PAPERS OF THE REGIONAL SCIENCE ASSOCIATION, VOL. 65, 1988, pp. 59–77

A PREDICTIVE MODEL OF RESIDENTIAL MOBILITY AND RESIDENTIAL SEGREGATION

James O. Huff
Department of Geography
220 Davenport Hall
607 S. Mathews Avenue
University of Illinois at Urbana–Champaign
Urbana, IL 61801

Brigitte Waldorf
Woodrow Wilson School of Public and International Affairs
Princeton University
Princeton, NJ 08544

ABSTRACT The residential mobility model presented in this paper is specifically designed to capture the potential sources of bias embedded in the residential mobility processes that give rise to the segregation of minority populations within West German cities. The hypothesized existence of a dual housing market (with foreign workers restricted to vacancies not chosen by Germans) is supported by the analysis. Geographically defined submarkets and areal variation in housing quality, in conjunction with economic and class differences between members of German and foreign worker cohorts, are also found to account for significant differences in the observed mobility patterns across age and ethnicity cohorts.

1. INTRODUCTION

The incidence of racial and ethnic segregation within cities is of continuing concern not only in the United States but also in almost every urbanizing culture throughout the world. Given the pervasiveness of the phenomenon and the magnitude of the social problems engendered by continued physical separation of ethnic minorities, it is essential that we come to a better understanding of the processes that serve to create and maintain ethnic enclaves within cities. Toward this end, we investigate the relationship between residential segregation patterns and residential mobility processes that reflect racial discrimination, as well as other social, economic, and geographic mechanisms that indirectly affect the ethnic mix of households moving into and out of small areas within the city.

The tack taken in this study is rather different from other behavioral studies of segregation that attempt to resolve the continuing debate between those arguing that segregation is due to discrimination in the housing market and those who argue that segregation is due to differences in preference for neighborhoods with different racial composition. Both possibilities will be considered in the proposed residential mobility model. The contribution of the study, however, lies in the recognition that both institutional and physical constraints within the housing market effectively limit the supply of certain types of housing. These constraints, coupled with changes in demand due to the selectivity of migration into and out of the city as a whole, tend to interact with and often reinforce (rather than mitigate) the more traditionally identified sources of segregation.

The specific aim of the study is to produce a model of the mobility process that incorporates both micro behavioral and macro structural assumptions and is capable of reproducing the ethnic- and age-specific mobility patterns that serve to generate and maintain existing segregation patterns. We shall calibrate and evaluate the model using 1981 residential mobility, population, and housing data for Germans and foreign workers residing in the city of Dusseldorf, West Germany.

2. BACKGROUND

This study draws on two very different literatures and research streams: (1) the largely theoretical work on residential mobility as a process giving rise to changes in the size and composition of the population living in small areas within the city; and (2) the predominantly empirical study of residential segregation of foreign workers and their families. This section first provides a review of the empirical studies, as well as the few theoretical studies, of foreign workers in European cities, with a special emphasis on the West German situation. The competing explanations of residential segregation advanced in the literature on foreign workers serve to motivate the subsequent selection of variables in the residential relocation model. The remainder of the section is devoted to a brief review of the relevant work on residential mobility models and residential choice processes.

Foreign Workers in European Cities

The existing literature on foreign workers in European cities has been, for the most part, descriptive and inferential in nature with little emphasis on theory development. Nevertheless, it defines the dimensions of the foreign worker problem and provides valuable insights into the determinants of foreign worker mobility and location patterns.

The location patterns of foreign workers are characterized by concentrations in innercity areas, areas surrounding industrial locations, and, in some instances, in inexpensive public housing or workers' barracks at the outskirts of the city (O'Loughlin, Waldorf, and Glebe 1987; Leitner 1983). The degree of concentration and segregation is, however, relatively low if compared with ethnic or racial segregation in U. S. cities (Clark 1975).

The relationships between native and foreign intraurban migration flows, and areas of higher foreigner concentrations, are poorly understood; empirical studies provide ambiguous results concerning the existence of flight or avoidance on the part of the native population (Glebe and Waldorf 1987; Lichtenberger 1984; Hoffmeyer-Zlotnik 1977). There is, however, sufficient and consistent empirical evidence concerning aggregate relationships between neighborhood variables and the location and mobility patterns of foreign workers. Foreign workers predominantly live in, and move into, neighborhoods with inferior housing quality, low socioeconomic status, and aging populations (Glebe 1984). Their spatially confined interaction and migration fields (Gans 1984) are likely to perpetuate these patterns over time. The same conclusion can be drawn from several microlevel studies and surveys (Petri 1984; Esser 1982; Naman 1978) which indicate that the primary information sources used by foreigners in their residential search process are friends and relatives.

Most of the empirical studies cited so far subscribe either explicitly or implicitly to a view of the city consistent with the urban ecological theory of the Chicago Sociological School. Lichtenberger (1984) and O'Loughlin (1987) convincingly show, however, the inadequacy of the ecological theory when applied to the context of ethnic spatial segregation in European cities. Their

main argument is that the underlying assumptions are not fulfilled in Europe. In particular, they point out that European urban housing markets do not meet free market conditions but, instead, are highly regulated with respect to prices, tenure contracts, and access to some submarkets.

Similarly, the applicability of the self-segregation concept — that views choice as the predominant causative force of foreign worker residential location behavior — has been questioned. Studies by Borris (1973), Naman (1978), and Esser (1982) indicate that ethnic minorities in European cities would prefer to live close to members of the host society and are willing to pay more for housing in order to do so.

The most promising explanatory frameworks for ethnic segregation in European cities are those that explicitly consider the role of housing markets in shaping residential mobility and residential choice processes. In this respect, O'Loughlin's (1987) Weberian analysis of the conflict between native and foreign workers, as expressed in the consumption of housing, emerges as a compelling explanation of ethnic segregation in European cities. The managerialist conceptualization of housing markets (Rex and Moore 1967) represents another fruitful perspective on the problem, emphasizing the importance of housing supply constraints as well as the influence of landlords, real estate agents, and housing authorities on residential location processes.

Supply-side constraints as factors affecting intraurban migration patterns take on added significance in the case of the foreign workers in West German cities, for whom the choice of residence is highly constrained, at best, and nonexistent, at worst. Foreign workers find themselves relegated to less desirable housing that is spatially concentrated in what local authorities see as undesirable ghetto formations.

Discrimination in the form of prejudicial assignment practices and selective provision of housing information constitutes one of the main reasons for spatial segregation in many West German cities. Households are in competition for a very small number of vacancies, and marginal groups of society, particularly foreign worker households, are relegated to an inferior competitive position. In both the private sector and in social housing, Germans tend to be given first choice (O'Loughlin 1987; Laumann 1984), thereby further limiting the effective supply of housing for foreign workers to the lowest quality housing in the least desirable areas of the city. With the lowest quality housing spatially concentrated in these undesirable areas, it follows that a stratified housing market arising from prejudicial assignment practices gives rise to a high degree of residential segregation.

Segregated housing patterns may well arise because the information source or agent is selectively filtering the information depending upon the race or ethnicity of the client (Palm 1978). Overt discrimination need not be, however, the only, or even the most important, means by which the selective filtering of information occurs. If the search process is heavily dependent upon informal information sources in which word of a vacancy moves via interpersonal contact, as is the case in most German cities, then biases in the flow of information may reflect the underlying ethnic composition of an individual's contact network — i.e., Germans tell Germans about a given vacancy, Turks tell Turks, etc. Furthermore, distance decay and directional biases in an individual's awareness space contribute to incomplete and spatially biased information about available housing alternatives which, in turn, may lead to self-reinforcing patterns of residential location, particularly for ethnic minorities with limited activity and awareness spaces (Cronin 1982; Huff 1984).

Models of Residential Mobility and Neighborhood Change

The modeling of residential mobility and the attendant redistribution of German and foreign worker subpopulations draws upon recent advances in our understanding of individual mobility behavior as a *constrained choice process*. The focus of attention is on *barriers to access* and *inadequate housing supply* as the critical features of dual housing markets, because minority and low income households are rarely involved in unconstrained choice situations when it comes to residential mobility decisions. The mobility process is modeled as the outcome of myriad individual decisions in which the choice of a new residence is conditional on external factors relating to the supply of, and access to, housing alternatives. These alternatives are differentiated on the basis of housing characteristics, including locational attributes.

Two general classes of models are of relevance to the current discussion: (1) residential mobility and residential choice models, and (2) housing and segregation models.

Disaggregated approaches to residential mobility have been developed in response to a strong dissatisfaction with the nonbehavioral character of aggregated models. The disaggregated models recognize that the primary impetus for the decision to move is residential dissatisfaction, either interpreted as a psychological phenomenon (Wolpert 1965; Brown and Moore 1970) or in economic terms as disequilibrium in housing consumption (Quigley and Weinberg 1977).

The behavioral literature in this area has contributed significantly to our understanding of mobility behavior at the household level. Of particular relevance to the current research is the work done on information acquisition (Clark and Smith 1982; Smith and Clark 1982), coupled with work on the spatial aspects of the actual search process (Huff 1982, 1984, 1986). An analysis of the search process — notably the spatial aspects of search — is directly relevant to our understanding of the ethnic segregation process (Cronin 1979), since we suspect that biases in the housing information made available to minority households affect the search patterns and, hence, the ultimate location of the new residence (Palm 1978, 1985).

Until quite recently, the behavioral literature in this area could be neatly divided between studies of the decision to move and studies of the subsequent choice of residence. We are now coming to see the importance and the necessity of handling both aspects of the mobility decision within the same modeling framework. The nested logit model proposed by Onaka and Clark (1983) and the two-stage mobility model put forward by Ament and Van der Knaap (1985) are examples of attempts to bring the two pieces back together. These new insights at the micro level are complemented by methodological advances that provide means of moving between models of individual behavior and of flows between areas of the city.

A major shortcoming of residential mobility studies conducted in the behavioral tradition is neglect of the supply side of the housing market (Moore 1982; Huff 1986). The resulting models tend to be purely demand-oriented, focusing on the decision to move or stay without any consideration of the housing set available to households. Particularly from a public policy perspective, intraurban migration models that fail to recognize the importance of institutional constraints on access and housing supply are indefensible, especially in situations where government agencies or private institutions play an active role as intermediaries in the allocation of housing — as is true in most European housing markets.

Large-scale models of the urban housing market, such as the NBER model

(Ingram, Kain, and Ginn 1972; Kain and Quigley 1975), the Urban Institute's simulation model (Leeuw and Struyk 1975), or Anas's (1976) Chicago model, are not directly concerned with the prediction of residential mobility patterns within the city; but they do have a great deal to say about minority housing — notably that minority households pay more on average for the same housing bundle. This work tends to be aspatial and closely tied to assumptions about the supremacy of price as a market-clearing mechanism; but the treatment of housing and households (supply and demand) within the same model, and the methods used to estimate parameters, are potentially quite useful.

More recently housing market models have been developed that recognize the existence of submarkets with decidedly different market modes ranging from uncontrolled, price-based markets through totally controlled housing allocation methods (Snickars 1978; Anas and Cho 1986). Such efforts are likely to be quite helpful as starting points for the modeling of the segmented Dusseldorf housing market. We shall depart, however, from these previous approaches at several critical junctures — notably in the interpretive phases of the analysis, but also in the decision to include explicitly the spatial distribution of available housing in the various sectors as one of our critical variables.

3. MODEL FORMULATION

Our objective is to specify a residential mobility model that admits the possibility of choice while recognizing the very real constraints that serve to restrict the domain of choice, particularly for minority households. The model is designed to predict ${}_kM_i(t)$, the number of people in a given age and ethnicity cohort, k, who move into area i during time interval t. For the present, we shall be concerned with the simple conditional case in which the number of movers in each cohort, ${}_kM(t)$, is given, a priori, and the problem is one of predicting where these movers will relocate.

The proposed model represents an attempt to integrate two rather different models of human behavior: a vacancy-chain model (White 1971) and a multinomial logit model (McFadden 1978). The process of choosing between alternatives is modeled as a Luce-type choice process, with the probability of choosing a given alternative j, r_j, as specified by the multinomial logit model:

$$r_j = \exp(c_1X_{1j} + \ldots + c_nX_{nj}) \Big/ \sum_i \exp(c_1X_{1i} + \ldots c_nX_{ni}),$$

where X_{nj} is attribute n that affects the probability of choosing alternative j, and the parameter c_n is interpreted as the marginal utility associated with X_n.

We are dealing, however, with a constrained choice process in which the specification of the choice set becomes a critical issue. A vacancy-chain perspective suggests that we explicitly recognize that households are constrained to select a new residence from the set of available vacancies. The problem with most vacancy-chain models, however, is the implicit assumption of an unconstrained choice process defined over the underlying distribution of vacancies, and that the resulting mobility differentials across cohorts is a reflection of differences in preference orderings. Restrictions on access for certain subpopulations generally are not included within the model. As a first step toward the explicit treatment of access constraints operating within the Dusseldorf housing market, we propose to formalize the observation that, in general, Germans receive preferential treatment vis-à-vis foreign workers when it comes to the competition for scarce housing vacancies across all but the least desirable sectors of the housing market.

Formal Statement of the Model

The simplest way to represent the relatively weak bargaining position of foreign workers relative to Germans is to assume that the German population gets "first choice" from the set of all available vacancies and that the foreign workers "choose" from the set of vacancies remaining after the Germans have chosen. The result is a dual housing market such that the probability that a German in cohort k moves to area j, ${}_kp_j$, is a function of V_j, the number of vacancies in area j (during time period t) and the relative attractiveness of a vacancy in area j, ${}_kA_j$, which is assumed to be an exponential function of a linear combination of independent variables, $X_1, X_2, \ldots, X_n$, describing attributes of area j that are assumed to affect the chances that a household in cohort k would move into a particular vacancy in area j. The formal expression of the model for the German population is:

$$ {}_kp_j = (V_j^{a_{jk}})_k A_j \Big/ \sum_i (V_i^{a_{ik}})_k A_i. \tag{1} $$

where:

$$ {}_kA_j = \exp\left(\sum_i a_{ik} X_{ij}\right). $$

Given the probability that a German in cohort k moves into area j, and given the number of such Germans who move, ${}_kG$, we have the expected number moving into area j:

$$ {}_kG_j = {}_kG\ {}_kp_j. $$

For a foreign worker in cohort k, the set of potential choices in area j is assumed to be restricted to R_j such that:

$$ R_j = V_j - G_j, $$

where V_j is the original set of vacancies in area j, and G_j is the number of German households moving into it during the designated time period and filling a portion of the original vacancy set.

The constrained probability of moving to that same area j for a foreign worker in cohort k is assumed to be:

$$ {}_kq_j = (R_j^{b_{jk}})\ {}_kB_j \Big/ \sum_i (R_i^{b_{ik}})\ {}_kB_i. \tag{2} $$

where:

$$ {}_kB_j = \exp\left(\sum_i b_{ki} X_{ij}\right). $$

The expected number of foreign workers in cohort k moving into area j (during the specified time period) is:

$$ {}_kF_j = {}_kF\ {}_kq_j, $$

where ${}_kF$ is the total number of foreign workers in the cohort moving during the specified time period.

The formal statement of the mobility model is complete at this point; however several aspects of the model deserve further mention. Throughout the above presentation, it is assumed that the population is partitioned into subpopulations homogeneous in probability of moving to area j. This assumption enables us to move from individual-level responses of the sort described in the above model to inferences concerning the expected number of people (from a given subpopulation) moving into area j during a particular time period. Changes in the distributions of these subpopulations and changes in the distribution of vacancies implied by the mobility process must be accounted for if the above model is to have a temporal component. This aspect of the model is not treated here because the analysis at this stage is purely cross-sectional.

Variable Specification

To complete the model we must specify $X_1, X_2, \ldots, X_m$ the independent variables responsible for observed differences in the chances of finding and selecting a vacancy in various areas of the city. The objective is to select variables that will enable us to differentiate between competing explanations of observed differences in residential mobility patterns across cohorts — particularly differences between Germans and foreign workers — while also maintaining a relatively high level of explanatory power within the overall model.

The selection of variables is constrained by data limitations and is made more difficult because we wish to predict the behavior of individuals facing a number of different life situations, ranging from the young foreign worker arriving in the city for the first time and seeking a place to live within a largely unknown environment, to the older German householder desiring a residence in a higher status neighborhood.

As shown in Table 1, the set of independent variables may be divided into three groups: housing-stock variables, social (human ecology) variables, and locational variables.

Housing-stock variables. The housing variables are intended to capture the influence of housing mode, quality, type, and availability on the mobility decisions of members in the various age and ethnicity cohorts.

The geographic distribution of vacancies is assumed to play a pivotal role in the residential mobility process. The form of the model suggests that the

TABLE 1. Variables Included in the Empirical Analysis

I. Dependent Variable: $Y(j)$	=	the natural logarithm of the proportion of the subpopulation that moved to community area j during 1981
II. Independent Variables		
A. Housing-stock Variables (as measured for each area j)		
SOCIAL HOUSING	=	% units classed as social housing
CENTRAL HEAT	=	% units with central heating
VACANCY 1	=	Estimated number of vacancies
VACANCY 2	=	Estimated number of vacancies left unfilled by Germans
B. Social Variables (as measured for each area j)		
FOREIGN WORKER	=	% population that is classed as foreign worker
CHILDREN	=	% population under 6
AGE 65	=	% population over 65
SOCIAL SUBSIDIES	=	% population receiving social subsidies
C. Locational Variables		
ACCESS	=	a measure of an area's access to employment opportunities (see text discussion)
ZONE 1*	=	zero/one variables indicating an area's location in Zone 1 or
ZONE 2		Zone 2 (see map, Figure 1)

*ZONE 1 and ZONE 2 are also classed as housing-stock variables in the analysis.

German cohorts should be responding positively to areas with a relatively large number of total vacancies: VACANCY 1 (V). On the other hand, foreign worker cohorts should be responding to the distribution of residual vacancies defined by the variable VACANCY 2 (R).

The vacancy data were estimated under the assumption that the number of vacancies in area j during the time period in question is equal to the number of vacancies created by households observed to change residence (in the area), minus the number of units demolished, plus the number of newly constructed units. The instantaneous vacancy rate at the beginning of the time period was assumed to be zero across all areas. We have reason to believe that the instantaneous vacancy rate is quite low (and therefore not a major source of error in the analysis) since housing supply continues to lag behind demand across the city and transition periods are minimized because tenants generally give three to five months notice before a move.

An important feature of the German housing situation is that certain sectors are publicly controlled with conditions on access as well as controls on rents. The measure of differences in housing mode used in this analysis is SOCIAL HOUSING (X_1). Ideally, social housing is meant to relieve the short supply of housing for poorer households (particularly those with children) not able to satisfy their basic housing needs in the private sector. On the basis of the above characterization, our naïve hypothesis would be that foreign workers should show a strong tendency to relocate into areas with large amounts of social housing owing to their generally inferior economic condition and the correspondingly high likelihood of qualifying for subsidized social housing. On the other hand, if foreign workers fail to gain access to social housing vacancies, even though they may qualify, we should see no tendency to move into areas with higher concentrations of social housing, ceteris paribus.

The expectation is that cohorts in stronger economic positions, and Germans relative to foreign workers, will actively select into higher quality housing areas, leaving the lower quality housing to the lower income German and foreign populations. (Since we do not have income data, we can only speculate that Germans in the 35–65 age cohort tend to be in a stronger economic position than either the younger or the older age cohorts.) The primary housing quality variable in this analysis is CENTRAL HEAT (X_2).

The residential areas of the city were divided into three roughly concentric zones based on a cluster analysis designed to group the 42 community areas on the basis of similarities in the type and quality of housing, as well as similarities in the geographic location of the areas. The cluster analysis was a two-step process. The first step was the clustering of community areas on the basis of similarities in the type of housing in the area, where "housing type" was operationalized in the form of three housing variables: the percentage of the housing units with four or more rooms, the average number of housing units per building, and the proportion of the units with central heating. In the second step, we introduced a contiguity condition coupled with a measure of "geographic similarity," as measured by an area's distance from the CBD.

The three housing zones are shown in Figure 1. Generally speaking, Zone 1 is comprised of relatively low-quality, high-density apartments near the center of the city; immediately beyond the central core, Zone 2 tends to contain larger and higher quality apartments; and the trend in quality and size continues in Zone 3 — a peripheral zone with newer housing surrounding older village centers engulfed by the expansion of the city.

All else being equal, we expect a stage-in-life-cycle distinction across the

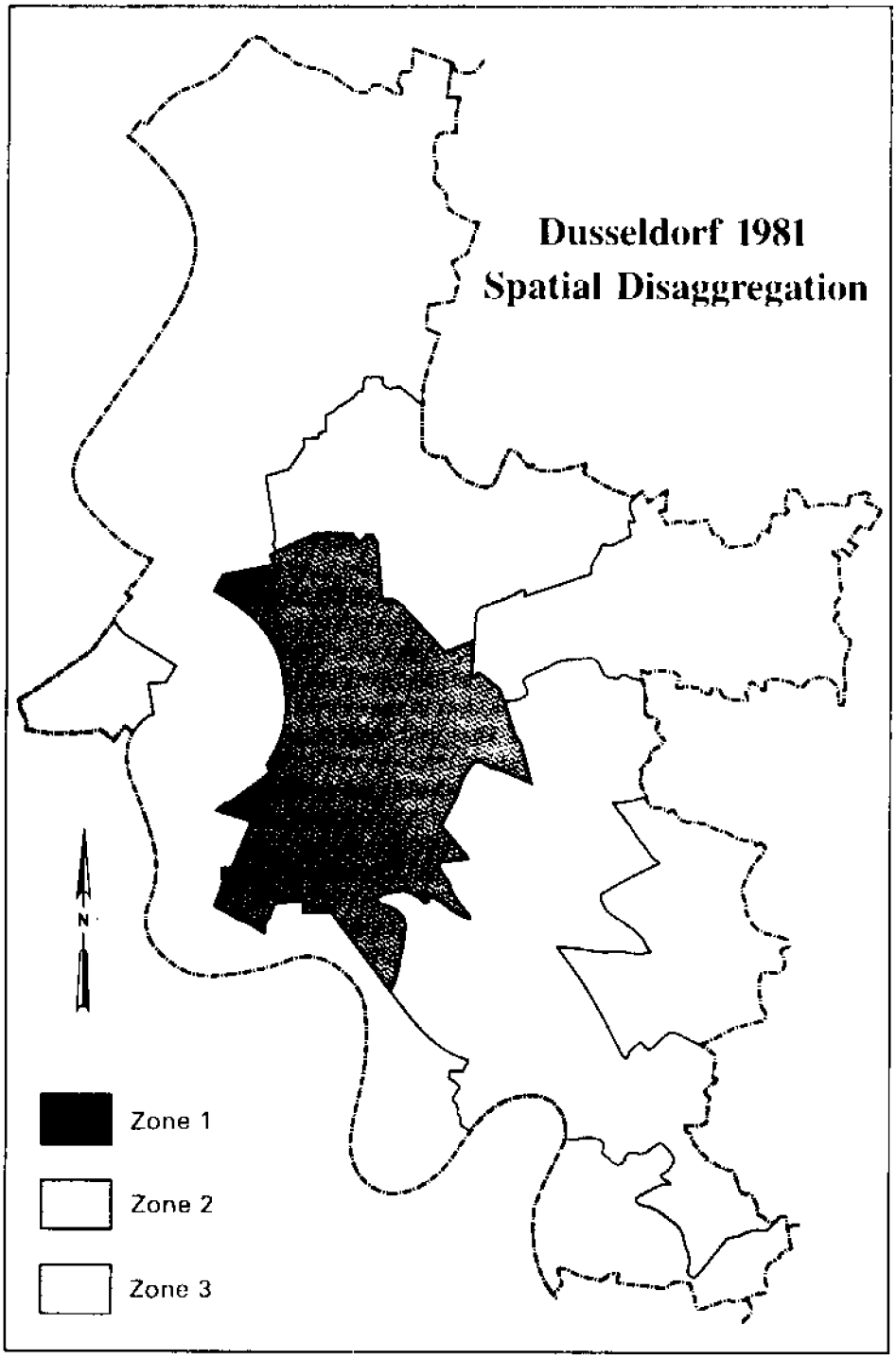

FIGURE 1. Housing Zones, Dusseldorf, 1981

zones, with the younger cohorts attracted to the inner portion of the city, and cohorts in the child-rearing stage preferring living conditions characteristic of Zone 3. The variables ZONE 1 (X_3) and ZONE 2 (X_4) were thus defined to proxy stage-in-life-cycle differences.

In addition to the number of vacancies in an area, a second, and less important, measure of housing availability is NEW CONSTRUCTION (X_5). All else being equal, an area of new construction will tend to attract migrants, and the composition of the in-migrant stream will tend to depend upon the housing mode, quality, and type. We had no a priori expectations concerning possible German/foreign-worker differences.

Social variables. The social variables are selected to capture the three basic dimensions arising out of the factorial ecology literature: ethnicity, stage-in-life-cycle, and socio-economic status (the criticisms of this perspective, as noted earlier, notwithstanding).

The ethnicity dimension is measured by FOREIGN WORKERS (X_6). Because of the continuing debate in the literature as to the role played by this variable, we set up two competing hypotheses. If foreign workers are self-selecting into areas of high foreign concentration, then the observed relationship should be positive and significant for foreign worker cohorts. On the other hand, if Germans are actively avoiding areas with high concentrations of foreign workers, then the associated coefficient should be negative and significant.

The expectation is that households will tend to select into areas containing other households like themselves both in terms of stage-in-life-cycle and in terms of socio-economic status. The stage-in-life-cycle dimension is measured by CHILDREN (X_7) and by AGE 65 (X_8). The obvious measure of socio-economic status would be an income variable, but since we don't have data on income, we use SOCIAL SUBSIDIES (X_9). The poor, and in particular the elderly poor, would be represented by this variable.

Locational variables. The variables in this group represent the influence that the relative location of an area can have upon the probability that a potential migrant (located in that area, another area of the city, or outside the city) moves into that area. Two aspects of location are considered in this analysis: accessibility and geographic submarkets.

We assume that areas more accessible to employment opportunities will be more attractive and that the youngest adult cohort (presumably persons without children) will tend to trade off space for accessibility more readily than other cohorts. The accessibility variable, ACCESS (X_{10}), is defined by the standard accessibility measure:

$$X_{10i} = \sum_j E_j / D_{ij}$$

where E_j is the estimated number of jobs in area j (based on 1970 census data on employment), and D_{ij} is the distance between area i and area j.

As noted in the previous discussion of housing variables, neighborhood areas within Dusseldorf have been divided into three concentric zones on the basis of housing type. The expectation is that households originating within a specific zone will have a strong tendency to move to another vacancy within that same zone. The existence of such a pattern would be consistent with search-based models of the mobility process of the sort mentioned earlier (Huff 1986).

Operational Model

Our modeling efforts are designed to provide an accurate depiction of the residential mobility process primarily responsible for the observed mobility patterns of each of the seven age and ethnicity cohorts across the 42 community areas within Dusseldorf.

The population and housing data for the 42 community areas are from the *1981 Statistical Yearbook of Dusseldorf* and a 1981 update of the housing census conducted in 1968. Cohort-specific mobility data for the 42 community areas are compiled from population registry information collected by the City Council of Dusseldorf. The at-risk population in this analysis is comprised of adult males who changed residence, moved into, or left the city of Dusseldorf during 1981. The German population is divided into four age cohorts: 20–35, 36–45, 46–65, and over 65; the foreign worker population is divided into three age cohorts: 20–35, 36–45, and over 45. The relatively small number of over 65 foreigners necessitated the decision to combine the two older age categories.

Throughout the remainder of the discussion, the term "foreign workers" will be used to denote foreign nationals from the following countries: Turkey, Italy, Greece, Spain, Yugoslavia, and Morocco. The remainder of the population will be designated as "German." The foreign worker population could not be broken down by nationality due to the sparsity of the data matrix implied by further disaggregation.

Each age and ethnicity cohort was further divided into those who made an intra-urban move (moves within Dusseldorf) and those moving into the city from an origin outside the city — interurban movers. Those making intra-urban moves were distinguished further on the basis of the location of their prior residence within the city. The location was described as one of the three zones shown in Figure 1. We disaggregate the population on the basis of age, ethnicity, and location of origin because we have reason to believe that each of these characteristics has an important bearing on the outcome of the mobility process.

The mobility model outlined in the previous section will be evaluated for each of 25 subpopulations. The resulting breakdown by age, ethnicity, and location is as shown in Table 2. Due to the small numbers in several of the non-German cohorts residing in various areas of the city, it was not possible to disaggregate all of the non-German cohorts on the basis of location.

The functional form of the operational model follows immediately from the formal model as defined in Equations 1 and 2. With a logarithmic transformation, the model can be expressed as a simple linear equation whose parameters may be estimated using standard OLS procedures:

$$ {}_kY_i = {}_kK_1 + a_k \ln V_i + a_{1k} X_{1i} + \ldots + a_{nk} X_{ni} + {}_k\varepsilon_i $$

for Germans in cohort k, and:

$$ {}_kZ_i = {}_kK_2 + b_k \ln R_i + b_{1k} X_{1i} + \ldots + b_{nk} X_{ni} + {}_k\varepsilon_i $$

for foreign workers in cohort k. The dependent variables in the above expressions are defined as the logarithm of the proportion of movers in the cohort that move to area j: ${}_kY_i$ for Germans, and ${}_kZ_i$ for foreign workers; and the independent variables are as defined previously.

4. SUMMARY OF RESULTS

The results of the analysis are summarized in Tables 3 and 4. The overall performance of the model is very good, with high proportions of the variance explained for most of the 25 age/ethnicity/location subpopulations.

TABLE 2. Subpopulation Breakdown Used in the Empirical Analysis

Nationality	Location of Origin	Cohort
German	Zone 1	20–35
		36–45
		46–65
		Over 65
	Zone 2	20–35
		36–45
		46–65
		Over 65
	Zone 3	20–35
		36–45
		46–65
		Over 65
	Interurban	20–35
		36–45
		46–65
		Over 65
Foreign Workers	All zones combined	20–35
		36–45
		Over 45
	Interurban	20–35
		36–45
		Over 45
	Zone 1	All age cohorts combined
	Zone 2	All age cohorts combined
	Zone 3	All age cohorts combined

In general, the most predictable subpopulations were to be found in the youngest cohort (20–35) and among those living in the inner-city area (Zone 1), while the least predictable subpopulations were drawn from the elderly population and from those originating in the outer ring of neighborhoods (Zone 3). The model appears to perform about as well in the prediction of foreign-worker mobility patterns as it does for the comparable German subpopulation for intra-urban movers; however, for interurban movers, the model does a better job of predicting the movements of the German subpopulations.

An analysis of the performance of specific variables across the different cohorts bears out most of our a priori expectations. Certainly the most consistent outcome is the strong, positive relationship between the distribution of housing vacancies and the observed mobility patterns across all German subpopulations and a correspondingly strong, positive relationship between the mobility patterns for foreign workers and the constrained vacancy set — VACANCY 2. The central role played by the distribution of housing vacancies is important, but not surprising; in fact it serves as a major cautionary note to studies of housing preference that make use of areally aggregated data while failing to include the distribution of vacancies as a variable in the analysis.

The second outcome that showed a consistent pattern was the overall importance of the geographically delimited housing submarkets (ZONE 1 and ZONE 2), indicating significant barriers to entry and exit. The insularity of Zone 3 (negative signs on ZONE 1 and ZONE 2) was particularly pronounced and was generally the case across all cohorts residing in Zone 3. One implication is that the mobility process should be modeled as a two-stage search process, with the selection of a specific area conditional upon the selection of a geographic

TABLE 3. Results of the Regression Analysis for Foreign Worker Subpopulations

Foreign worker Subpopulation: Age/Zone	R^2	VACANCY 2	SOCIAL HOUSING	CENTRAL HEAT	ZONE 1	ZONE 2	NEW CONST.	FOREIGN	CHILDREN	AGE 65	SOCIAL SUBSIDIES	ACCESS
20–35/ All zones	.93	.86* (6.98)			+		+	+		+	+	
36–45/ All zones	.82	.64* (3.59)		−			+					
>45/ All zones	.89	.80* (5.49)		−.038* (−2.99)	−.73 (−1.88)	−.74* (−2.10)	.0037* (2.44)					+
20–35/ Interurban	.84	1.04* (6.02)		−				−		+		
36–45/ Interurban	.70	.88* (4.12)								−		
>45/ Interurban	.80	.58* (3.55)		−.030* (−2.14)				−				+
All ages/ Zone 1	.89	.67* (4.07)		−	1.02* (2.32)						1.73* (2.06)	
All ages/ Zone 2	.81	.73* (3.79)				.77 (1.65)						
All ages/ Zone 3	.72	.73* (3.91)	+		−1.49* (−2.98)	−1.52* (−3.36)		+		+	−	$.36\times10^{-4}$ (1.84)

Note: The sign of the coefficient is shown if the standard error is less than the absolute value of the coefficient. The value of the coefficient and the associated t-statistic are shown if the coefficient is significantly different from zero at the .1 level. An asterisk indicates significance at the .05 level.

TABLE 4. Results of the Regression Analysis for German Subpopulations

German Subpopulation: Age/Zone	R^2	VACANCY 1	SOCIAL HOUSING	CENTRAL HEAT	ZONE 1	ZONE 2	NEW CONST.	FOREIGN	CHILDREN	AGE 65	SOCIAL SUBSIDIES	ACCESS
20–35/		.80*		−.021*	.50*	−.29	.0037*	−.036*	.22			$.20\times10^{-4}$*
Zone 1	.96	(9.50)		(−3.50)	(2.68)	(−1.71)	(2.25)	(−2.37)	(1.94)			(2.41)
36–45/		.88*	−.011*		.49							
Zone 1	.91	(7.30)	(2.38)		(1.83)							$.30\times10^{-4}$
46–65/		.53*			.75*		.0025		.38	.11*		(1.90)
Zone 1	.87	(3.27)			(2.10)		(1.74)	−	(1.78)	(2.62)		
>65/		.65*								.13*	3.41*	
Zone 1	.84	(3.32)	+		+			−	+	(2.62)	(4.06)	
20–35/		.75*	.014*	−.019					.344			
Zone 2	.88	(5.14)	(2.59)	(−1.85)		+	+	−	(1.78)			+
36–45/		.75*				.71			.57*			
Zone 2	.72	(3.70)	+			(1.77)		−	(2.15)			
46–65/		.61*	.019			.86						
Zone 2	.70	(2.38)	(1.98)			(1.67)		−				
>65/		.68*									3.07*	
Zone 2	.72	(2.43)				+	+	−			(2.53)	
20–35/		.94*			−1.18*	−1.08*						
Zone 3	.78	(6.34)	−	−	(−3.64)	(−3.61)	+				−	+
36–45/		.61*	−.018*	.022*	−.87*	−.68*	.0033*	.056				
Zone 3	.71	(3.91)	(−3.05)	(2.03)	(−2.54)	(−2.18)	(2.42)	(2.02)		+	−	
46–65/		.60*			−1.34*	−1.12*		−.080*				
Zone 3	.68	(3.44)		−	(−3.47)	(−3.19)		(−2.59)	+	+		+
>65					−1.31*	−1.04				.16*		
Zone 3	.53	+			(−2.38)	(−1.97)				(2.44)		
20–35/		.87*										$.13\times10^{-4}$
Interurban	.96	(12.23)	−						+		+	(1.90)
36–45/		.91*			.57							
Interurban	.86	(7.03)		+	(1.98)			−	+		+	
46–65/		.96*	−.014*	.018		.61*						
Interurban	.88	(7.26)	(−2.82)	(1.88)		(2.29)						
>65/		.92*				−.78			.46			
Interurban	.71	(4.60)			−	(−1.88)		−	(1.74)	+		+

submarket (see Huff 1986 for a discussion of an area-based search model that is consistent with these findings).

It is worth reiterating at this point that we are primarily interested in those features of the residential mobility model that provide insights into the segregation process as it affects the location of foreign workers and as it operates within the specific context of the Dusseldorf housing market.

The distinction between the two opportunity sets — VACANCY 1 and VACANCY 2 — clarifies the general nature of the dual housing market prevailing in West German cities; and this distinction is a direct indication of preferential treatment accorded German households, either indirectly through the transfer of information pertaining to the availability of vacancies, or directly at the point of transaction.

The evidence of bias in the social housing sector and the implied influence of urban managers is to be found in a "nonresult." Foreign workers should exhibit a strong tendency to move into cheaper social housing, but they do not. A key task in subsequent work on this problem will be to uncover the structural features of the various market modes that lend themselves, both directly and indirectly, to the further limitation of the residential location decisions of the foreign worker population. These structural features will become an important part of the resulting residential mobility model in that they will often serve as key regulators in the system — regulators that potentially can serve as policy instruments.

Ethnic segregation can occur as a result of self-segregation in which the ethnic composition of the potential destination (neighborhood or apartment building for that matter) enters as a significant variable in the household's preference function. If one or more of the ethnically defined subpopulations shows a marked preference for neighborhoods with high concentrations of that same subpopulation, then the residential areas in the city are likely to become increasingly segregated — the dynamics of the process are likely to follow a Schelling-type tipping model (Schelling 1978).

We do find that Germans tend to actively avoid areas with higher concentrations of foreign workers, particularly Germans originating in Zones 1 and 2 of the city. On the other hand, there is only a weak indication that foreign workers actively select into foreign worker areas. In fact, if anything, foreign workers moving into the city for the first time tend to avoid areas with higher concentrations of foreign workers.

Finally, ethnic segregation may arise as a result of the geographical differentiation of subpopulations on the basis of some other characteristic that is highly correlated with ethnicity. The most prevalent example of this "associative segregation" is class-based segregation. In the present analysis, we find evidence for class-based or income-based patterns of segregation and of the biased mobility patterns associated with such patterns in the behavior of the CENTRAL HEAT coefficient. Foreign workers and younger German cohorts tend to "avoid" areas with higher quality housing. The most likely explanation for this behavior is that these cohorts tend to be poorer and are unable to afford the higher rents for better quality housing.

5. CONCLUDING REMARKS

This study responds to a persistent criticism of previous work on behavioral models of residential mobility and residential search. Invariably this work is justified in terms of its potential for providing insights into the processes responsible for the observed pattern of human occupance within the city; and

yet, the critical links between the changing pattern of the urban mosaic at the neighborhood level and the residential mobility processes affecting and affected by those patterns are rarely made.

The mobility model we have developed is a direct response to these criticisms in that it explicitly recognizes the duality between moves and vacancies in the housing stock. As such, the model is a member of a general class of vacancy-chain models (White 1971). In this case, however, a dual housing market is assumed to exist in which the potential choice set for Germans (the preferred tenants) is the underlying distribution of vacancies across the city, whereas the potential choice set for foreign workers (the ethnic minority) is comprised of the vacancies not chosen by German movers. The resulting mobility model proves to be a very good representation of the observed mobility patterns both for Germans and for foreign workers, and the dual housing market hypothesis is also supported.

The residential mobility model developed in this paper is also designed to formalize and to integrate a number of competing explanations for the continued geographic segregation of racial and ethnic minorities within cities. The results of the empirical analysis generally support previous work in this area; the analysis, however, serves to establish the relative importance of different sources of ethnic bias in the mobility process for different age and ethnicity cohorts. The results also clearly indicate the importance and influence of geographically defined submarkets in the mobility process.

The analysis serves to clarify the role of foreign worker self-segregation and German avoidance/flight behavior in the segregation process. We find only a weak indication that foreigners actively select into established foreign worker neighborhoods, while for some German subpopulations avoidance of foreign worker areas appears to be a common decision criterion.

Finally, the existence of class-based, economically induced segregation is supported by the analysis. We are unable to find significant ethno-specific differences in the preference for areas with different housing quality when we compare the behavior of foreign workers with that of younger (and presumably lower income) German subpopulations.

Future Modifications to the Model

The residential mobility process described in this paper ultimately will be embedded within a small-area population forecasting model that serves as an accounting framework for describing the implied changes in the distribution of different subpopulations arising from differential rates of in- and out-migration of these subpopulations dispersed across the various parts of the city. The accounting framework also provides a means of following the changing distribution of housing vacancies associated with the ongoing mobility of the different subpopulations — an essential component of the residential mobility model.

Aside from developing an overall accounting framework to track changes in the distribution of population and housing, we also are working on the portion of the model concerned with predicting changes in cohort-specific mobility rates. The model recognizes that the probability of staying in one's current residence may be a function of the number and distribution of available alternatives, which means that the mobility rates for the various subpopulations in the study are endogenous to the model. This is an important feature of the model because West German housing markets are characterized by chronic under-supply and a correspondingly low level of residential mobility (Monheim 1979). By making the mobility rates endogenous, the model also becomes better suited for the

simulation of policies that have an impact upon the supply of housing. We also recognize that the duration of residence — particularly in controlled or partially controlled housing — may affect the probability of staying.

A consistent criticism of the model in its present form has been that the high level of ethnic diversity within the "foreign worker" population presents a serious problem, both in terms of analysis and in terms of the subsequent interpretation of the results. In response to this criticism, we are presently working on a model in which the foreign worker population is disaggregated by nationality.

An important feature of the project is the decision to treat in-migration and out-migration to and from the city as explicit elements in the modeling effort and not as inputs to be determined exogenously. Our previous work with small-area forecasting models suggests that intraurban mobility patterns (as well as segregation patterns) may be very sensitive to changes in the size and composition of the population moving into and out of the city (Huff 1981; Huff and Waldorf 1987).

We are currently working on submodels that predict the size and composition of the migration flows to and from Dusseldorf. The flows are differentiated depending upon whether the external regions represent predominantly suburban housing zones in the immediate vicinity of the city or destinations outside the local labor market. In the first instance, the suburban zones are considered to be part of the local housing market from the vantage point of the prospective migrant, and locational decisions are made accordingly. In the second instance, we have a two-stage migration process in which the flows of migrants among labor markets are assumed to be primarily a function of differences in employment opportunities, while housing considerations play a subordinate role, with housing adjustments made at a later stage (Goodman 1982). We have also made some progress toward the prediction of international migration (Waldorf and Esparza 1987), where job-related immigration is a function of employment opportunity differentials between origin and destination countries.

Ultimately, we are also interested in using the model for prescriptive purposes. The characterization of the mobility process as a vacancy chain is attractive since one popular policy alternative in response to chronic housing shortages (experienced by the foreign worker population) is some form of filtering (Grigsby 1963), and a vacancy-chain model can be used to evaluate the potential effectiveness of such a policy. Furthermore, supply constraints can be directly addressed within a vacancy-chain model. The micro aspects of a Schelling-type tipping point model (Schelling 1978) can also be investigated within a vacancy-chain framework because the micro dynamic is the change in the probability that a vacancy created by a German, for example, is filled by a foreign worker household.

ACKNOWLEDGMENTS

The research reported in this paper was carried out under NSF Grant SES87-12142. We wish to thank the editors and two anonymous reviewers for valuable comments and suggestions.

REFERENCES

Ament, D. C. and van der Knaap, G. A. 1985. A two-stage model for the analysis of intraurban mobility processes. *Environment and Planning A* 17: 1201–16.

Anas, A. 1976. Short run dynamics in the spatial housing market. In *Mathematical land use theory*: ed. S. J. Papageorgiou, Lexington, MA: D. C. Heath, pp. 262–75.

Anas, A. and Cho, J. R. 1986. *A dynamic policy oriented model of the regulated housing market: the Swedish prototype.* Evanston, IL: Northwestern University, working paper.

Borris, M. 1973. *Ausländische Arbeitnehmer in einer Großstadt: eine empirische Untersuchung am Beispiel Frankfurt.* Frankfurt: Eurobische Verlagsanstalt.

Brown, L. A. and Moore, E. G. 1970. The intra-urban migration process: a perspective. *Geografiska Annaler* 52 B: 1–13.

Clark, J. R. 1975. Residential patterns and social integration of Turks in Cologne. In *Manpower mobility across cultural boundaries*, ed. R. E. Krane, Leiden: E. J. Brill, pp. 61–76.

Clark, W. A. V. and Smith, T. R. 1982. Housing market search behavior and expected utility theory: II. the process of search. *Environment and Planning A* 14: 717–37.

Cronin, F. J. 1979. *Low income household's search for housing: preliminary findings on racial differences.* Washington, DC: The Urban Institute.

Cronin, F. J. 1982. Racial differences in the search for housing. In *Modelling housing market search*, ed. W. A. V. Clark, London: Croom Helm, pp. 81–105.

Esser, H. 1982. *Sozialökologische Bedingungen der Eingliederung ausländischer Arbeitnehmer im Ruhrgebiet — am Beispiel Duisburg.* Duisburg: Rhein-Ruhr Institut für Sozialforschung und Politikberatung.

Gans, P. 1984. Innerstädtische Wohnungswechsel und Veränderungen in der Verteilung der ausländischen Bevölkerung in Ludwigshafen/Rhein. *Geographische Zeitschrift* 72: 81–89.

Glebe, G. 1984. Tendenzen ethnischer Segregation und Konzentration von Gastarbeiterminoritäten in Düsseldorf 1974–1982. *Zeitschrift für Wirtschaftsgeographie* 28: 91–111.

Glebe, G. and Waldorf, B. 1987. Migration patterns of Germans and foreigners in three Düsseldorf neighborhoods. In *Foreign minorities in continental European cities*, eds. G. Glebe and J. O'Loughlin, Stuttgart: Franz Steiner Verlag Wiesbaden GmbH, pp. 139–62.

Goodman, M. 1982. Linking local mobility rates to migration rates: repeat movers and place effects. In *Modelling housing market search*, ed. W. A. V. Clark, London: Croom Helm, pp. 209–23.

Grigsby, W. 1963. *Housing markets and public policy.* Philadelphia: University of Pennsylvania Press.

Hoffmeyer-Zlotnik, J. 1977. *Gastarbeiter im Sanierungsgebiet. Das Beispiel Berlin-Kreuzberg.* Hamburg: Christians Verlag.

Huff, J. O. 1981. Population dynamics and population projection techniques for local areas. In *Dynamic spatial models*, eds. D. Griffith and R. MacKinnon, Rotterdam: Sijthoff/Noordhoff International, pp. 78–101.

Huff, J. O. 1982. Spatial aspects of residential search. In *Modelling housing market search*, ed. W. A. V. Clark, London: Croom Helm, pp. 106–29.

Huff, J. O. 1984. Distance decay models of residential search behavior. In *Spatial statistics and models*, eds. G. L. Gaile and C. J. Willmott, New York: D. Reidel Publishing, pp. 345–66.

Huff, J. O. 1986. Geographic regularities in residential search behavior. *Annals of the Association of American Geographers* 76: 208–27.

Huff, J. O. and Waldorf, B. 1987. Residential mobility: patterns and processes. Urbana–Champaign, IL: University of Illinois, working paper.

Ingram, G. K., Kain, J. F., and Ginn, J. R. 1972. *The Detroit prototype of the NBER urban simulation model.* New York: Columbia University Press.

Kain, J. F. and Quigley, J. M. 1975. *Housing markets and racial discrimination.* New York: National Bureau of Economic Research.

Laumann, W. 1984. Ausländer im sozialen Wohnungsbau — Wirkungen und Grenzen der Belegungspolitik. In *Ausländerintegration – – Politiek ohne Alternative*, ed. Deutscher Verband für Angewandte Geographie E. V., Bochum: DVAG, pp. 63–71.

Leeuw, F. and Struyk, R. 1975. *The web of urban housing: analyzing policy with a market simulation model.* Washington, DC: The Urban Institute.

Leitner, H. 1983. *Gastarbeiter in der städtischen Gesellschaft.* Frankfurt: Campus Verlag.

Lichtenberger, E. 1984. *Gastarbeiter: Leben in zwei Gesellschaften.* Wien: Hermann Bohlaus Verlag.

McFadden, D. F. 1978. Modelling the choice of residential location. In *Spatial interaction theory and planning models*, eds. A. Karlqvist, L. Lundqvist, F. Snickars, and J. W. Weibull, Amsterdam: North Holland, pp. 75–96.

Monheim, R. 1979. Wohnungsversorgung und Wohnungswechsel: Probleme einer mobilen Gesellschaft. *Geographische Rundschau* 31: 17–28.

Moore, E. G. 1982. Search behavior and public policy: the conflict between supply and demand perspectives. In *Modelling housing market search*, ed. W. A. V. Clark, London: Croom Helm, pp. 224–38.

Naman, H. 1978. *Türkische Arbeiter in Münster: ein Beitrag zum Problem der temporären Akkulturation.* Münster: F. Coppenrath Verlag.

O'Loughlin, J. 1987. Chicago an der Ruhr or what? Explaining the location of immigrants in European cities. In *Foreign minorities in continental European cities*, eds. G. Gilebe and J. O'Loughlin, Stuttgart: Franz Steiner Verlag Wiesbaden GmbH, pp. 52–69.

O'Loughlin, J., Waldorf, B., and Gilebe, G. 1987. The location of foreigners in an urban housing market: a micro-level study of Düsseldorf-Oberbilk. *Geographische Zeitschrift* 75: 22–41.

Onaka, J. and Clark, W. A. V. 1983. A disaggregate model of residential mobility and housing search. *Geographical Analysis* 15: 287–304.

Palm, R. 1978. Spatial segmentation of the urban housing market. *Economic Geography* 54: 210–21.

Palm, R. 1985. Ethnic segmentation of real estate agent practice in the urban housing market. *Annals of the Association of American Geographers* 75: 58–68.

Petri, A. 1984. Die Notlösung als Dauerzustand. In *Ausländerintegration — Politik ohne Alternative*, ed. Deutscher Verband für Angewandte Geographie E.V., Bochum: DVAG, pp. 55–62.

Quigley, J. M. and Weinberg, D. H. 1977. Intraurban residential mobility: a review and synthesis. *International Regional Science Review* 2: 41–66.

Rex, J. and Moore, R. 1967. *Race, community and conflict*. London: Oxford University Press.

Schelling, T. C. 1978. *Micro motives and macro behavior*. New York: W. W. Norton.

Smith, T. R. and Clark, W. A. V. 1982. Housing market search behavior and expected utility: I. measuring preferences for housing. *Environment and Planning A* 14: 681–98.

Snickars, F. 1978. A dynamic stock-flow model of a regulated housing market. In *Spatial interaction theory and planning models*, eds. A. Karlqvist, L. Lundqvist, F. Snickars, and J. W. Weibull, Amsterdam: North Holland, pp. 157–76.

Waldorf, B. and Esparza, A. 1987. *Re evaluating international labor migration to Western Europe, 1960–1982*. Urbana–Champaign: University of Illinois, working paper.

White, H. 1971. Multipliers, vacancy chains, and filtering in housing. *Journal of the American Institute of Planners* 37: 88–94.

Wolpert, J. 1965. Behavioral aspects of the decision to migrate. *Papers of the Regional Science Association* 15: 159–69.