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The location of new residential areas in The Netherlands

A statistical analysis for the period between 1980 and 1995

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Abstract

As a consequence of the ongoing growth in demand for more and larger houses in the Netherlands in the last decades, the part of the total surface used for residential purposes has expanded rapidly. The location patterns of new residential construction are the result of two types of forces: government intervention via zoning, new towns and 'compact city' policies, and market forces reflecting the preferences at the demand side.
The main factors influencing the location of residential construction will be analysed by means of multiple regression analysis. The most significant variables appear to be the location with respect to existing residential areas, location in new towns receiving government support, accessibility of work places, distances to railway stations and highway exits, and to a lesser extent the accessibility of nature, surface water and recreational areas. The model estimates obtained in this way are used to predict the location of future expansion of Dutch residential areas.

1. Introduction

Even in a densely populated country such as the Netherlands[1], only 6,4% of the total land area (in 1993) is used for residential purposes (CBS, 1997) and about 83% of the area consists of open space[2]. Compared with other European countries the share of open space is low, however. In the United States the open un-built area is estimated to be about 99%, in Denmark this is about 91% and in England approximately 90% (Ottens, 1999). Measures for density are important in both a socio-economic and an environmental point of view. In general, low-density urban development, usually associated with urban sprawl, is called inefficient. It increases transportation costs, consumes excessive amounts of land, and adds to the cost of providing and operating public utilities and public services (Peiser, 1989). In densely populated countries with a limited amount of open space and natural areas, the cutting up of open space is a particular concern. Small and vulnerable natural areas are increasingly split up and isolated and loose their viability. At the same time civilians loose even more of their, already limited, possibilities for enjoying free open space and nature. Excessive sub-urbanisation contributes as well to the decay of central cities by reducing the incentive to redevelop land near the centre (Brueckner, 2000). In the last decades many countries have therefore developed land use policies for growth management, particularly aimed at the prevention of urban sprawl. The question if policies aimed at preventing spatially discontinuous development will lead to land use patterns in which densities will be lower than they would be in the absence of such a policy, is however still a subject of discussion. Peiser (1989) for example argues that a competitive land market will achieve the desired result of higher density precisely by the process associated with urban sprawl -namely, spatially discontinuous development followed by later infill. True or not, Peiser relates urban sprawl mainly to the resulting urban density and the total volume of open space and not to other effects of urban sprawl which are more related to spatial patterns which have direct effects on traffic flows or on the fragmentation of natural areas. In the United States the debate on *laissez-faire* and urban sprawl versus planning regulations and concentrated development is still ongoing (see for instance Hayard, 1996; Gordon and Richardson, 1997; Nelson, 1999). Recently Brueckner (2000) treats the subject by not questioning the spatial expansion of cities itself, but questioning the speed of this expansion and the involvement of different market failures. He mentions for example the failure to take into account the social value of open space when it is converted to urban use and the failure of individual commuters to recognise the social costs of congestion created by their use of the road network. The third failure he mentions is related to the real estate developers who do not take into account all of the public infrastructure costs generated by their projects. Outside the United States more consensus exists over the need to curb urban sprawl and encourage compact forms of urban development which contributes to urban sustainability (Breheny, 1995 in: Razin, 1998). It should however be noted that the American situation with in average extremely low building densities is difficult to compare to the European situation. For example in the United States central city housing densities in the 1990 were only 4,1 houses per hectare urban area and compact city housing density is defined as 13-15 houses per hectare (Gordon and Richardson, 1997). The average housing density in 1989 in the Netherlands on the contrary was 27 houses per hectare residential area (or 9 houses per hectare built-up area[3]) and 37 houses per hectare residential area (or 14 houses per hectare built-up area) for the urbanised western part of the Netherlands.

The recent attention paid to spatial planning in Europe is demonstrated by the adoption of the European Spatial Development Perspective (ESDP) in May 1999, in which common policies are proposed in the field of spatial planning in Europe. In the small densely populated area of the Netherlands spatial policy has already been a standard national policy since the mid sixties. The latest spatial policy will be published in the Fifth National Physical Planning Report in the year 2000. In this report much attention will be given to the location planning of new residential areas, knowing the high need for new and bigger dwellings (approximately 40 to 80 thousands hectare of new residential area until 2030). This new spatial policy seems to break with the policy of the earlier physical planning reports in which the spatial policy departed from bundled deconcentration (with new towns for overflow from the Randstad) in the second report of 1966, untill the new towns policy from the third report of 1974 and the compact city policy of the fourth report (extra) of 1994 which connected again well to the policy of the first planning report of 1960, in which a strong separation between urban and rural areas was promoted. In the preparation phase for the fifth physical planning report the Dutch government has estimated the spatial effects of different spatial perspectives and compared them with a nul-scenario for residential growth. The historical statistical analysis of the spatial developments of the housing market between 1980 and 1995 in this research has formed the basis for the calculation of this nul-scenario. For the simulation results of the period 1995 – 2020 in this second study we refer to Schotten and Rietveld (2000). In the following sections the historical analysis and the modelling of the residential development in the Netherlands will be described. In section two we start with a general overview of the urban and residential development in the Netherlands since the second half of this century. In the third section the goals and the operating principles of Dutch spatial policy related to the construction of new houses, is explained. In the fourth section the theoretical basis is given for the modelling of the choice of location for residential construction. The actual empirical statistical analysis for the calibration of this model is described in section 5 and conclusions are drawn in section 6.

2. Urban and residential development in the Netherlands

The urbanisation rate of the Netherlands increased strongly during the past 130 years. At the start of the industrial revolution in 1870 only one percent of the national area was built-up area[3] growing to 6 percent in 1950, 15 percent in 1983 and 17 percent in 1993 (Ottens, 1999)[4].

The growth rates of population and the percentage built-up area in table 1 show clearly that the accelerated growth of urban land use after the fifties is not caused by an increased population growth.

Table 1 Annual growth rates of population, number of households and urban land use in the period 1870 – 1996. Source: (CBS, 1997)

	Growth rate 1870 –1950	*Growth rate 1950 - 1979*	*Growth rate 1979 –1989*	*Growth rate 1989 – 1996*
Population	1.3	1.2	0.6	0.7
Number of households	n.a.	2.1	1.9	1.5
Built-up area	2,3	3,3	0,43	0,97
Residential area	n.a.	n.a.	0.8	0.9

The accelerated growth of land use in the first two periods is among others the result of the reduction in the average household size[5] (e.g. from 2.8 in 1980 to 2.4 persons in

1995; VROM, 1997). This reduction is among others caused by diminishing size of families, the growing number of young people living alone, the increased divorce rate, the smaller number of children per family and finally the increase of individual housing for the elderly (Pellenbarg, 1994). Although the 29 % growth of the number of households in the Netherlands (1980 – 1995) is the highest in Europe, the residential area[7] is growing with a much lower speed, comparable with that of the population growth. This implies that the expansion of the housing stock occupies less space than could be expected. This is also shown by the increasing average number of dwellings per hectare of residential area from 25 in 1983, 27 in 1989, to 28 in 1993 (Ottens, 1999). The figures in table 1 also show the strong reduction of the growth of the built-up area in the last two periods. This can be interpreted as an indication for the densification of the existing urban area and the relative success of the spatial policy of the last four decades which has prevented excessive urban sprawl.

The population figures in table 2 shows clearly that the developments described are not evenly distributed over the Netherlands. After the Second World War both the big cities and the rural areas have lost a large part of their population to urbanised rural municipalities. It will therefore not come as a surprise that nowadays the most common living form in the Netherlands is the single-family terraced house in a medium sized urban municipality and that the larger part of the daily commuting takes place between these and the main cities. The main driving force behind urban sprawl in the Netherlands could be characterised as a common residential desire for a single family house with a private front garden and backyard.

Table 2 Population distribution Netherlands 1947-1997 (from Ottens, 1999)

% Dutch population in	*1947*	*1960*	*1971*	*1981*	*1990*
Rural municipalities	29	22	11	12	11
Urbanised rural municipalities	17	23	34	37	38
from which ‘commuting’ municipalities	5	7	13	14	15
Urban municipalities < 100.000 inhabitants	24	23	26	27	27
Urban municipalities > 100.000 inhabitants	30	33	29	25	24
from which the four main cities	n.a.	n.a.	17	14	13

3. Residential construction between public and private interests.

Given the externalities involved in land use, it is no surprise that the Dutch government has opted for a rather strong involvement in the planning of residential construction, both in terms of the total volume of land involved, and in terms of the location. Several objectives can be distinguished in this respect. First, there is the objective to keep the volume of *open space* at reasonably high levels. The second objective is to arrive at a spatial structure where the *cutting up of open space* is avoided. The third objective is to create favourable conditions for *efficient spatial interaction patterns* where there is scope for transport modes other than the car. In addition to these objectives related to the public interest, there are of course the interests of the individuals living in the dwellings, or waiting for a dwelling to be realised. These objectives have been pursued with varying intensity during the past decades. During some periods individual preferences received more attention compared with the public objectives. Also within the group of public policy objectives the emphasis has varied from time to time as can be seen from the policy documents of the Ministry of Physical Planning during the course of years (1966, 1974, 1990, 1999).

Note that the first public policy objective relates to the total volume of open space, whereas the second objective concerns the spatial distribution of the open space. The first objective has stimulated the design of residential areas with high densities in terms of the number of dwellings per acre. The second objective led to the policy to concentrate residential construction in particular centres. The third objective has received two interpretations: clustered deconcentration and compact city. An example of clustered deconcentration is the growth centre policy, which was the dominant policy concept during the 1980's. New towns have been created at some distance from the larger cities, usually with good railway connections to the large cities. The second interpretation of this objective, the compact city, has been that residential construction takes place within and immediately adjacent to large cities in order to create opportunities for non-motorised transport modes (the modal share of the bicycle is very high in The Netherlands) and for public transport within the urban area. Another potential advantage of the compact city concept is that distances from the newly created residences to the main location of employment are rather small.

The government has indeed achieved some successes in these policy objectives. For example, the average parcel size in the Netherlands is considerably lower than in its neighbour countries (28,0 dwellings per hectare residential area in 1993). This implies that open space has been saved. In addition, the policy to concentrate residential construction in some particular places has also been successful to some extent. Some new towns have indeed experienced rapid growth, implying that a strongly dispersed pattern of residential construction has been avoided (see Bontje and Ostendorf, 1999). The success in achieving the third objective has been much more limited, however. New towns have experienced very rapid growth during the 1980s but many people living in these cities use the car in stead of public transport to travel to the main city, implying considerable environmental and congestion problems. Also the more recent creation of housing near large cities does not necessarily lead to short commuting distances. The polycentric urban system of the Western part of the Netherlands implies that there is usually a good number of centres of employment from a certain city within a range of some 40 km. A strategy of residential construction near large cities does not guarantee that residents work in the same city (Van der Laan et al., 1998, Maat, 1999). Another problem the government had to face is that the restrictive policies keep land prices for residential construction high (Aalbers et al., 1999. Buurman and Rietveld, 2000) and also that many consumers are not satisfied with the size of the parcels and the resulting quality of the dwellings. Thus there is a certain tension between private and public interests, and it is not evident that the present patterns of location of residential construction and the size of the parcels reflect a proper balance between the two.

It is important to emphasise that the government is not a monolith: national, regional and local governments play distinct roles in land use planning. Local governments develop land use plans specifying at which locations residential construction is allowed. These local plans have to be consistent with more global land use policies formulated at the provincial and national level. The local plans need approval by the provincial governments. Conflicts between higher and lower governments may easily arise in this context. A frequently observed case is that municipalities want to allow the construction of substantial numbers of dwellings, whereas the higher level governments try to prevent such a development because it would lead to a cutting up of open space.

Two types of government involvement in the land market can be distinguished. In addition to *allowing* the construction of new residential areas, governments may also intervene in a second way, i.e., by *commanding* the construction of new dwellings. The difference between the two is that allowing the construction of new residences does not necessarily imply that construction actually takes place. There may be a lack of private sector response to use the opportunities offered by allowing the use of agricultural land for residential construction. In the case of commanding the construction the government is much more heavily involved. Involvement can take place among others by the supply of accompanying infrastructure (road and/or rail) and by the direct involvement of the government in the rental share of the housing market. Most of the post war period has been characterised by a strong control of the rental sector via public housing corporations so that the opportunities for a commanding policy were favourable.

A characteristic feature of the Dutch housing market during the past decades has been that excess demand prevailed in most market segments. This excess demand already existed immediately after World War II, and it continued to exist. One of the reasons is the rather high annual growth rate of the number of households of about 2% during a period of 50 years. This figure is higher than in most other European countries. It is only rather recently that the gradual removal of a low rent policy has led to the occurrence of excess supply in low quality rental apartments in some regions. But for most market segments the restrictive policies have led to a rather chronical excess demand. An important implication is that the vacancy rates have been low and that new residential construction will easily find renters or buyers. In this situation it is difficult to detect to what extent residential construction has been in harmony with consumer demand. In the situation of excess demand the policy of commanding the construction of dwellings at particular places is not very risky. However, when the market regime would switch, the success of this policy is no longer guaranteed.

We conclude that, especially when excess demand will decrease, governments cannot ignore the interests of individuals in their land use policies. In the case of the *allowing* policies governments will find that at certain locations there will simply be no residential development even when it would be allowed. In this case ignoring consumer preferences is not really risky. In the case of *commanding* policies there is of course a risk for over-investment in housing of certain qualities and at certain locations leading to high vacancy rates. It may also demonstrate itself in a lack of interest from the side of the private sector to invest in the places where the government has ordered the investment. For example, given the much lower involvement of the government in social housing, it is not always clear how the government can make the compact city projects sufficiently interesting for the private sector (see Bontje and Ostendorf, 1999).

We conclude that the historical development of residential construction was the result of both commanding and allowing policies. In the commanding policy we may expect a strong representation of public sector preferences, whereas the allowing policy would be an expression of private preferences. There is a danger of oversimplification, however. First, commanding public policies are not necessarily ignoring private preferences. For example the success of the growth centre policy is probably partly due to the fact that it resulted in dwellings that were attractive for many consumers. Second, when governments are very restrictive, allowing policies may result in construction activity that is only second best from a consumers point of view: the really attractive locations are not available. We conclude that it is difficult to disentangle where the resulting patterns of residential construction reflect the preferences of the public sector, and where they reflect those of the private sector.

4. The choice of location for residential construction.

The location of residential construction is modelled from the perspective of an actor (a household) who compares all potential locations from the viewpoint of their locational attractiveness. The location with the highest suitability is assumed to have the highest probability of realisation. This can be modelled as follows. Consider a number of grid cells c=1,...,C. Given the small size of the grids in the study, the total number of grids is very large (about 140,000). The suitability of grid cell c for residential use is represented by s_c. The suitability index is assumed to depend on a number of features x_{ck} (k=1,..,K) of grid cell c:

$$s_c = b_1x_{c1}+ b_2x_{c2}+...+ b_Kx_{cK} \qquad \text{for all c.} \qquad (1)$$

The features x_{ck} in (1) relate to factors such as accessibility, quality of nature and the price of the land. Consider an actor (for example 'households') that compares all potential locations c according to their suitability s_c. Assume that the households have idiosyncratic preferences implying that they base their choice on the suitability indicator s_c plus a stochastic term ε_i that represents household i's departure from the structural term s_c. Then, when ε_c is distributed according to the Weibull distribution, the probability P_c that location c is chosen by a household can be represented by the logit model (cf. Cramer, 1991). This probability is:

$$P_c = \exp s_c / [\exp s_1 + \exp s_2 + ... + \exp s_C] \qquad (2)$$

This equation is based on the implicit assumption that all cells are equally large. When we take into account that some grid cells are larger than other cells this equation has to be modified. Let L_c denote the size of cell c, then the adjusted formulation reads as:

$$P_c = L_c \exp s_c / [L_1 \exp s_1 + L_2 \exp s_2 + ... + L_C \exp s_C] \qquad (3)$$

Clearly, when all grid cells are equally large, (3) would coincide with (2).

This approach can be followed for all households. Let the total number of households be N. Then the final result of the analysis is a set of probabilities P_1, P_2,...,P_C for all households. Since we assume here that all households have the same structural valuation of the grid cells (s_c does not vary among households) the expected number of households that will ultimately locate in grid cell c is equal to $N.P_c$.

Note that a similar approach can be followed for other types of land use so that we would arrive at expected land use for all types of land. Then prices (being one of the suitability indicators x_{ck}) would have to adjust in such a way that total demand of space is equal in all grid cells. Since we only focus on the demand for land in this paper we do not go into these equilibrium conditions (for an exposition see Rietveld, 1998).

In this theoretical model we have used the term 'households' to represent the demand side at the housing market. In reality the situation is more complex, however, since residential construction often takes place by construction firms or by real estate developers. Thus an implicit assumption is that these actors have perfect knowledge of the preferences of the final consumers. Another complication is that, as explained in section 2, the realised patterns of location of dwellings may be strongly influenced by government intervention. This implies that the suitability indicators s_c as used here are assumed to reflect the joint outcome of consumer preferences and government preferences. For example, individual preferences may favour locations far away from existing cities, whereas it is the governments objective to stimulate construction near the large cities.

A third remark about the model is that in its present formulation it assumes an empty space to be filled at once. Thus, it does not take into account that there is a strong historical component in human settlement patterns: factors that played a role centuries ago in the growth of a city may have had a strong impact on the current settlement system which in its turn has a strong impact on its future development. Therefore it is better to use the model in such a way that it takes the settlement pattern at a certain point in time as given and uses this as a starting point to explain the expansion (or contraction) of space used for residences. This is indeed what is done in our empirical analysis. Thus we do not investigate land use for residential purposes per se, but changes in this land use. This means that L_c in (3) is interpreted as the total amount of land available for additional residential construction; the current use for residences is excluded from L_c. This means that although within urban areas very high values for s_c may be observed, the total construction volumes will be relatively small, since the available land L_c is small.

The data on the dependent variable on which the estimations are based relate essentially to the total surface of the grid cells c that became in use for residential purposes during a certain period. In order to make these data compatible with our model we assume a certain standard area of land per housing unit. This leads to the need to distinguish various dwelling types since the area per dwelling varies among dwelling types. The dwelling types used are further discussed in section 5. Given the change in size of land used for dwellings one can compute the number of dwellings realised in a cell c (S_c). This number may be interpreted as the observed value for $N.P_c$ derived above where N is the total number of additional dwellings built during the period.

The aim of our analysis is the estimation of the parameters b_k underlying the suitability indicators s_c according to equation (1). A straightforward way to estimate the b_k would be to transform (3) such that

$$\ln(N.P_c/L_c) = b_1 x_{c1} + b_2 x_{c2} + ... + b_K x_{cK} + A + \mu_c \qquad (4)$$

On the left hand side of the equation we have the natural log value of the share of total available land that is converted to residential use, at the right hand side we find the suitability components x_{ck} plus the attached parameters b_k. The term A is defined as $A = \ln[L_1 \exp s_1 + L_2 \exp s_2 + ... + L_C \exp s_C]$. Since it is equal for all cells it does not have an index c. The term μ_c is added as an error term. The problem with this equation is that in many zones actual residential construction equals zero. This implies that $\ln(N.P_c/L_c)$ goes to minus infinity for these cells. Ignoring these cells would obviously lead to biased estimates for the b_k values.

Therefore we have to develop a formulation of the model to be estimated such that the case of zero observations can be included. The expected number of dwellings built in grid cell c equals $N.P_c$. Let M_c be the maximum number of dwellings that can be accommodated in grid cell c. Then, when $N.P_c$ dwellings would be built in c, the probability that an arbitrary available empty plot in grid cell c is used equals $N.P_c/M_c$. This probability will be denoted as Q_c. Let N_c be the number of dwellings actually built in c. N_c can vary between 0 and M_c. We interpret the model in terms of a binomial probability process where Q_c is the probability that a dwelling will be constructed on a given plot in cell c. Thus the probability that N_c is the number of dwellings realised in grid cell c [$L(N_c)$] equals:

$$Pr_c(N_c) = [N_c!(M_c-N_c)!/M_c!].\ Q_c^{Nc}.\ [1-Q_c]^{Mc-Nc} \qquad (5)$$

where Q_c equals $N.P_c/M_c$. This is the standard formulation of the binomial distribution. The case that N_c equals 0 does not lead to difficulties: $L_c(0)$ can simply be computed as $[1-Q_c]^{Mc}$. In this respect this method performs better than the method outlined above. Based on this formulation of the probability $Pr_c(N_c)$ of the realisation of observation N_c in grid cell c the maximum likelihood method can be used to estimate the values of the b parameters.

5. Empirical results

1.Introduction

In this section we carry out a statistical analysis to explain the locational pattern of the increase of single and multiple family dwellings between 1980 and 1995. The statistical relations are analysed with the help of a logistic regression model, which has been discussed in section 4. For details on the methodology and the data used we refer to Wagtendonk and Rietveld (2000).

We start with the formulation of various types of dwellings to allow the analysis of sub-markets. Data are available on the following types:

Dwelling type 1 = single-family detached / semi-detached / farmhouse
Dwelling type 2 = single-family terraced house
Dwelling type 3 = multi-family, ground-floor / upper-storey flats
Dwelling type 4 = multi-family, flat
Dwelling type 5 = non-independent accomodations / restgroup

To avoid an overly detailed presentation for part of the analytical results, we will make use of a less detailed typology of dwelling types, i.e. single family dwellings (types 1 and 2) and multiple family dwellings (types 3-5). Digital maps with the spatial distribution of these two types of dwellings were made by combining parcel co-ordinate files (PAP-files) with residential statistics of the Central Statistical Office (CBS).
In figure 1 it can be seen that single-family dwellings in 1980 are distributed rather evenly over different urban concentrations in the Netherlands while the multi-family dwellings in figure 2 are mainly concentrated in the three major cities of the Randstad.

2. Dependent variable

As explained above the existing distribution of the existing dwelling stock is not a function of recent driving forces but of historic circumstances, which may date back to centuries ago. Therefore we have chosen the recent dynamics between 1980 and 1995 of the residential development as our focus. The spatial policy of this period connects well with the current policy of 'compact urbanisation', which started approximately in 1983

Structuurschets Stedelijke Gebieden' (national structure plan for urban areas).

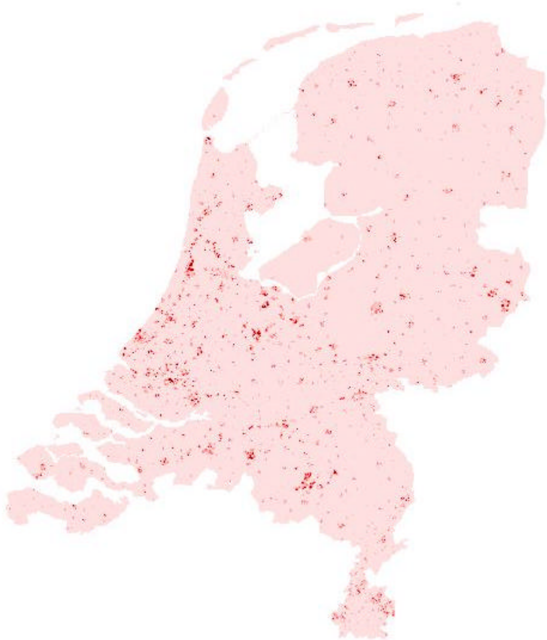

Figure 1 *Distribution of single family dwellings in 1980 (number of dwellings per square of 500 x 500 meters)*

Figure 2 *Distribution of multi family dwellings in 1980 (number of dwellings per square of 500 x 500 meters)*

The current policy is distinctly different from the preceding period of clustered de-concentration in which new towns like Almere and Hoorn were created. However, we have to take in account a considerable time lag between the implementation and the actual effects of new spatial policy.

For the calculation of the dependent variable a number of assumptions are made. It is assumed that there is a maximum to the increase of dwellings per cell, which is equal to or smaller than the observed maximum amount of dwellings per cell in 1995 (1280 single-family dwellings and 3846 multi-family dwellings)[6]. The possible number of new dwellings is divided by the area which is available for new building activities. The available area is 25 hectares per grid cell minus the existing residential area, minus the existing area for work, minus the area occupied by surface water, like lakes, rivers and canals[7]. These operations result in the maximum possible growth of the number of dwellings per grid cell. Dividing the observed number of new dwellings and the maximum possible number of dwellings yields the share of space that is eventually used for construction during this period.

3. Independent variables

The aim of our analysis is to find the determinants of the locational choice in residential construction. These determinants relate to available space, spatial policy and personal preferences (of the real estate developer and his target market)[8]. The following driving factors are distinguished:

- Proximity and concentration of existing residential areas (maximum radius 500 meter)

  Although the search-radius of people looking for a dwelling is rather large (Goetgeluk, 1997), in the Netherlands the majority of people move inside their own neighbourhood or municipality. New residential areas situated near to existing residential areas may therefore be expected to be attractive for residents.
- Proximity and concentration of employment (maximum radius 60 km)

  People attach value to the amount and the accessibility of work in their surroundings and in reverse they accept to a certain extent the disadvantage of commuting because of the better living environment and cheaper housing at the home end of the commute (Mills and Hamilton, 1994). This implies that the distance to work should be weighted according to a certain distance-decay function and depending on the concentration of available work. Different investigations point out that for most people the maximal accepted commuting distance in the Netherlands is between 30 and 60 minutes (Gerritsen, 1997). The average commuting time is about 20 minutes (Rietveld, 2000). This is also confirmed by Van Ham (1999) who shows that the majority of jobs is found on short distance from home.

- Proximity (maximum radius 15 km), quality and size of nature conservation, forest and recreation areas (including wetlands).

  Also rest, open space, nature and recreational possibilities are relevant determinants.
- Distances to railway stations and highway exits.

  The distance to the closest enter points of the railway and highway systems are used to measure overall accessibility of a location.
- The proximity of railways, highways and airports can be a negative factor in the case of noise, air or visual pollution.
- Location in new towns or expanded towns

  The public sector has a strong influence on the spatial distribution of residential construction via new town policies. In the period from 1980 till 1995 the larger part of the building program was concentrated in new towns and expanded towns (RIVM, 1998).

Details on the measurement of theabove variables are given in Wagtendonk and Rietveld (2000). For the computation of accessibility and proximity of dwellings we used gravity type indicators (see Hilbers and Verroen, 1993 and Rietveld and Bruinsma, 1998).

Correlation analysis

Our first step is to use correlation analysis to find the most important relationships. This is done by testing the strength of the relationship between each of the independent (increase of dwellings) and the dependent (explanatory) variables, like the proximity of recreational areas, expressed in the correlation coefficient. Given the large number of observations (about 140,000 grid cells) it is no surprise that many significant relationships are found. The results of the correlation analysis in table 3 confirm most of the expected relations. A strong positive relation is found between the *increase* in the density of single-family dwellings and the proximity of *existing* single-family dwellings and a considerably weaker relation with the multi-family dwellings. These differences are confirmed by the rather different spatial distributions of single and multi-family dwellings (see figures 1 and 2). Comparable relations are found for the increase in the density of multi-family dwellings and the proximity of *existing* multi-family dwellings. Relatively strong positive correlations for all dwelling types are found with the accessibility of jobs in the various sectors. The sector agriculture has lower correlations than the other sectors.

Table 3 Correlations between variables

Correlations		*Dependent variables*	
		Increase housing density 1980 –1995	
Independent variables		Single family dwellings	Multi family dwellings
Proximity to existing housing stock:	Single family dwellings	0.412	0.282
	Multi family dwellings	0.174	0.302
Accessibility of labour according to sector:	Construction	0.125	0.120
	Retail	0.127	0.128
	Wholesale	0.113	0.115
	Industry	0.133	0.113
	Knowledge	0.115	0.134
	Public sector	0.128	0.131
	Agriculture	0.070	0.047
	Transport	0.115	0.122
Accessibility of natural areas:	Forest	-0.002	-0.013
	Forest-leisure	0.065	0.056
	Nature dry	0.001	0.004
	Nature wet	-0.012	-0.001
	Water	0.042	0.050
Euclidian distance to infrastructure:	Highway exit	-0.088	-0.054
	Railway station	-0.105	-0.072
Presence of infrastruc-ture in zone:	Highway	0.046	0.006
	Railway	0.039	0.037
Status of planning zone:	New town	0.084	0.028
	Expanding town	0.048	0.037

Because of multicollinearity problems it is not feasible to use all these variables in a multiple regression. Our regression analysis is therefore based on a selection of these variables (for details on the stepwise approach refer to Wagtendonk and Rietveld , 2000).

Regression-analysis

The second step of the statistical analysis is the estimation of the model described in section 4. To get an indication of the explanatory value of the independent variables, we conduct a 'stepwise regression analysis'. This leads to two sets of respectively nine and ten variables for respectively single- and multi-family dwellings. Because it is expected that the variables will have different relations with the dependent variable under different social-economic conditions and spatial policies, the regression analyses have been repeated but divided into three regional zones, the Randstad, the Intermediary zone and the Peripheral zone. Because we did not find clear distinctions between the Intermediary zone and the Peripheral zone we decided to combine these to one single zone (the rest of the Netherlands). For each set a group of 9 to 11 explanatory variables results, which are presented in table 4.

Table 4 Regression results

	Randstad			
	Single-family		*Multi-family*	
	B	t-value	B	t-value
Intercept	-7.020	-389.6	-20.352	-255.6
Accessibility of employment: knowledge sector	n.a.	n.a.	0.996	160.0
Accessibility of forest-leisure	-0.023	-27.5	n.a.	n.a.
Accessibility of forest	n.a.	n.a.	0.064	36.0
Presence of highways	-0.343	-94.7	-0.363	-69.6
Presence of railways	-0.580	-91.3	0.045	7.0
Distance to highway exit	0.041	33.0	0.122	61.3
Distance to railway station	-0.137	-103.5	-0.121	-87.4
New town dummy	1.126	264.0	0.738	101.0
Proximity of single-family dwellings	0.731	548.0	0.537	242.1
Proximity of multi-family dwellings	0.062	75.7	0.386	331.7

	Rest Netherlands			
	Single-family		*Multi-family*	
	B	t-value	B	t-value
Intercept	-11.811	-462.2	-15.021	-329.8
Accessibility of employment: industry sector	0.283	121.3	n.a.	n.a.
Accessibility of employment: knowledge sector	n.a.	n.a.	0.345	79.3
Accessibility of forest-leisure	0.035	39.9	n.a.	n.a.
Accessibility of conservation areas wet nature	0.072	69.1	0.106	39.6
Presence of highways	-0.107	- 42.5	-0.149	-27.0
Presence of railways	-0.371	-85.1	-0.303	-35.8
Distance to highway exit	0.050	56.6	n.a.	n.a.
Distance to railway station	-0.118	-117.2	-0.179	-109.7
New town dummy	1.632	366.0	1.083	121.6
Proximity of single-family dwellings	0.828	934.1	0.878	300.8
Proximity of multi-family dwellings	0.098	126.0	0.495	328.7

We will discuss now the results single and multi-family dwellings in respectively the Randstad and the rest of the Netherlands.

Randstad

A remarkable result for single family dwellings in the Randstad is the absence of the explanatory variable accessibility of jobs. A possible explanation for this result is the large offer of jobs and the high accessibility over the extended infrastructure-network to work areas. The exact location in the Randstad seems to be irrelevant for this factor. These figures are in line with the results of Dingemanse (1993) who measured a growing discrepancy between living and working. For multi-family dwellings however a slightly positive relation is found with the accessibility of jobs in the knowledge sector, which is not surprising as both variables are mainly concentrated in the city regions of the Randstad. The negative parameter for forest areas is explained by the low availability of forest areas on a short distance. Also the other environmental indicators (presence of highways and railways) have the expected signs. In grid cells where these infrastructures are present the probability that open land will be converted into residential use is smaller than in other regions. Distances to railway stations tend to have a negative impact on the probability of residential construction in a zone. This can partly be explained by governmental policies to stimulate residential construction near railway stations. As indicated by Rietveld (2000) such a policy of building near railway stations certainly makes sense given the importance of non-motorised transport modes as access modes to the railway network. For highways distance does not play such a clear role as a determinant of residential construction. Further can the probability of residential construction near highway exits be smaller because of the attraction of these locations to other land users (business). Finally the results show that patial patterns of existing dwellings have a very strong impact on residential construction. New residences tend to be built in the immediate neighbourhood of existing residential areas. In addition to existing residential areas new towns appear to play an important role in residential construction between 1980 and 1995. For all market segments the assignment of a new town (or growth centre) status has led to a strong increase in residential construction in the grid cells concerned.

Rest Netherlands

Most of the results are quite similar for the rest of Netherlands and differ mainly in the magnitude of the parameters. An important difference is that the accessibility of jobs in the different labour sectors, especially industry, have a bigger influence on the probability of residential construction. Industry is more often located outside the Randstad, which corresponds to the results of Hilbers & Verroen (1993) and van Ham (1999), that low and middle educated workers have relatively shorter commuting distances. In the rest of the Netherlands also forest and (wet) nature conservation areas show slight but clear positive relations with residential growth.

6. Conclusions

Growth of residential areas has been substantial during the last century in the Netherlands. The emerging spatial patterns are the result of market forces and of government interference. We have developed a model to analyse choice probabilities that available land is converted to use it for housing. The pattern during the last 15 years demonstrates that proximity to already existing residential areas is important. This underlines that growth is focussed at the fringe of existing centres. Proximity of infrastructure access points (railway stations, highway exits) also plays an important role. The coefficient for rail tends to be higher than for highways; this may indicate the influence of physical planning that has been aimed at stimulating housing developments near railway stations. The impact of the presence of natural areas is rather small: a tendency can be discerned that governments discourage residential construction in and near natural areas.

[1] Highest population density of Europe (1995): 371 persons / km2.
[2] Including agriculture, natural areas and forests. Water is excluded in the estimation of the total land area.
[3] This includes all artificial area (i.e. built-up area, infrastructure, leisure area and other artificial areas) except agriculture, forests, nature conservation areas and surface water areas
[4] Comparison of these figures is hampered by the fact that changes occurred in the way of land use registration by the CBS (national statistics office) during the last decades.
[5] For instance in the period 1979 to 1993 the individual living space (including the used infrastructure, parking lots, green structures, public space, etc.) increased from 180 m^2 per person in 1979 to 190 m^2 in 1993 (Ottens, 1999)
[6] Although in some grid cells the number of dwellings decreased in the period 1980 – 1995 by change of land use function or in the process of city renewal (demolition and rebuilding in lower densities), only grid cells in which the number of dwellings increased were incorporated in the statistical analysis.
[7] We should note however that also the already existing residential area is theoretically available for increasing the building density and that from the existing area for work a considerable area, like old industrial areas, has been transformed lately to residential area. And from the area occupied by surface water, it should be noted that still parts are reclaimed for residential use, like the new residential area 'IJburg' (in the 'IJ'-lake north of Amsterdam). Next the available building area was multiplied with the maximum number of dwellings per acre in 1995.
[8] See for instance WBO 1989/1990 and VROM-rapport 'Woonwensen en de realisatie van VINEX-locaties in de Randstad', 1994).

7. References

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