head; non-h=non household member; 2 (3, 4+)p=two (three, four+) person household; part.=partner; new=new household formations; diss.=household dissolutions; tot=total

	household size			
age of head	1	2	3	4+
1) <25	1	2	3	4
2) 25-34	5	6	7	8
3) 35-44	9	10	11	12
4) 45-54	13	14	15	16
5) 55-64	17	18	19	20
6) 65+	21	22	23	24

Table 2A. The definition of the 24 household types

	no. of rooms			
dwelling type	1-2	3	4	5+
rented apartments	1	5	6	9
owner occ. apartments	2	2	2	2
rented single family	3	3	7	10
owner occ. single fam.	4	4	8	11

Table 2B. The definition of the 11 dwelling types

These transitions pertain to the population alive and resident in the city of Amsterdam at the beginning of 1984. If the city were a closed system this table could be used for population and household forecasts. However, the population and household composition will also change as a result of in- and outmigration (see also Figure 1).

A closer look at the marginal totals of the transitions in Table 1 teaches us that these show the net change in the household composition of the cohort. While there is a net increase in the total number of households (9682 - 1847 = 7835, or 2.5 percent), the increase in the number of singles is only 0.3 percent (141697 - 141240 = + 457), while the number of two person households decreases slightly (-787, or -0.8 percent). The other household categories remain relatively constant.

Another interesting feature is the stability of the household categories. A simple measure of stability is the percentage of all households which do not change (i.e. the main diagonal entries as percentage of the row totals). It is noteworthy to observe that singles are the most stable group: 97.6 percent remains single. Three person households tend to change most: only 89.4 percent does not change in one year.

Combining the household transition table with the housing market situation of the household is now straightforward (see equation (4)). As an example we take the group of households living in a rented apartment with one or two rooms in Amsterdam (dwelling type 1, see Table 2B). From the occupancy table the size distribution of this household group can be determined. Next, household transitions are estimated with the dynamic household model (1)-(3); the result is given in Table 3. This table is a small part of the entire extended occupancy table O. This table O can be used to predict residential mobility at a highly disaggregate level (equations (7) and (8)).

size primo 1984	size ultimo 1984					total
	single	2 pers.	3 pers.	4+pers.	dissol.	
single	14813	319	154	2	53	15841
2 persons	55	1533	50	1	31	1670
3 persons	0	0	195	8	7	215
4+ persons	0	0	0	10	2	12
total	14868	1852	399	21	93	17738

Table 3. Estimated household transitions for households in 2-room rental apartments (dwelling type 1) in Amsterdam

In the Amsterdam model a number of key variables were regarded as relevant for predicting residential mobility. In Table 4 these variables are shown together with the pertaining coefficients. These estimates were derived from sample information (viz. the National Housing Survey 1981 and the Noordvleugel Study (NEI, 1980, 1981, 1983a,b, for more details on these explanatory variables the reader is referred to Van Wissen and Rima, 1988). Moreover, the coefficients pertain to the propensity to change residence, not to the actual move.

variables	coefficients
- (household size t=2-number of rooms)/number of rooms)	0.66028
- single family unit/flat (flat=1)	0.65677
- tenure status rent/buy (buy=1)	-0.54641
- log(household size t=1/ household size t=2)	-3.70322
- age	-0.02733

Table 4. Coefficients used in the calculation of the residential mobility preferences in Amsterdam (all coefficients were estimated from sample data and were significantly different from zero at the 95 % confidence level)

In many countries supply side considerations and market constraints have to be taken into account in order to explain the revealed migration decisions of households. In the Amsterdam model the household life cycle transitions have a direct impact on the propensity to move. This is shown in the estimated coefficient of the variable "log(household size t=1/household size t=2)" in Table 4. The negative value of this coefficient implies that household growth has a positive impact on the propensity to move. This is depicted in Tables 5 and 6 for the households in dwelling type 1 in Amsterdam. In Table 5 the estimated probabilities of households which are willing-to-move is given as a function of household transitions. The figures presented here pertain to the smallest and lowest quality dwellings in the city so that here the estimated probabilities are quite high. A decrease in household size has a diminishing effect on the willingness to move.

size primo 1984	size ultimo 1984			
	single	2 p.	3 p.	4+ p.
single	.41	.93	.99	1.00
2 p.	.05	.49	.86	.96
3 p.	.01	.18	.58	.85
4+ p.	.00	.07	.32	.65

Table 5. Estimated propensity to move for households in dwelling type 1 by transition category
Legend: 2 (3, 4+) p.: two (three, four+) person household

The effect of dwelling size versus household size is clear if we compare the entries in the main diagonal. The propensity to change residence increases if household size increases relative to dwelling size.

size primo 1984	size ultimo 1984			
	single	2 p.	3 p.	4+ p.
single	6073	297	152	2
2 p.	3	751	43	1
3 p.	0	1	113	7
4+ p.	0	0	0	7
total	6076	1049	308	17

Table 6. Expected mover-pool of households in dwelling type 1 by transition category
Legend: 2 (3, 4+) p.: two (three, four+) person household

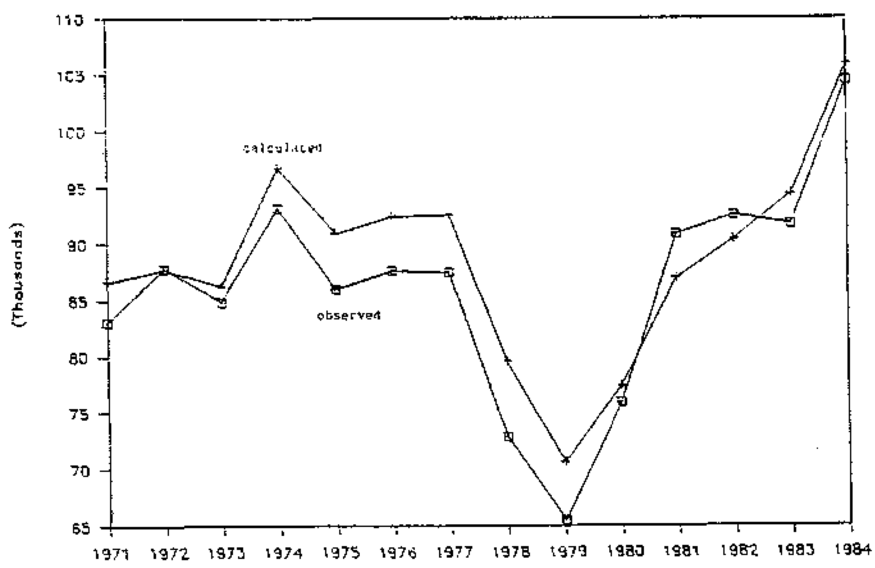

Figure 4. Intra-zonal migration within Amsterdam, 1971-1984

Housing demand cannot be observed directly at the regional level. Only the outcome of the matching of total demand and supply is observable by means of migration flows. The combined effect of life cycle dynamics and migration is a change in the household composition at the zonal level. Although the allocation model itself is treated elsewhere (Rima et al, 1987, Van Wissen and Rima, 1988), some results are presented here.

In Figure 4 total intrazonal migration Amsterdam is depicted for the period 1971-1984. The model outcomes reflect strongly the observed trend: a sharp decrease in mobility at the end of the seventies, followed by a strong increase in the eighties.

Next, Figure 5 shows the model outcomes for the development of households by size and by age class of the head in the period 1971-1984 for the city of Amsterdam.

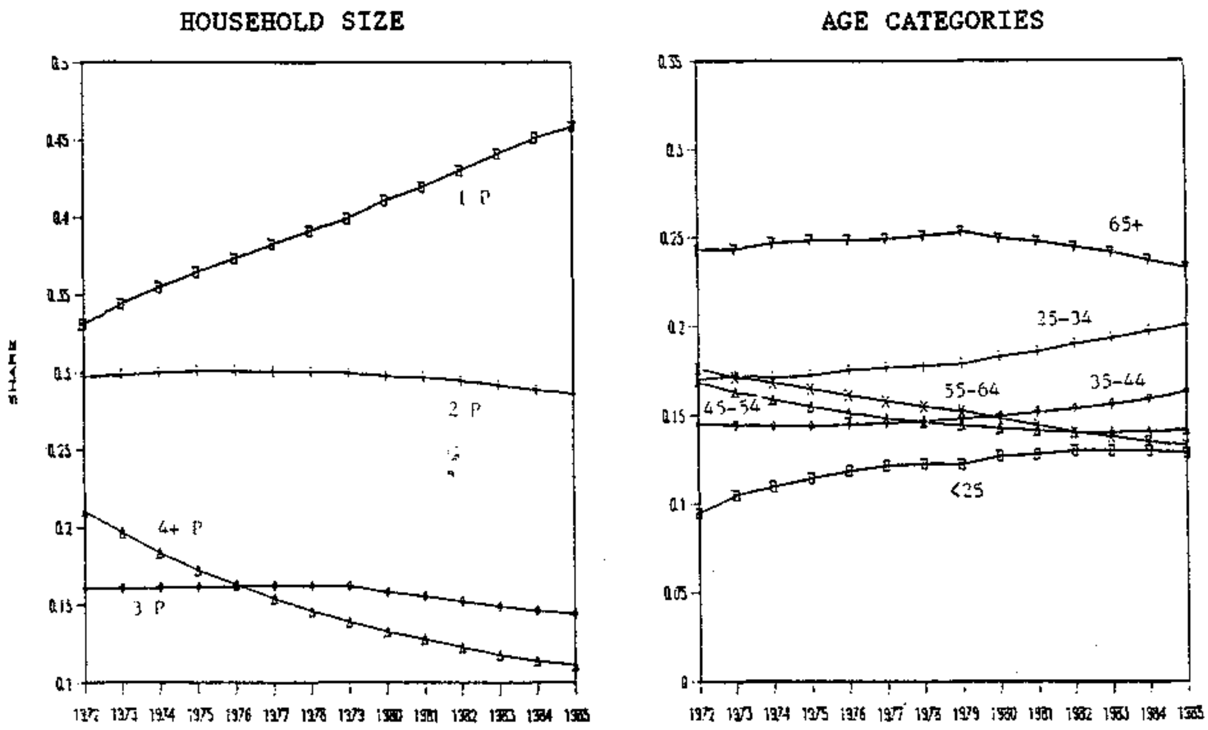

Figure 5. Developments in household size and age categories in Amsterdam, 1972-1984

Household information for determining the goodness of fit of the model was only available for the year 1982. Table 7 shows the results of comparisons between predicted and observed figures. The results for Amsterdam as a whole were satisfactory.

Variables	Predicted	Observed
1. Totals		
Population	697	701
Household	325	330
2. Size		
single	43 %	42 - 44 %
two persons	29 %	31 - 33 %
three persons	15 %	12 - 13 %
four+ persons	12 %	12 - 15 %
3. Age of head		
0 - 24 Y.	13 %	9 %
25 - 34 Y.	19 %	25 %
35 - 44 Y.	15 %	15 %
45 - 54 Y.	14 %	13 %
55 - 64 Y.	14 %	15 %
65 + Y.	24 %	24 %

Table 7. Observed and predicted outcomes for total population, total households and households by size and age of head in Amsterdam (1982)

5. Epilogue

In the present paper the dynamic household model has been presented in the context of housing market demand. As can be seen from the empirical results in section 5, the model is well capable of reproducing the developments on the housing market at the disaggregate level. As such, the model can be used for policy questions on different zonal levels and for forecasting future housing market developments.

It can be concluded that the life cycle concept is a very fruitful concept for predicting household mobility. The household life cycle is modeled by means of multistate demography which turned out to be a very useful device for studying the household development process. The multistate life table is a most elegant and sophisticated technique to be used at the micro scale of household dynamics. The level of analysis in the household model is the individual one. The transition probabilities can be derived at the individual level, and the consequences for the household level can be constructed through the household composition matrix. All problems concerning the individual-household dichotomy are not solved however. This will probably be one of the future major research topics in household demography in years to come.

The multistate life table focusses on the age- and time-dependency of household transitions. A further development would be to make the transition rates endogenous. So instead of a rate $\mu(x)$ (x being age, see model (1)) a more general formulation could be $\mu(\underline{z})$ where $\underline{z}$ is a vector of relevant variables. If such a function could be specified and estimated, the problems encountered in the present household model with the time-variance of the demographic intensities could in principle be solved. Another interesting development could be to extend the state space of th[illegible] demographic model to include housing market aspects. A simultaneou[illegible] treatment of housing market decisions and life cycle decisions woul[illegible] be feasible in such a model. However, the micro-economic theory und[illegible]ying the random utility models such as the logit model used would [illegible]ve to be translated to this multistate form and much work has still [illegible]e done in this field.

The [illegible] requirements of a dynamic household model are large. The applicabi[illegible] of multistate demography in modeling household dynamics hinges on [illegible] availability of data. In absence of census information on household [illegible]amics data estimation techniques had to be used. A longitudinal s[illegible] can provide transition rates that cannot be observed in a cross-s[illegible]onal survey. If such a data source is available, the choice of [illegible]ultistate model is no doubt a good strategy for household modelling [illegible] a micro scale. In this respect, the availability of a longitudi[illegible] data set in which the transition rates can be distinguished in t[illegible] and by zone is necessary for the empirical testing of sophistic[illegible] demographic modelling and could certainly stimulate further r[illegible]ch in this field.

<u>Referenc[illegible]</u>

- Akkerma[illegible]., 1980, On the Relationship between Household Composition and Po[illegible]ion Age Distribution, <u>Populations Studies</u>, vol. 34, pp. 525-53[illegible]
- Akkerma[illegible]., 1982, Demographic Input to Regional Planning, <u>Demosystems</u>, E[illegible]ton.
- Akkerma[illegible]., 1985, The Household Composition Matrix as a Notion in Multire[illegible]al Forecasting of Population and Households, <u>Environment and Pla[illegible] A</u>, vol. 17, pp. 355-371.
- Amsterda[illegible] in Cijfers, 1971-1986, Yearbooks of Amsterdam, Bestuursinformatie [illegible]meente Amsterdam, afdeling Statistiek.

- Anas, A., and J.R. Cho, 1986, A Dynamic, Policy Oriented Model of the Regulated Housing Market: the Swedish Prototype, Research Paper, Northwestern University, Evanston, Illinois.

- Andersson, A.E., and R.E. Kuenne, 1986, Regional Economic Dynamics, Handbook of Regional Economics, vol. 1, P. Nijkamp (ed.), North-Holland Publ. Co., Amsterdam, pp. 201-256.

- Bahrenberg, G., M.M. Fischer and P. Nijkamp (eds.), 1984, Recent Developments in Spatial Data Analysis: Methodology, Measurement and Models, Gower, Aldershot.

- Barentsen, W., and P. Nijkamp, 1988, Non-linear Dynamic Modelling of Spatial Interactions, Environment and Planning A, (forthcoming).

- CBS, 1971, Central Bureau of Statistics, Volkstelling, 's-Gravenhage.

- Clark, W.A.V., and W.F.J. Van Lierop, 1987, Residential Mobility and Household Location Modelling, Handbook of Regional Economics, vol. 1, P. Nijkamp (ed.), North-Holland Publ. Co., Amsterdam, pp. 97-132.

- Clarke, M., and A.G. Wilson, 1985, A Framework for Dynamic Comprehensive Urban Models: the Integration of Accounting and Micro-Simulation Approaches, paper of the 25th RSA conference, Budapest, August.

- Dendrinos, D.S., and H. Mullally, 1983, Optimal Control in Nonlinear Ecological Dynamics of Metropolitan Areas, Environment and Planning A, vol. 15, pp. 543-550.

- Dendrinos, D.S., and H. Mullally, 1985, Urban Evolution, Oxford University Press, New York.

- Dunn, R., and N. Wrigley, 1985, Beta-Logistic Models of Urban Shopping Centre Choice, Geographical Analysis, nr. 17, pp. 95-113.

- Fischer, M.M., and P. Nijkamp, 1987, From Static towards Dynamic Discrete Choice Modelling, A State of the Art Review, Regional Science and Urban Economics, vol. 17, pp. 3-27.

- Gleave, D., and M. Cordey-Hayes, 1977, Migration Dynamics and Labour Market Turnover, Progress in Planning, no. 8, pp. 1-96.

- Haag, G., and W. Weidlich, 1984, A Stochastic Theory of Interregional Migration, Geographical Analysis, vol. 16, no. 4, pp. 331-357.

- Hårsman, B., and F. Snickars, 1983, A Method for Disaggregate Household Forecasts, Tijdschrift voor Economische en Sociale Geografie, vol. 74, no. 4, pp. 282-290.

- Heckman, J.J., 1981, Statistical Models for Discrete Panel Data, Structural Analysis of Discrete Data with Econometric Applications, C.F. Manski and D. McFadden (eds.), the MIT Press, Cambridge (Mass.), pp. 114-178.

- Keilman, N., 1984a, Dynamic Household Models, paper presented at the NIDI-workshop 'Modelling of Household Formation and Dissolution', 12-14 December, Voorburg, The Netherlands.

- Keilman, N., 1984b, Internal and External Consistency in Multidimensional Population Projection Models, paper Annual Meeting of the Population Association of America, Minneapolis, Minnesota, May 3-5.

- Ledent, J., 1980, Multistate (increment-decrement) Life Tables: Movement versus Transition Perspectives, Environment and Planning A, vol. 12, pp. 553-562.

- McMillan, D.B., and R. Herriot, 1985, Towards a Longitudinal Definition of Households, Journal of Economic and Social Measurement, vol. 13, no. 3/4, pp. 349-360.

- Möller, K.P., 1982, Entwicklung von Bevölkerung und Haushalten in der Bundesrepublik Deutschland bis zum Jahre 2000, Duncker und Humblot, Berlin.

- NEI, 1980, Verkeers- en locatiegedrag in het Noordelijke deel van de Randstad, deelrapport 1, Rotterdam.

- NEI, 1981, Woon- en Werkplaatsveranderingen in de Noordvleugel van de Randstad, deelrapport 2, Rotterdam.

- NEI, 1983a, Woon- en Werkplaatsveranderingen in de Noordvleugel van de Randstad, deelrapport 3, Rotterdam.

- NEI, 1983b, Woon- en Werkplaatsveranderingen in de Noordvleugel van de Randstad, deelrapport 4, Rotterdam.

- Nijkamp, P., and A. Reggiani, 1988, Dynamic Spatial Interaction Models: New Directions, Environment and Planning A, 1988 (forthcoming).

- Rima, A., and L.J.G. van Wissen, 1987, A Dynamic Model of Household Relocation: a Case Study for the Amsterdam Region, PhD-thesis, Free University Press, Amsterdam.

- Rima, A., L.J.G. van Wissen and P. Nijkamp, 1988, Some Empirical Results of the Dynamic Model of Household Relocation for the Amsterdam Region, Netherlands Journal of Housing and Environmental Research, vol. 2, no. 4, Delft University Press, pp. 357-369.

- Rogers, A., 1973, The Mathematics of Multiregional Demographic Growth, Environment and Planning A, vol. 5, pp. 3-29.

- Rogers, A., 1975, Introduction to Multiregional Mathematical Demography, Wiley, New York.

- Rogers, A., and J. Ledent, 1975, Multiregional Population Projection, DP-128, Center for Mathematical Studies in Economics and Management Science, Northwestern University, Evanston, Illinois.

- Rossi, 1955, Why Families Move, The Free Press, Glencoe.

- Van Wissen, L.J.G. and A. Rima, 1988, Modelling Urban Housing Market Dynamics, North-Holland Publ. Co., Amsterdam.

- WBO, 1983, Woningbehoefte-onderzoek 1981, Central Bureau of Statistics, The Hague.

- Webber, M.J., 1983, Life-cycle Stages, Mobility, and Metropolitan Change: 2. A model of migration, Environment and Planning A, vol. 15, pp. 307-317.

- Wegener, M., 1983, A Simulation Study of Movement in the Dortmund Housing Market, Tijdschrift voor Economische en Sociale Geografie, vol. 74, no. 4, pp. 267-281.

- Willekens, F.J., 1980, Multistate Analysis: Tables of Working Life, Environment and Planning A, vol. 12, pp. 563-588.

- Willekens, F.J., 1984, The Marital Status Life Table, Family Demography, Models and Applications, J. Bongaarts et al. (eds.), Oxford University Press, London.

- Willekens, F.J., and P. Drewe, 1984, A Multiregional Model for Regional Demographic Projection, Demographic Research and Spatial Policy, H. ter Heide and F.J. Willekens (eds.), Academic Press, London, pp. 309-334.

- Wilson, A.G., 1981, Catastrophe Theory and Bifurcations: applications to urban and regional systems, Croom Helm, London.

1986-1	Peter Nijkamp	New Technology and Regional Development
1986-2	Floor Brouwer Peter Nijkamp	Aspects and Application of an Integrated Environmental Model with a Satellite Design (E 85/4)
1986-3	Peter Nijkamp	25 Years of Regional Science: Retrospect and Prospect
1986-4	Peter Nijkamp	Information Centre Policy in a Spatial Perspective
1986-5	Peter Nijkamp	Structural Dynamics in Cities
1986-6	Peter Nijkamp Jacques Poot	Dynamics of Generalised Spatial Interaction Models
1986-7	Henk Folmer Peter Nijkamp	Methodological Aspects of Impact Analysis of Regional Economic Policy
1986-8	Floor Brouwer Peter Nijkamp	Mixed Qualitative Calculus as a Tool in Policy Modeling
1986-9	Han Dieperink Peter Nijkamp	Spatial Dispersion of Industrial Innovation: a Case Study for the Netherlands
1986-10	Peter Nijkamp Aura Reggiani	A Synthesis between Macro and Micro Models in Spatial Interaction Analysis, with Special Reference to Dynamics
1986-11	E.R.K. Spoor	De fundamenten van LINC
1986-12	V. Kouwenhoven A. Twijnstra	Overheidsbetrekkingen in de strategie en organisatie van ondernemingen
1986-13	F.C. Palm E. Vogelvang	A short run econometric analysis of the international coffee market
1986-14	M. Wortel A. Twijnstra	Flexibele Pensioenering
1986-15	A. de Grip	Causes of Labour Market Imperfections in the Dutch Construction Industry
1986-16	F.C. Palm C.C.A. Winder	The Stochastic life cycle consumption model: theoretical results and empirical evidence
1986-17	Guus Holtgrefe	DSS for Strategic Planning Purposes: a Future Source of Management Suspicion and Disappointment?
1986-18	H. Visser H.G. Eijgenhuijsen J. Koelewijn	The financing of industry in The Netherlands
1986-19	T. Wolters	Onderhandeling en bemiddeling in het beroepsgoederenvervoer over de weg
1986-20	S.C.W. Eijffinger J.W. in 't Veld	De relatieve posities van de EMS-valuta's
1986-21	E.R.K. Spoor	Knowledge Eliciting and Modelling using the entity Relationship Approach
1986-22	J.T.C. Kool A.H.Q.M. Merkies	On the Integration of Multi-step Prediction and Model Selection for Stationary Time Series
1986-23	W. van Lierop L. Braat	Multi-Objective Modelling of Economic-Ecological Interactions and Conflicts
1986-24	R.M. Buitelaar J.P. de Groot H.J.W. Wijland	Agrarian Transformation and the rural labour market: the case of Nicaragua
1986-25	E.R.K. Spoor & S.J.L. Kramer	Revaluatie van het E-R model
1986-26	Herman J. Bierens	Armax model specification testing, with an application to unemployment in the Netherlands
1986-27	Jan Rouwendal Piet Rietveld	Search and Mobility in a Housing Market with Limited Supply
1986-28	W. Keizer	The concept of 'consumer' sovereignty Exposition, critique and defense.
1986-29	Max Spoor	Finance in a socialist transition: the case of the republic of Viet Nam (1955-1964)
1986-30	L.J.J. van Eekelen	De ontwikkeling van het solvabiliteitstoezicht van de Nederlandsche Bank
1986-31	F.A. Roozen	Een verkenning naar invloeden van flexibele produktie automatisering op het management informatie systeem
1986-32	H.J. Bierens	Model-free asymptotically best forecasting of stationary economic time series
1986-33	R. Huiskamp	Large corporations, industry bargaining structures and national industrial relations: a comparitive and organisational approach
1986-34	W.J.B. Smits	Directe buitenlandse investeringen: invloed op export- en importwaarde; een cross-sectie analyse voor 30 ontwikkelingslanden
1986-35	P. Nijkamp	Informatics or oracles in regional planning
1986-36	H. Blommestein P. Nijkamp	Adoption and diffusion of innovations and evolution of spatial systems