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12 SMALL-AREA HOUSEHOLD PROJECTIONS: A MULTI-STATE DEMOGRAPHIC DESIGN

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12.1 Introduction

Demographic projections are commonly used as input for decision making with respect to housing policies and spatial planning. It is less common for policy measures to provide a basic input for demographic projections. At the national level, the need to incorporate population influencing policy measures in the projection process is limited. At this level, policy is largely population responsive and it suffices to know the number of people per category at consecutive points in time (Willekens, 1984: 22). Multiplying these numbers with rates reflecting the need for public facilities generates the information required. This information can be produced using standard demographic methodology and these needs-assessment models therefore provide little impetus for innovations in demographic research.

The smaller the spatial unit, the more policy shifts from population responsive to population influencing. At this level, the relation between policy and demographic research becomes far more challenging. The information requirements are more far-reaching. Instead of wanting information on the outcomes of demographic projections in terms of number of people, age structure and household composition, an interest develops in the components of demographic change, in the events that produce the outcomes (childbearing, death, household formation and dissolution, and migration), and in the policies that might affect the occurrence of these events.

Even population-influencing measures hardly ever affect demographic behaviour directly in the sense that, e.g., childbearing or household formation is promoted or discouraged, or that the propensity to migrate is stimulated. Instead, policy measures aim at structuring the context by offering opportunities or imposing constraints that either enable or restrict certain types of behaviour. This contextuality of human behaviour, however, is often lacking in demographic projection models. Three basic aspects of this context determine (spatial) household dynamics; the housing market, the labour market, and the transportation infrastructure. Each of these sectors has been used in the Netherlands to influence population structure, not just at the local level, but at various spatial levels.

The implication of this indirect way in which policy influences population is that the relevant context should be endogenised within the model, rather than policy itself. Endogenising the context is also needed for two other reasons:

- First, policy does not have full control over the operation of the housing and labour markets. The present (spatial) household structure might be more decisive in determining the operation of both markets than any form of government intervention.
- Secondly, although population change might be the intended outcome of a policy, this is not necessarily the case. Many policy measures with respect to housing, labour, or transportation will influence the (re)distribution of the population unintentionally.

Any demographic projection should be based on the modelling of causative factors that determine population change. In producing small-area household projections, the regional housing market is the most relevant aspect of the context. The interactions between (spatial) household dynamics and the operation of a regional housing market are manifold and complicated. Small-area household projections, therefore, require the design of a fully integrated housing-market model in which these interactions can be simulated. Policies with respect to housing and spatial planning have a decisive (but often unintended) impact on the local supply and allocation of housing opportunities. Consequently, the model design should allow for the evaluation of the impact of various policy measures, both from the point of view of improving the forecasts and of improving the rationality of public decision-making.

In this contribution we will sketch the design of an integrated household and housing market projection model that is rooted in multistate demography. It will be shown that the methodology used in demographic accounting models can be stretched to incorporate housing-market change along with household dynamics. In the next section, the functional requirements of the model will be specified on the basis of recent changes in the housing system (including the housing policy) in the Netherlands. In the subsequent sections, the various components of the model will be described, after which some concluding remarks on the feasibility of calibrating the model will be made.

12.2 Problem Definition: Household Dynamics in a Changing Housing System

The growth of the number of household in the Netherlands is very high compared to other countries in Europe. The most recent national household forecast estimates a growth rate of over 11 per cent for the last decade of this century (from 6 million to 6.7 million in 2000 - Heida, 1991). Including replacement of dilapidated dwellings in the existing stock and alleviating the present housing shortage, this household increase implies the construction of another million dwellings over the ten-year period. Most of these dwellings must be built in the Randstad (the urbanised western part of the Netherlands), due to a shift in the nation's spatial policy. In recent decades, population growth was diverted away from this part of the country, by stimulating employment opportunities in the peripheral regions in the North and South-East in the 1950s and 1960s, and by concentrating new housing opportunities at the outer flanks of the central conurbations in the 1970s. As a result, the present metropolitan area shows a high degree of deconcentration and ample space for the development of new commercial and residential areas. Current spatial policy supports the general trend of concentration of commercial and residential development close to the existing urban centres.

The abandonment of the deconcentration policy with respect to economic activity and the continuation of this policy with respect to residential development has generated large regional disparities in housing shortages. Outside the Randstad, long-term vacancies arise, while housing shortages increase in the conurbations of the Randstad. This trend has been accompanied by a, to Dutch standards, revolutionary change in the national housing policy.

As part of a more general reevaluation of the role of the government in providing welfare, housing expenses have been cut by more than 15 per cent over the last five years (DGVH, 1992). Within the budget for housing a further shift has taken place from subsidizing new construction (object subsidies) to subject subsidies (bonuses for low-income (first-time) buyers and rent supplement programs). Consequently, the percentage of new construction involving substantial government subsidies decreased from 75 per cent in 1985 to less than 45 per cent in 1990. Rent increases have been fixed to a level exceeding inflation to cut housing improvement subsidies. Instead of applying strict rent control and subsidizing the construction of dwellings in the social rented sector, now home-ownership is promoted vigorously and housing opportunities for low-income households are expected to arise within the existing stock due to a general filtering process, triggered by new starts in the owner-occupied sector. Housing allocation policy has also changed. In the past, the allocation policy only restricted access of higher-income groups to inexpensive housing. Now it also involves restrictions on the allocation of expensive housing to lower-income households to limit the rent supplement payments.

The most pervasive change in terms of the modelling effort at hand, however, is the decentralisation of the housing policy. In the past the local administration could apply for national housing subsidies on the basis of a rather crude assessment of the need of the local population for specific types of housing. Nowadays, local authorities receive a general housing budget that is fixed a-priori and which should be applied to stimulate market forces to provide the housing opportunities needed. This requires a detailed insight of the operation of the local housing market within the context of the regional housing market. As municipalities are granted autonomy of policy by law, a complex system of incentives and sanctions has been created to prevent the wealthier municipalities to shift the burden of housing the poor onto the municipalities with a less affluent population (the larger cities).

Summarizing the problem, the new housing policy involves the cooperation of local authorities to provide housing for the regional population, working with a budget from which less than half of the new construction needed can be subsidized, and which affects the intra-regional distribution of households to a large extent.

Setting goals for and evaluating the impact of such regional housing policies requires a far more detailed insight into the relation between household and housing market dynamics than present models can provide.

In designing a model that could generate this detailed insight, a number of requirements had to be met[1]:

- As regional cooperation is to some extent the result of self-selection, the definition of the region should be flexible and be made by the user of the model. To avoid parochialism, the model should supplement the user-defined region until some objective criterion for the delineation of the housing market area has been met.
- The model should provide full information on the effects of household formation, expansion, reduction, and dissolution on housing demand and supply, in quantitative and qualitative terms.
- It should provide projections of the number and composition of households at the local level, both as a result of household evolution processes, and of the operation of the regional housing market and distinguish between housing-related moves within the region and migration for other reasons.
- It should include an explicit algorithm of housing market adjustment behaviour in case of (qualitative) mismatches between sectoral and spatial housing demand and supply.
- It should be easily transportable and should run on a PC/AT in a DOS environment.

12.3 The General Structure of the Model

The overall design of the model is that of a multi-dimensional deterministic demographic accounting model in which individuals occupy various states and are exposed to transition probabilities which are fixed during each interval of calculation. Figure 12.1 depicts a generalised flow chart of the model. The starting point of the model is the occupancy matrix of households in dwellings in the various municipalities selected by the model at the start of the projection period.

The first step in the model is the demographic module in which household transitions are being estimated. A number of demographic events have a direct effect on the housing market; household formation of people living with their parents results in new housing demand, as does separation of couples, and immigration of households. Other demographic events, like household expansion and household reduction, will affect the housing preferences of the household and therefore, its propensity to move to another dwelling (indicated as 'filtering' demand). Housing demand is largely demography-driven.

A large share of the housing supply is also generated by demographic events; household dissolution as a result of mortality among singles, moves to institutions, and outmigration generates primary supply on the housing market. The rest of the primary supply (i.e., supply that forms the start of a vacancy chain) is generated by new construction. The remaining supply is generated in the filtering process as people move from one dwelling to another.

In the housing-market module demand and supply are matched by a housing allocation algorithm. Within each projection year, this confrontation between demand and supply takes place six times, reflecting an average vacancy duration of two months. In each allocation cycle vacancies are being occupied and other vacancies released if the new occupant leaves a dwelling behind.

Each step in the model is based on transition probabilities describing events which define the transition from one state to another. This dynamic approach is superior to comparative-static approaches in three ways:

- it offers full detail on the processes that cause household and housing-market dynamics and the interaction between the two (e.g., using dynamic headship rates to estimate levels of household dissolution would not provide a quantitative estimate of the supply generated by this process within the existing stock);
- it simulates the feed-back mechanisms between household behaviour and the housing-market context (e.g., the rates describing residential mobility are produced by the model based on the availability and accessibility of supply on the housing market, constrained by the demand for this type of supply);
- it enables the user to change this context (e.g., by changing the level and composition of new construction or by restricting access to certain types of dwellings in various municipalities), and to evaluate the impact this has on the functioning of the system.

To illustrate these points, we will describe each step in the model in some detail in the following sections.

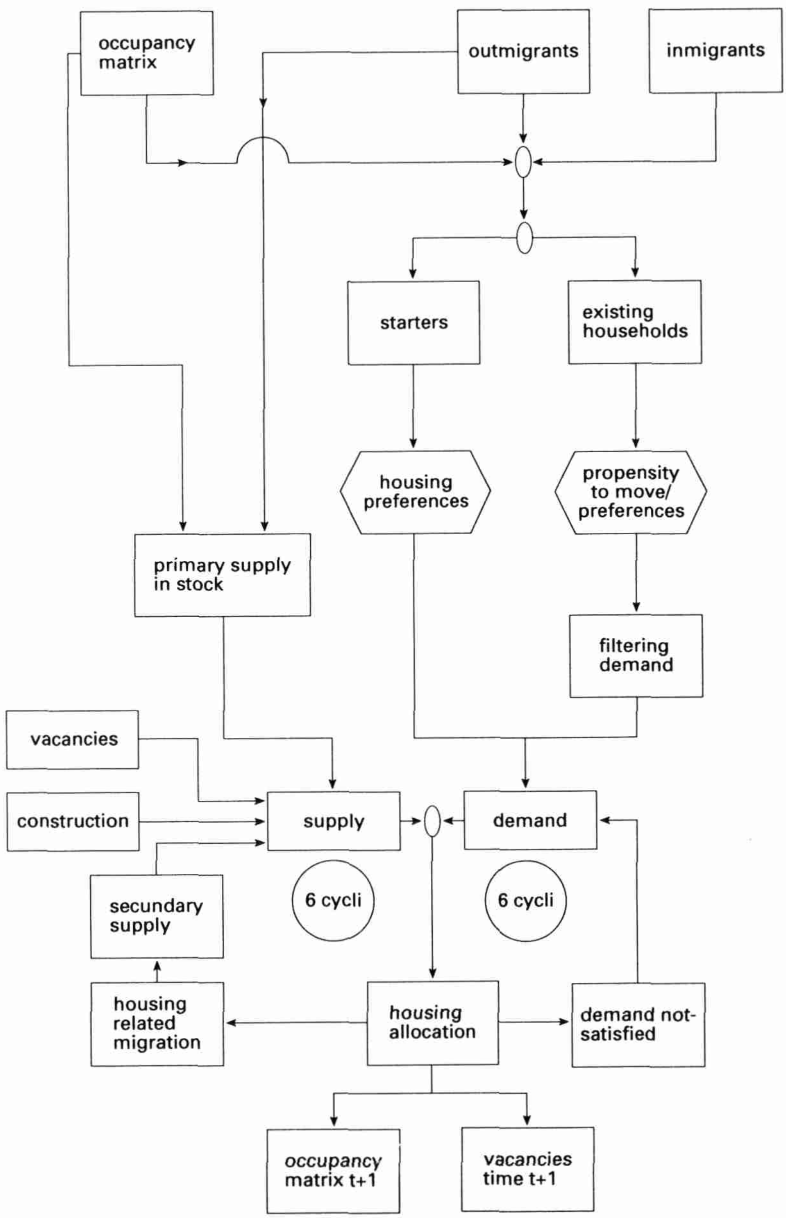

Figure 12.1 A generalised flow-chart of the model

12.4 *Defining the State Space: The Occupancy Matrix*[2]

The spatial unit in the model is the municipality (672 in the Netherlands in 1991). From a modelling point of view this far from ideal (as the size of the population varies between a few hundred to over 500,000), but it is the administrative division of the Netherlands most pertinent for research. In absence of census material on households and the housing stock, an approximation of the occupancy matrix at the level of the municipality had to be made. The methodology to generate household information at a low spatial level developed by Heida and Gordijn (1985) has been extended to estimate occupancy matrices.

Table 12.1 The typology of dwellings used in the model

1	Dwellings n.e.c. (bed-sitters, house-boats, etc.)
2	Rental, multi-family, < = 3 rooms, < *f* 450
3	Rental, multi-family, < = 3 rooms, *f* 450 - *f* 600
4	Rental, multi-family, <= 3 rooms, > *f* 600
5	Rental, multi-family, > 3 rooms, < *f* 450
6	Rental, multi-family, > 3 rooms, *f* 450 - *f* 600
7	Rental, multi-family, > 3 rooms, > *f* 600
8	Rental, single-family, < = 3 rooms, < *f* 450
9	Rental, single-family, < = 3 rooms, *f* 450 - *f* 600
10	Rental, single-family, < = 3 rooms, > *f* 600
11	Rental, single-family, > 3 rooms, < *f* 450
12	Rental, single-family, > 3 rooms, *f* 450 - *f* 600
13	Rental, single-family, > 3 rooms, > *f* 600
14	Owner-occupied, multi-family, < *f* 110,000
15	Owner-occupied, multi-family, *f* 110,000 - *f* 150,000
16	Owner-occupied, multi-family, > *f* 150,000
17	Owner-occupied, single-family, < = 4 rooms, < *f* 110,000
18	Owner-occupied, single-family, < = 4 rooms, *f* 110,000 - *f* 150,000
19	Owner-occupied, single-family, < = 4 rooms, > *f* 150,000
20	Owner-occupied, single-family, > 4 rooms, < *f* 110,000
21	Owner-occupied, single-family, > 4 rooms, *f* 110,000 - *f* 150,000
22	Owner-occupied, single-family, > 4 rooms, > *f* 150,000

The occupancy matrix itself consists of a cross-classification of 72 household types over 22 dwelling types (the dwelling typology is depicted in Table 12.1).

The categories in the typology reflect the basic features of the segmentation of the housing market in the Netherlands. The relatively fine detail in the typology is needed, especially in areas where supply is rather abundant. In these areas, housing demand may be very specific and supply that does not meet this demand will not be occupied.

The number of dwellings in each category in each municipality can be derived from Housing Information Systems which are monitored by the Ministry of Housing, except for the price level which was estimated using the Housing Needs Survey (WBO). This survey was also used extensively in estimating parameters in other modules. It is a 0.65 per cent sample of people aged 18 or over, collected under the responsibility of the Netherlands Central Bureau of Statistics (NCBS) every four years. The questionnaire includes a wealth of retrospective and prospective information on household and housing market behaviour.

The 72 household types represent the multiplication of the following household characteristics:
- household composition: single, one-parent, couples, families;
- age of the marker (the female): 18-24, 25-29, 30-34, 35-44, 45-64, 65^{+};
- net annual household income (in *f* 1,000): < 22, 22-30, > 30.

Until now, the NCBS only provides statistics on age, gender, and marital status. Household statistics at the level of the municipality may become available in the years to come, but cannot be provided at this moment. Two basic spatial differentials exist with respect to the age-specific household composition of municipalities in the Netherlands. Inter-regional differences occur due to the uneven distribution of educational and employment opportunities. Intra-regional differences occur as a result of the uneven distribution of housing opportunities within each region. The general equation to estimate the number of household in each category is as follows (see Heida, 1991 for more detail):

$$Hh_{h,a,m} = (Pop_{a,m,g} - Pin_{a,m,g} - Ed_{a,m,g} * Efac_{a,g}) * (Pnah_{h,a} * Ufac_{h,a,m} * Rfac_{h,a,m}) \quad 12.1$$

where

$Hh_{h,a,m}$ = number of households of type h in age group a in municipality m
$Pop_{a,m,g}$ = population in age group a in municipality m of gender g
$Pin_{a,m,g}$ = population in institutions
$Ed_{a,m,g}$ = number of university students
$Efac_{a,g}$ = factor describing the extra number of singles among students
$Pnah_{h,a}$ = national proportion of households type h in age group a
$Ufac_{h,a,m}$ = relative deviation from the national proportion for municipality m; this factor depends on the degree of urbanisation
$Rfac_{h,a,m}$ = relative deviation from the national proportion for municipality m; this factor depends on the region in which m is located

In cities with a university, the ($Ed_{a,m,g}$ * $Efac_{a,g}$) factor becomes larger than 0. All household types are estimated on a population without the number of students which tend to be single more than other people of that age. This number of singles is added to the number of households after applying equation 12.1.

The next step involves the addition of the income distribution per household category, using the age-specific statistics on personal income for each municipality from the NCBS (for more detail, see Leering and Relou, 1990).

After having established the distribution of the dwellings over the dwelling typology and the population over the household typology, the combination of both typologies in an occupancy matrix has to be estimated. Again the starting point is the national distribution of households over dwellings derived from the Housing Needs Survey (WBO), which was corrected in two steps for the specific deviation in municipalities in various regions and of various degrees of urbanisation:

$$HhDw_{h,d,u,r} = HhDw_{h,d} * Ufac_{h,d,u} * Rfac_{h,d,r} \qquad 12.2$$

where

$HhDw_{h,d,u,r}$ = the relative distribution of households over dwellings per region and degree of urbanisation
$HhDw_{h,d}$ = the national relative distribution of households over dwellings
$Ufac_{h,d,u}$ = correcting factor for degree of urbanisation
$Rfac_{h,d,r}$ = correcting factor for region

This relative distribution is the distribution matrix which is then used to estimate the actual number of households in various dwelling types using Iterative Proportional Fitting. From the number of dwellings the vacancies are subtracted. If the total number of occupied dwellings does not match the total number of household, the number in dwelling type 1 (Dwellings n.e.c.) is lowered or raised until it does. Multiplying the entries of the relative matrix with this number provides the starting matrix for the IPF routine.

As described above, the model allows the user to define its own region by listing a number of municipalities for which the model should provide output. This procedure however, does not ensure that all municipalities of a functional part of the regional housing market will be selected. The model therefore, supplements this choice on the basis on housing-related migration with the user-defined municipalities. The algorithm takes the following steps[3]:

1 All municipalities within a radius of 60 kilometers from the largest municipality in the user-defined region are selected and from the total migration flows between the individual municipalities, the housing-related migration is derived by using a distance deterrence function. This function specifies the decrease in proportion of housing-related moves in the total migration with increasing distance.
2 Municipalities are added to the user-defined region on the basis of the size of the number of housing related moves with the municipalities in the user defined region, until 75 per cent of all housing-related moves with the municipalities of this region (including the moves between these municipalities) have been covered.

The number of municipalities selected in this way is usually around 15, depending on the relative concentration of migration patterns in the region. The total state space of the model is therefore not fixed beforehand, but is usually less than 15,000 cells, on average representing some 200,000 households. This large state space allows for various forms of aggregation to apply parameters in the various modules.

12.5 The Demographic Module: Structural Migration

Migration patterns are very much age and household specific. The reason is that the motives for migration vary over the life course of the individual. At a relatively young age, many migrations are motivated by engaging in higher forms of education, accepting a job at a large distance from the present residential location, or union formation (which might occur both at short and at long distances). Later in life, these motives become less important and most moves are made to improve the housing situation. In terms of the modelling exercise, this distinction is crucial. Housing-related moves will be affected by the development of the marginal supply on the regional housing market, and people might easily postpone the move if this supply does not meet their demand. Migration for other reasons is less prone to be affected by housing market conditions. Not moving would for instance mean that one cannot accept the job. Research shows that people moving for other reasons than improving their housing situation have a very high probability of securing a vacancy within a year. The evidence suggest that substitution of housing preferences, taking what is available rather than what one would prefer, is an essential part of this process (Goetgeluk *et al.*, 1991).

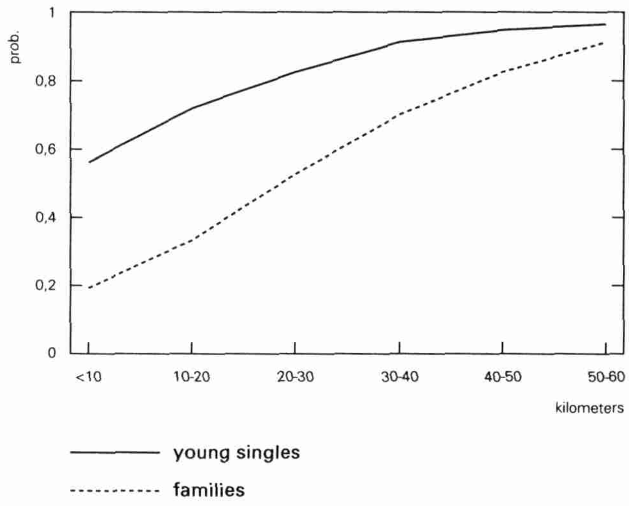

Figure 12.2 Distance deterrence in migration motives

The model therefore, distinguishes between these types of migration[4]. The starting point is the total migration matrix between all municipalities and the household and age specific vectors of outmigrants and inmigrants per municipality. From these statistics, the yearly migration based on the average of observed statistics over the last five years, is estimated. The next step is to distinguish between housing-related migration and structural migration. Any migration across the region's boundary is treated as structural migration. Within the region, migration flows are divided into structural migration and housing-related migration. The disaggregation is performed by using distance deterrence functions, that describe the decreasing proportion of housing-related moves with increasing distance (Figure 12.2). The specific form of the function depends on the size of municipality of origin and the household type.

The model assumes that structural migration will lead to housing search in the municipality of destination, and will always occur regardless of housing market circumstances. Inmigration from outside the region is included as absolute numbers. Structural outmigration both within and from the region takes the form of rates which are applied in the household model.

12.6 The Demographic Module: Household Evolution

The household module serves two very important purposes in the overall model. The first is to estimate the changes in household structure which occur as a result of household evolution processes. The second is to 'translate' demographic events that are directly related to the housing market, into the quantitative and qualitative effects on housing supply and/or demand within the region.

The household module is an adapted version of the PRIMOS Household model (Heida and Gordijn, 1985). The original formulation of the model has been extended in two ways (Heida *et al.*, 1991):

- Although the original model was specified in a period-cohort framework, transition probabilities were derived from age-period data. As many household transitions were highly dynamic, changes in localisation resulted in incorrect estimates of the overall intensities. A longitudinal specification of transition probabilities (period-cohort) supplemented with explicit quantitative hypotheses with respect of future rates for unfinished cohorts had a very positive effect on predictive performance of the model.
- The original model lacked a sound algorithm to ensure consistencies between processes which affected more than one individual. As a result, the model produced outcomes for individuals rather than for households. To apply the model in a housing market context, a consistent output on household data was needed. By introducing age-relation matrices, this problem was solved (this ensures among others a consistent transition to widowhood as a result of the mortality rates applied to the partners).

The application of the model to municipalities necessitated further adjustments. The national model operates with one year age-groups, while the local model only has six age groups in its state-space. This has been solved by calculating the weighted average of the one-year transition probabilities. No attempt has been made (as yet) to differentiate transition probabilities by region or degree of urbanisation. Although this does introduce some heterogeneity, this has been shown to be rather limited (Crommentuijn and Hooimeijer, 1991).

The model is fully parameterised by fitting mathematical curves to observed transition probabilities. This ensures a smoothing of the data and corrects for random fluctuations which become important when the population at risk decreases. It is unknown whether nationally derived and smoothed transition probabilities will perform better than locally specified transition rates, which will suffer from random fluctuations to a large extent.

Hypotheses with respect to fertility and mortality are derived from the national population forecast ensuring consistency with this forecast.

Apart from fertility, mortality, and migration, the local model estimates the transition listed in Table 12.2. We will not detail the way parameters are estimated for the (national) model, but will concentrate on those transitions which have a direct effect on the housing market. As the household transitions described above are estimated on the full occupancy matrix, the link between household events and housing market effects can be estimated directly. The model operates as follows:

Leaving the parental home -- Apart from inmigration, leaving the parental home is the most dominant cause of sustained additions to quantitative housing needs. Whether or not this event leads to extra demand on the housing market, depends on the destination. If the person leaves to live alone, an extra dwelling is needed. If the persons leaves to live with someone that also lived with the parents before, only half a dwelling is needed. If the person moves in with someone who lived independently before, no extra demand is generated. The present model distinguishes between these destination in estimating transitions, but only assumes age-specificity in partner selection. The housing situation before the event does not influence partner choice, apart from the fact that this situation will be different in various age groups. An indirect effect of leaving the parental home is that the number of children living with the parents decreases. When the last child leaves, housing preferences of the parents will change. This transition is estimated using an mother-child age-relation matrix.

Table 12.2 Transitions in the household model

	Child	Single	1-Parent	Couple	Family	Institution
Child	*	1	-	1/2	1/2	6
Single	-	*	-	2	2	6
1-Parent	-	1	*	-	2	6
Couple	-	4/5	-	*	3	6
Family	-	4/5	4/5	1	*	6
Institution	-	-	-	-	-	*

1. Leaving parental home; 2. Cohabitation; 3. Birth of child; 4. Separation; 5. Widowing; 6. Moves to institutions

Cohabitation -- Housing market effects of this event again depend on the housing situation before the event. The model estimates cohabitation for females on the basis of their age and household position (living with parents, living alone, being divorced or widowed). Using the age-relation matrix, a male is selected for each female transition. Housing-market effects depend on the housing-market situation of both. If neither of them has a dwelling, they are added to the group of starters on the housing market. If one of them has a dwelling, it is assumed that they will occupy this dwelling. If both have a dwelling, the smallest dwelling is released to the market.

Separation -- This always leads to extra demand on the housing market and changes the housing preferences of the partner that remains behind.

Mortality and transitions to institutions -- The death of a one-person household releases a vacancy onto the market, as does the transition into a home for the aged. The type of dwelling released can be derived directly from the occupancy matrix and will depend on the age, household and income position of the person(s) exposed to the event. No interaction is assumed between the housing situation and the occurrence of the event. In a more-person household, mortality will cause a transition to widowhood, changing the housing preferences of the partner that remains behind.

The birth of a child -- This has no direct housing market effect, but will affect the housing preferences of the parents.

In summary, the household model generates three types of input for the housing market model:
- A full specification of the housing supply that is generated as a result of outmigration, cohabitation, the death of one-person households, and moves to institutions.
- A full vector of new demand on the housing market as a result of inmigration and household formation.
- An update on household composition of the local population in households and in dwellings, which serves as a starting point to estimate the propensity to move and the housing preferences.

12.7 The Housing Market Module

The housing market module consists of two elements: a housing-search model and a housing-allocation model. The description below sketches the various steps in the algorithm[5]. The housing market module changes the household structure of the municipalities in two ways. The first is through a feed-back mechanism to the household module. If the primary supply of dwellings is insufficient to accommodate the number of new-entrants (starters and inmigrants) on the regional housing market, the resulting vector of new-entrants that have not been allocated a dwelling are returned to the household module (implying that the demographic event could not take place). Secondly, if households are allocated a dwelling, the occupancy matrix is updated, including the moves from one dwelling and municipality to another. The whole process is steered by the balance between the (qualitative) demand of various types of households and the supply of these dwellings in the municipalities that make up the region. The first step, therefore, is the estimate of demand.

At the start of the model run, a pool of housing demand is established. This pool is estimated by applying the probability that households in dwellings will be active in housing-market search at the start of the model. The probabilities were derived from the Housing Needs Survey and is estimated using a binary logit model. The expected log-odds that are output by the model, were used to estimate these probabilities. The absolute number of people in search of a dwelling is then estimated using equation 12.3.

$$Ndem_{h,d,m} = HhDw_{h,d,m} * Pdem_{h,d,m} + St_{h,m} + Inm_{h,m} \qquad 12.3$$

where

$Ndem_{h,d,m}$ = Number of households in search for a dwelling of household type h and of present housing situation d from municipality m

$HhDw_{h,d,m}$ = Number of households of type h in dwellings of type d in municipality m

$Pdem_{h,d,m}$ = Probability of being in search at the start of the model depending on household type h, dwelling type d and municipality m

$St_{h,m}$ = Number of starting households of type h from municipality m

$Inm_{h,m}$ = Number of (structural) inmigrant households of type h moving to municipality m

From this pool of potential moves, the number of households in search of a specific dwelling type is derived using equation 12.4:

$$Qdem_{p,h,d,m} = [\ (Ndem_{h,d,m} * Ppref_{p,h,d,m}) \qquad 12.4$$

where

$Qdem_{p,h,d,m}$ = Number of households of type h in present dwelling type d in municipality m having a preference for supply type p

$Ndem_{h,d,m}$ = Number of households of type h in dwelling type d in municipality m that is in search for (another) dwelling

$Ppref_{p,h,d,m}$ = Probability that a household of type h in dwelling type d in municipality m has a preference for supply type p

All probabilities are read from input files. Default files specify generalised national probabilities estimated on the basis of loglinear analyses of the relation of characteristics of household, their dwellings, and municipalities with the specified probability. The user may specify locally detailed preferences by overwriting these files.

Once the sectoral demand is estimated, the housing-allocation module starts. Supply is allocated to demand in six cycles for each year. A (short-term) vacancy rate is needed to enable people to move from one dwelling to another. The estimated duration of vacancies is about two months. Allocation proceeds in a number of steps in each cycle. The main loop refers to the preferred dwelling (Qdem - sectoral demand). Within this loop, supply in this sector is allocated in each municipality. The steps in the allocation can be summarised as follows:

Localising demand in municipality s -- The total sectoral demand is localised by estimating the number of potential movers resident in each municipality that will exert demand for the dwelling type at hand in the municipality were supply is offered (12.5):

$$SQdem_{p,s,h,d,m} = [Qdem_{p,h,d,m}] \text{ for } m = s \; + \; [Qdem_{p,h,d,m} * Pout_{p,h,d,m} * Pdis_{p,s*m}\ ] \text{ for } m \neq s \qquad 12.5$$

where

$Pout_{p,h,d,m}$ outside	=	Probability that a household h in dwelling d in municipality m searches the municipal boundaries
$Pdis_{p,s,m}$	=	Probability that a household searching outside the municipal boundaries from municipality m searches in municipality s (these probabilities depend on the distance from s to m)

As can be seen from equation 12.5, a household can search for a dwelling in more than one municipality. Every household is assumed to consider supply in the present municipality of residence. The structural migrants form an exception. By definition they only search in the municipality to which they move. Once they have become a resident, they may search for a dwelling elsewhere.

Calculating supply in municipality s -- For each dwelling type p and each municipality s, total supply is calculated using:

$$Sup_{p,s} = Vac_{p,s} + (Con_{p,s}/6) + (Prim_{p,s}/6) \qquad 12.6$$

where

$Sup_{p,s}$	=	Total supply of vacancy of dwelling type p in municipality s
$Vac_{p,s}$	=	Number of vacancies that were released in the past and have not been occupied
$Con_{p,s}$	=	Number of vacancies produced in new construction during the year
$Prim_{p,s}$	=	Number of vacancies that arise in the stock due to household dissolution (outmigration, cohabitation, deaths of one-person households, move into institutions) during the year

The initial vacancies ($Vac_{p,s}$) were determined in the definition of the state space and are updated by the model after each cycle. Supply due to new construction is read from input files. These files contained default construction programmes that may be altered by the user interactively. The vacancies due to household dissolution are output of the household module (cannot be changed by the user).

Allocating supply -- For each dwelling type p in every municipality s, the allocation factor is determined by dividing supply by the sum of demand. Allocation is skipped if demand or supply equal zero.

$$Afac_{p,s} = Sup_{p,s} \,/\, \Sigma^h\Sigma^d\Sigma^m\ SQdem_{p,s,h,d,m} \qquad 12.7$$

The allocation factor is set to 1 if it is larger than this number. The factor is used to estimate the characteristics of the households that have been allocated a dwelling, and to calculate the number of the vacancies which are left behind as a result of this allocation. After each allocation the number of households in demand for a dwelling type from each municipality is reduced by the number that has been allocated a dwelling.

$$Qdem_{p,h,d,m} = [Qdem_{p,h,d,m} - \Sigma^{s} (Afac_{p,s} * SQdem_{p,s,h,d,m})] \qquad 12.8$$

This is done to prevent that people who have been allocated a dwelling in municipality s=1 will continue searching in municipality s>1. Each time dwellings of type p are allocated, a different municipality is selected where allocation begins. Hereby it is avoided that the supply in the first municipality is always allocated and that long-term vacancies arise in the municipality which is last in the row.

The completed model contains an option for the user to manipulate the matrix $SQdem_{p,s,h,d,m}$, to input allocation rules by (temporarily) setting demand of various household groups (from specific municipalities) to zero, which prevents them of being allocated a dwelling.

Updating supply and demand -- After each cycle the supply of dwellings is being updated by calculating the number of vacancies that have not been occupied or have been released:

$$\begin{aligned} Vac^{t+1}_{p,s} = & [Sup^{t}_{p,s} - \Sigma^{h}\Sigma^{d}\Sigma^{m} (Afac_{p,s} * SQdem_{p,s,h,d,m})] \\ & + \qquad\qquad\qquad\qquad 12.9 \\ & [\Sigma^{p}\Sigma^{s}\Sigma^{h} (Afac_{p,s} * SQdem_{p,s,h,d,m})] \text{ for each } d = p \text{ and each } m = s \end{aligned}$$

The number of vacancies for the next cycle is thus estimated as the supply at the beginning of the cycle minus the dwellings which have been allocated, plus the dwellings which have been vacated by movers from this particular dwelling type in this municipality. The resulting $Vac_{p,s}$ is used in equation 12.6 to estimate supply at the start of the next cycle.

The demand for each type of dwelling is being decreased during the allocation loop in each cycle. This could eventually lead to a situation where the balance of supply and demand becomes distorted. It might be possible that there is a high demand for 4-roomed, single-family dwellings with a rent of *f* 450 - *f* 600 and a low supply in this sector, while the same type of dwelling in rent categories <*f* 450 and >*f* 600 are abundant in supply. This is unrealistic. To some extent households will adjust their preferences and decide to accept a cheaper of more expensive dwelling. To solve this problem, the preferences of the households are updated on the basis of the original vector of demand, specified at the beginning of the housing market module. The number of potential movers decreases as a result of allocation, but the relative preferences remain constant, implying a substitution of preferences towards sectoral and spatial sub-markets which are more abundant in supply.

A second feature of the update of demand is that new demand arises among household that were not in search before. These are added to the pool of searchers at the end of every cycle. The update of demand is therefore as follows:

The pool of movers is being adjusted:

$$\begin{aligned} Ndem^{t+1}_{h,d,m} = & [Ndem^{t}_{h,d,m} - \Sigma^{p}\Sigma^{s} (Afac_{p,s} * SQdem_{p,s,h,d,m})] \\ & + \\ & [(HhDw^{t}_{h,d,m} - Ndem^{t}_{h,d,m}) * Pstr_{h,d,m}] \end{aligned} \quad 12.10$$

where

$Pstr_{h,d,m}$ = The probability that a household h in dwelling d in municipality m becomes involved in housing market search within a period of two months

These probabilities have been derived from the Housing Needs Survey by fitting a binary logit model to the group in search of housing for less than two months, and the group not in search of other housing. $Ndem^{t+1}_{h,d,m}$ is used in equation 12.4 to estimate the sectoral demand in the next cycle, after which a new round of allocations starts.

Feed-back to the household module -- This feed-back occurs once a year. At the end of the year, the original occupancy matrix is updated. Their housing characteristics and their place of residence is updated on the basis of the allocation of the dwellings, effectuating a change in household structure of both the spatial sub-markets (the municipalities) and the sectoral sub-markets (the dwelling types). This includes the allocation of dwellings to starters and inmigrating household. This new occupancy matrix is the starting point for the next round of demographic changes in the households.

The new entrants which have not been allocated a dwelling are also returned to the household module. In its present formulation they are kept apart and returned to the housing-market module in the next year. Eventually it will be possible to estimate the delay in the occurrence of demographic events (for instance, leaving the parental home or separating from a partner) due to a lack of housing opportunities.

12.8 Concluding Remarks: The Feasibility of the Model

Until a few years ago, a model of this complexity would hardly make any serious chance of being calibrated and applied. Only main-frames could handle the large number of calculations involved. Also the data requirements would prevent any user to apply this model in a local or regional context. However, times have changed. Elaborate compilers have been developed for PC's, and the hardware has rapidly become much more sophisticated. The algorithms described in this contribution have been programmed[6] using Turbo Pascal and run in 4.5 hours on a PC with a 386 processor and a 387 co-processor for a region including 15 municipalities over a period of five years.

Data requirements still are a problem. Much energy had to be devoted to specifying the state space of the model. With the rapid development of geo-demographic information systems, this will be redundant in the future.

The model has been applied to a number of regions in the Netherlands. It provides plausible results, both in regions where the housing shortage is (still) acute and in regions where long-term vacancies prevail in sub-markets that are low in demand. The next step in the development is the testing of the model against empirical data. To do so, the model has been run for the period 1986-1990. In a post-validation using material from the Housing Needs Survey 1990 the performance will be put to a test.

The multi-state demographic approach has proven to be sufficiently flexible to provide a sound design for models which actually endogenise relevant aspects of the context of household-evolution processes. Even though the state-space of the (general) model described here will contain a large number of empty cells in (small) municipalities in the Netherlands, it will be faster than a concomitant microsimulation model. An obvious draw-back in the approach is the lack of insight in the effect of random fluctuations on the outcomes of the model.

Notes

1 The functional requirements of the model were defined in a series of discussions with housing market experts in the Netherlands, in particular research staff of the Directorate-General of Housing (DGVH), Companen BV, the Institute of Spatial Organisation (INRO/TNO), and the Faculty of Geographical Sciences of Utrecht University.
2 The generation of the occupancy matrices for all municipalities in the Netherlands has been carried out by Heida, Leering and Relou at the Institute of Spatial Organisation INRO/TNO.
3 A prototype of this algorithm was developed by Van der Waals of Companen BV.
4 A prototype of the algorithm was supplied by Salet of Kuijper Compagnons.
5 A prototype of this algorithm was devised and programmed by Drost, Hooimeijer and Kuijpers-Linde of the Faculty of Geographical Sciences.
6 The actual programming was done by Geert Rozenboom, Joost Drost and Ingrid Ooms.

References

Crommentuijn, L. and P. Hooimeijer (1991) *Leaving the Parental Home*. PDOD-paper nr. 6. Amsterdam: Institute of Planning and Demography.

Directoraat-Generaal van de Volkshuisvesting (1992) *Volkshuisvesting in cijfers 1992*. Den Haag: Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer.

Goetgeluk, R., P. Hooimeijer and F. Dieleman (1991) Household formation and access to housing in the Netherlands. Paper presented at the conference "Housing Policy as a Strategy for Change", Oslo.

Heida, H. (1991) *PRIMOS Huishoudenmodel: dynamische simulatie van de huishoudensontwikkeling*. Delft: INRO/TNO.

Heida, H. and H. Gordijn (1985) *PRIMOS Huishoudenmodel: analyse en prognose van de huishoudensontwikkeling in Nederland*. Den Haag: Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer.

Heida, H., P. Hooimeijer and M. Linde (1991) *PRIMOS Huishoudenmodel: Evaluatie, uitbreiding en aanpassing*. Delft: INRO/TNO.

Leering, D. and W. Relou (1990) *De schatting van de basismatrix*. Delft: INRO/TNO.

Willekens, F. (1984) Spatial Policy and Demographic Research Opportunities. In: H. Ter Heide and F. Willekens (eds.), *Demographic Research and Spatial Policy*. London: Academic Press.