Chapter 25
Agent-Based Modelling of Residential Mobility, Housing Choice and Regeneration

René Jordan, Mark Birkin, and Andrew Evans

Abstract Dynamics in the housing market can be simulated using agent-based modelling. Focusing on the theme of urban regeneration, we present a housing market model framework which explores the causal relationships that occur in this market.

25.1 Introduction

The housing market is a dynamic system of intricately woven interdependent processes. It is affected by the volatility in the financial markets and the conditions of this market affect discriminatory individual level behaviour. Like other applications, agent-based models (ABMs) can be used to simulate activity in this market with a view to gaining a better understanding of how the market works as well as to realise causal relationships that occur.

The terms residential mobility and housing choice are standard within housing market research and can be found across the housing studies literature (Kim et al. 2005; Tu and Goldfinch 1996). These terms encapsulate the movement questions which lead households to decide whether to move and subsequently choose a new home. One of the most influential factors which affect these processes is the family life cycle, in collaboration with income (Dieleman 2001). Changes in the family life cycle affect location choice whilst overall government policy affects demand and supply of the housing stock. The linkages between these processes are important. We can use ABMs to answer this question.

R. Jordan (✉) • M. Birkin • A. Evans
Centre for Spatial Analysis and Policy, School of Geography, University of Leeds, Leeds, UK
e-mail: r.j.jordan@leeds.ac.uk; m.h.birkin@leeds.ac.uk; geoaje@leeds.ac.uk

A.J. Heppenstall et al. (eds.), *Agent-Based Models of Geographical Systems*,
DOI 10.1007/978-90-481-8927-4_25,

In this chapter, we first build the foundation of such a model by taking a look at the theory of residential mobility and housing choice with particular emphasis on the family life cycle, income, location choice and government policy. The link between this theory and ABMs will be made while exploring how ABMs have been used to simulate aspects of the housing market. A modelling framework is presented illustrating how housing market behaviour can be represented programmatically. Results of the model are then presented followed by a discussion of the usefulness of this technique for land use planners and housing study practitioners.

25.2 Residential Mobility and Housing Choice

Residential location decisions are strongly influenced by national housing policies, local planning constraints, and by a wide range of fiscal and social policies. In addition to government policy, household characteristics often initiate movement and in turn influence where the household will move. In a more basic sense, households progress through the family life cycle with various levels of income at their disposal. Changes in either of these attributes – the family life cycle or income – are likely to trigger residential mobility. These are the main links between the household's characteristics and residential mobility. While some households may choose not to move because of limitations in income and/or supply on the market, other, less constrained households will try to find a new house. By taking a closer look at these processes, we can build an understanding of how the housing market operates.

25.2.1 Family Life Cycle, Income and Location Choice

Figure 25.1 illustrates the general progression of the family life cycle. Typically, the cycle begins with a single individual and advances through varying household formations. This process is punctuated by significant events such as job losses or gains, marriage, births, deaths, divorce or separation, retirement and adult children leaving the parental home. As these significant events occur, changes in household attributes can be observed. For example, events such as marriage and births result in larger families while the converse is true for deaths. Thus the need for larger or smaller homes is likely to be triggered.

The financial budget is by far one of the most important factors when the decision to move is considered (Boehm 1982). There is a direct positive correlation between the amount of disposable income that can be used for housing and the cost of the house. For example, a promotion may make more money available and can trigger a move to a more expensive house. The converse of this statement is also likely to be true.

Therefore, income has a knock-on effect for the type of property which households can afford, the size of the house and the housing tenure. In the case of the

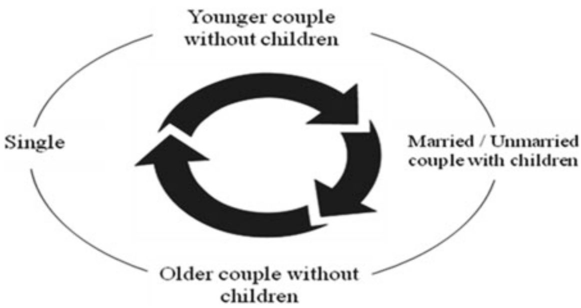

Fig. 25.1 The family life cycle

framework that we develop in this chapter, we use type to indicate the accommodation type, i.e., whether a house is detached, semi-detached, terrace, a flat or maisonette. Size is represented by the number of rooms in the house and tenure type indicates whether a house is on the private rental market, the public rental market or up for full ownership. If we consider every combination of these three variables, we can quickly come to the conclusion that when these combinations are compared, stratification in the housing market can be observed. For example, a detached house, up for ownership, with ten rooms is likely to be more expensive than a publicly rented house with five rooms.

In addition to these factors, the influence of neighbourhood quality must be underscored. The physical conditions of the neighbourhood, and amenities such as shops, school quality, security, transport connections, green spaces, and the proximity to built up areas, are characteristics which can alter house prices. Understandably this further increases the complexity of household preferences and choice. The choice of a new home can be conceptualized as a choice between a weighted combination of dwelling alternatives. The strength of each weight may be based on the changing needs of the household. These weights are discussed when the modelling framework is introduced.

25.2.2 Housing Policy

None of the determinants of movership work in isolation; they are interrelated and interdependent. They are also largely affected by market conditions. A household's choice of dwelling is constrained by the demand for and the requisite supply of houses as well as the availability and accessibility of financial instruments such as mortgages. Each of these factors is influenced by government policies in general. More specifically, changes in housing policy can affect the supply of new houses. Demographic changes can affect demand. Economic policy can alter interest rates, which can affect house prices and access to lending instruments. Therefore, households will choose homes based on the extent to which government policies affect them.

Although there are numerous government and housing policies that can be mentioned here, we focus on urban regeneration policy and its effect on public housing or council tenants.

25.2.2.1 The Evolution of Urban Regeneration Policy

Council housing in the UK has gone through significant changes over the last century. Also known as public housing, it was initially created to improve dwelling conditions for those without the means to do so for themselves. Government-owned housing transitioned to a market which provided another housing option for anyone regardless of income (Mullins and Murie 2006). Over time the housing market changed; many of the houses in good condition were sold off leaving an inventory of poor quality houses in the council housing market. Poor quality housing and low-income tenants entangled in the cycle of poverty added to the melee of problems that plagued this sector (Power and Mumford 1999). It was in this context that Urban Regeneration policies were conceptualized.

Aimed to encourage social mixing, policies focusing on urban regeneration were introduced in the 2007–2008 period. Proponents of such policies believe that communities of mixed socio-economic status can encourage social development among disadvantaged households (Tunstall 2003). In theory, different classes of people have the potential to attract a wider range of new businesses and new residents in communities affected by social problems. This type of cross tenure community is likely to comprise of a range of people at different socio-economic levels, with different lifestyles, values and attitudes where the more productive socio-economic groups are thought to positively influence the other groups (Bridge 2002). The government believes that regeneration efforts are likely to create stable communities and disadvantaged households can experience reduced financial dependence on the public purse as a result of increased aspirations and availability of jobs.

25.2.2.2 The EASEL Case Study

One example of the implementation of Regeneration Policy can be observed in the East and South East district of Leeds in the UK (EASEL). Home to approximately 36,000 households, the area is noted to have some of the worst deprivation statistics (Index of Multiple Deprivation) in the country as reported by the Office of National Statistics. Issues of poor housing, high unemployment rates and low educational attainment are some of the negative characteristics that add to the stigma associated with this area. With an aim to improve these statistics, Leeds City Council has initiated intense regeneration efforts to the tune of £90 million (Leeds City Council 2007). Improvements in housing stock quality and quantity are designed to provide more affordable homes nestled in new mixed tenure communities.

Policies such as these appear legitimate in theory, but in reality their practical impact is questionable. Regeneration policy attributes the inherent social problems in low-income communities to the fact that these communities are segregated. Although there is evidence to support this, it is unlikely that households with sufficient disposable income would choose to live in neighbourhoods that are badly stigmatised. Furthermore, the early work of Thomas Schelling suggests that, if people are allowed to exercise slight demographic preferences when relocating, they will cluster together based on these preferences (Schelling 1969). This is one of the major challenges to mixed communities, one which can be explored through the implementation of an ABM.

25.3 Where Do the Agents Come In?

We can take these theoretical observations and use them to build our agent-based simulation. Households and houses can be classified as agents while housing policy can be simulated by altering the housing stock available.

We may associate various attributes such as age, number of children, number of cars, socio economic status, accommodation type and tenure type with each household. This list is not exhaustive but captures the type of information that is useful when modelling the household. One may choose to model the entire household as one agent or model every possible person while using the unit household, to represent an aggregation of individuals dependent on the sophistication in the life-cycle model to be used. Where houses are concerned, we can use attributes such as accommodation type, value, vacancy status, etc. A collection of houses may form a district or some other aggregated unit used in the real world.

The work of Schelling (1969), Aguilera and Ugalde (2007), Laurie and Jaggi (2003) and Yin (2009) illustrate how these entities can be used to simulate housing market activity via ABMs. Schelling (1969, 1971) examined the role of preferences in an artificially created community and illustrated how individual behaviour can create significant collective results not directly intended by the individual. Schelling (1969) demonstrated this by using only one rule, i.e., all agents preferred to live among at least 33% of agents of the same ethnic group as themselves. The result was total segregation.

Aguilera and Ugalde (2007) attached house prices to each space on a lattice grid. Individuals were rated by socio-economic status and income. House prices were strongly related to the type of neighbourhood each house was located in and evolved in such a way that prices fluctuated at times. Agents moved momentarily in order to match their status with house prices by exchanging their location with other agents. This inequality in income among agents was noted to be the factor strongly, positively correlated to segregation. In other words, the more unequal a neighbourhood is, the more segregated it becomes.

The work of Laurie and Jaggi (2003) also used the basic segregation model as proposed by Schelling (1969, 1971) in examining the role of vision in effecting segregation. Vision is used in this sense to describe the number of neighbours the agent assesses in determining whether or not they wish to move. The model illustrated that with only slight preferences and increasing vision, the society became more and more integrated. The converse is true when vision and the level of tolerance are decreased, i.e., society becomes more and more segregated.

Yin (2009) increased the dynamics in his model by devising a social simulation based on the City of Buffalo in the United States. In his model, the issue of race and social class are examined as they relate to residential segregation. Yin's research builds on Schelling's theory and illustrates how factors such as race and economic constraints, when exercised as a part of the housing choice process, can cause segregation of varying degrees at the aggregate level. However, Yin illustrated that when housing policies were implemented, this segregation could be reduced once racial sensitivity was low.

These and other models such as those by Pancs and Vriend (2007), Zhang (2004a, b) and Benenson (2004) give us an idea of how agents can be used to simulate and test phenomena in the housing market. Notice how each of these models focus on a different aspect of the housing market. Whether ethnicity preference, socio-economic status, neighbourhood distance, house prices, or integration policy, the dynamics are diverse and yield varying results. We can build on these examples by introducing other dynamics in order to create a complete agent-based market model.

25.4 The Model Framework

Using the entities, households, houses and the surrounding environment, a modelling framework is presented here to recreate the housing market. Fundamentally, we know that amidst a list of households, some choose to move while others do not. We also know that once these households choose to move, they need to find a house to relocate to.

25.4.1 How Do We Know Which Households Want to Move?

For ABMs, individual records are ideally needed to represent households. In the UK, these households can be derived from data sources such as the Household Sample of Anonymised Records (H-SAR). The H-SAR contains attributes such as age, ethnicity, accommodation type, tenure type and the propensity to move statistic. The propensity to move is a migration indicator which dictates if the household moved within the last year of the recorded census (CCSR 2010). It is very important for our model as it is used to determine which households need to find a new house. A more extensive discussion of the use of this variable can be found in the paper by Jordan et al. (2011).

Other data such as Output Areas, roads, and significant buildings are also used. This data is stored in shapefile format and can be obtained for the UK through data providers such as Edina UK Borders and Ordnance Survey MasterMap.

25.4.2 Where Do These Households Go?

Seven rules are used to determine where households will move to. The rules are defined as follows:

1. *Households move to areas where the ethnic makeup is tolerable.*
   When a household desires to move, the search for a new house begins. A house is deemed favourable if at least 33% of the surrounding households are of the same ethnicity type as the household wanting to move. The rule is augmented for minority groups with strong religious ties; i.e., the new house must also be within close proximity (~5 miles) to a religious centre, for example, a mosque (Johnston et al. 2002; Phillips 1998, 2007; Peach 1999; Schelling 1969).
2. *Households look for a new house within known areas.*
   Communities where households frequent for the purpose of work and other activities can be characterized as known areas. Since this simulation focuses on housing, for each household, we create memory by storing all the districts in which the household may have lived. The proximity of the surrounding community is thought to be between 6 and 20 miles. For public renters this distance is close to 6 miles while for private sector households, the distance from the previous house may vary between either extremes of this range (Cho et al. 2004; Cho 2004). Therefore, when a new, vacant house is found, its location is checked to ensure that it is within a known area.
3. *Households move to houses where the size of the house is adequate.*
   Ensuring that the size of the house is acceptable is important (Dieleman 2001). This can be determined by trying to find a house with the desired number of rooms for each household. This variable is derived from the H-SAR, i.e. number of rooms required.
4. *Households move to areas where schools are accessible.*
   If the household contains school aged children, the proximity to schools is taken into consideration. Desirable schools are generally thought to be within a 5 mile radius of the home although this distance may increase with secondary school aged children (Gibbons and Machin 2003; Black 1999; Strand 2002). This distance measure is used in the current implementation.
5. *Neighbourhood quality plays a role in influencing household choice.*
   The determinants of neighbourhood quality include amenities such as shops, schools, green spaces and security. Households often take this into account when choosing a new home (Tu and Goldfinch 1996). Using the Index of Multiple Deprivation (IMD), the neighbourhood (Output Areas) in which a house exists is compared to that of the current house. The IMD is a statistic which ranks Output Areas across the UK. It is made up of average statistics pertaining to crime rates, employment deprivation, education and barriers to housing. A new house is thought to be more favourable if the IMD within the new Output Area is higher than that of the current house.
6. *The socio-economic status of a household influences the type of house chosen.*
   Households in higher socio-economic brackets are likely to be owner occupiers while households in lower socio-economic brackets are likely to be private or

public renters (Cho et al. 2004; Cho 2004). For example, a manager in a larger organisation is likely to live in an owner occupied home. On the contrary, an unskilled worker is likely to live in the public or private rental market.

7. *Households will move to areas where transport routes are accessible.*

Although this rule applies to all households, it is especially important for households without cars. As a means of ensuring that the journey to work is manageable, this rule ensures that a major road is found within a 1 mile radius of the new house (Böheim and Taylor 1999; Gjessing 2009). Therefore, for a household without cars, a new house is favourable if it is located within a 1 mile radius of a major road. For households without cars, it is not important that this criterion be satisfied.

25.4.2.1 Ranking the Ruleset

The model is initiated with a realistic proportion of vacant houses. As each household is interrogated with the movement questions, each vacant house is taken through a process of ranking. For example, in Rule 1, a house found within a neighbourhood where the ethnic mix is not tolerable (less than 33%) would be ranked with a value of 0 while for a tolerable mix the house would be ranked with a value of 1. Similarly, for the socio-economic status by tenure (Rule 7), if a public rented house is found and the household is deemed to be low-income, then this council house will be ranked higher than an owner occupied house. For a household with a managerial role, a council house will be ranked lower than an owner occupied house.

The choice of a new house is a combination of dwelling alternatives (Tu and Goldfinch 1996; Dieleman 2001). Using this process of ranking, the profile of the household is compared to the characteristics of all available houses. The house with the highest combined ranking is chosen.

25.4.2.2 Advancing the Model in Yearly Timesteps

In order to move the model from year to year, we create a threshold based on the percentage movers in any given year. This statistic can be calculated using the original data source, i.e., the number of people who have moved in a given year divided by the total number of people. Once this threshold is met, another year begins. Note that yearly time spans measured in timesteps may not be equal from year to year as this threshold condition must first be met.

With the framework in place, we can begin to explore some of the results of the model.

25.5 Results and Application

Let us use a series of scenarios to examine the model results. Scenario 1 is the result of running Rule 4 in isolation. Scenario 2 is the result of running all the rules simultaneously. In this instance, the number of vacant houses is severely constrained.

Fig. 25.2 Initialised EASEL area display before execution of Rule 4. Here the *coloured dots* are used to represent households of varying ethnic types while the *small rectangular polygons* are representative of houses. The *larger green polygons* are used to represent Output Areas

Table 25.1 Details of the starting conditions

Initial state	
# Households	465
# Houses	490
# Iterations	Unspecified; not linked to actual time

Households are limited by a vacancy rate of 4% of the total houses. Scenario 2 is executed a second time with a significant increase in vacant houses.

25.5.1 Scenario 1 – Rule 4: Households Move to Areas Where Schools Are Accessible

Figure 25.2 is a pictorial representation of the initial distribution of households before Rule 4 is executed and Table 25.1 contains the starting conditions. Notice how the households are reasonably distributed across the Output Area zones after initialisation.

Assuming that only households which move contain school aged children, Fig. 25.3 is the result of this rule. Notice the shift in the households toward the lower left area of the diagram. This is because there is a school in the vicinity of this area as shown above.

In executing each rule separately, similar trends are realised. In the case of Rule 1 – Ethnicity, households begin to cluster around others who are of the same

Fig. 25.3 Resultant EASEL area display after execution of Rule 4 (~40 timesteps). Here the system has reached a point of stability, i.e. movement within the model is negligible indicating that the majority of the households are satisfied with their current location

ethnic type as themselves. Rule 2 – Known Areas, households choose a new house in areas previously known to them; this limits the number of potential new locations where they may choose to live. In the case of Rule 6 – Socio-economic Status, households begin to cluster together based on their socio-economic status. This is largely because tenure types are clustered together in a similar manner.

These trends are most pronounced when each rule is run separately. However, when the ranking system is employed, the individual trends become less distinct.

25.5.2 Measuring Diversity

We can extend our interpretation of Scenario 1 to include an index by which diversity is measured. In the case of the previous scenario, the question can be asked: how does the schools rule affect the demographic makeup of Output Areas once implemented? In the case of Rule 6 – Socio-economic Status, we can query how a household's social class can affect the demographic makeup of Output Areas once implemented. If the goal of urban regeneration is to create mixed communities, then such a statistic can be used to inform us of the extent of this mixing over time. This can be illustrated by using the Index of Diversity (Blau 2000).

The index of diversity is a statistical indicator that can be used to examine the relative diversity of households within each Output Area. Diversity can be measured based on any variable of interest. Thus, ethnic diversity, socio-economic diversity and demographic diversity are some of the scenarios that can be examined. The index is defined as follows:

$$D = 1 - \sum_{i=1}^{N} p_i^2$$

Here p_i is the proportion of households in Output Area i of a specific type, e.g. ethnicity, N is the total number of Output Areas and D returns values between 0 and 1. Values closer to 0 indicate that the Output Area is not very diversified while values closer to 1 are indicative of heterogeneous Output Areas, i.e., where communities are mixed. Let us explore the usefulness of this indicator using Scenario 2.

25.5.3 Scenario 2 – All Rules

We can explore the results of our model when all of the rules are implemented together. Using the initial states shown in Table 25.2, the model is first executed for a period of 50 years with a 6% vacancy rate. The model is then executed a second time with a less constrained vacancy rate as detailed in the table below. The results are shown in Fig. 25.4.

Table 25.2 Details of the starting conditions. Approximately 625 houses are used with a vacancy rate of 6%

Initial state	Constrained vacancy	Less constrained vacancy
# Households	587	587
# Houses	625	875
# Iterations	1,089	1,086
# Years	50	50

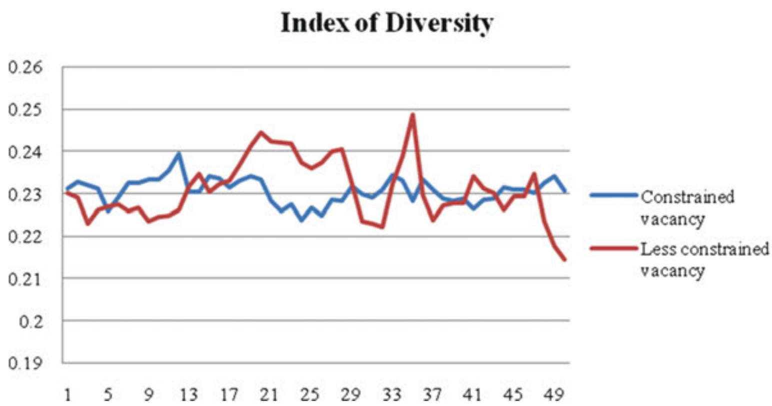

Fig. 25.4 Index of diversity

Figure 25.4 shows the result of the simulation executed under two different conditions and uses the Index of Diversity to analyse the variation in diversity. Although the variation in the statistics is limited, varying from 0.21 to 0.25, we can still observe a difference in the two simulation runs. When the simulation is executed with a 6% vacancy rate, the variation is more limited than when the simulation is executed with a higher vacancy rate. One may link this contrasting pattern to the fact that under constrained conditions, households have fewer housing options and may compromise on their ideal home, an effect of the ranking system mentioned in Sect. 25.4.2.1. When housing options increased, households have a wider selection of vacant houses to choose from and are more likely to choose homes that are ideal for their circumstance, if available. Thus, more variation in diversity can be seen.

25.6 Discussion and Conclusions

The ABM framework, which has been introduced in this chapter, can be used to give insights into the dynamics of the housing market in relation to urban regeneration plans. What is interesting about the rules introduced is that they are all limited by parameters. Rule 1 dictates that households will search for homes where the ethnic makeup is tolerable. This is limited to a percentage of at least 33%. Rule 2 dictates that households look for houses in known areas. A distance measure of 6–20 miles is used in this rule. A similar distance measure of 5 miles is used in Rule 4 (Schools).

In general, these parameters are used to constrain the model each time it is executed. They can be used to explore how different combinations of parameters affect the model outcome. Thus as shown in Scenario 2, a higher vacancy rate increases the potential range of new homes which households can occupy and leads to greater homogeneity. Other scenarios can be created to examine lower tolerance levels in terms of the ethnicity rules while distance measures can be increased or decreased again to examine their effects.

This is how we can analyse the effects of regeneration policy. When new houses are built, this increases the previously limited housing stock, therefore increasing the housing options for households. If new schools are built or schools are demolished, the distance to schools is affected. Socio-economic status can be monitored as these changes are made, and overall, the change in diversity in the study area can be measured over time.

Even with these considerations, further work is proposed for this model. The model variables need to be updated from year to year, parameters need to be calibrated and the correctness of the model should be validated.

As mentioned in Sect. 25.2, changes in the family life cycle cause changes in housing needs. Therefore, it is important that family characteristics be altered from time to time to reflect reality. At the very least, mortality and fertility rates should be a consideration. Another consideration may be the fact that households may move out of the region of interest. These changes are important as they affect demand and supply of the housing stock and the distribution of households.

Calibration can be used to find the most suitable combination of parameters that replicate reality, which may be determined using a genetic algorithm to analyse the performance of various combinations of parameters. In turn, the validity of the model can be tested by comparing yearly diversity indices generated by the model with yearly diversity indices generated from known datasets such as the Pupil Level Annual School Census (PLASC) data available in the UK. Such a data source contains details on ethnicity at the Output Area level. The distribution of school age children in the PLASC dataset can then be compared to the distribution of households with school aged children in our model.

We have created a framework to explore and analyse the dynamics of the housing market and urban regeneration. Such a framework allows us to unpack the building blocks of the housing market with a view to understanding not only how the market works but also the effects that changing parameters can have on housing market outcomes. This allows us to explore the extent to which urban regeneration schemes can result in the creation of mixed communities.

Acknowledgements Census output is Crown copyright and is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland.

References

Aguilera, A., & Ugalde, E. (2007). A spatially extended model for residential segregation. *Discrete Dynamics in Nature and Society*. doi:10.1155/2007/48589.

Benenson, I. (2004). Agent-based modeling: From individual residential choice to urban residential dynamics. In M. F. Goodchild & D. G. Janelle (Eds.), *Spatially integrated social science: Examples in best practice* (pp. 67–95). Oxford: Oxford University Press.

Black, S. (1999). Do better schools matter? Parental valuation of elementary education. *Quarterly Journal of Economics, 114*, 578–599.

Blau, J. (2000). Group enmity and accord: The commercial press in three American cities. *Social Science History, 24*(2), 395–413.

Boehm, T. (1982). A hierarchical model of housing choice. *Urban Studies, 19*(1), 17–31.

Böheim, R., & Taylor, M. P. (1999). *Residential mobility, housing tenure and the labour market in Britain* (ILR working papers 035). London: Institute for Labour Research.

Bridge, G. (2002). *The neighbourhood and social networks* (Centre for Neighbourhood Research, Paper, 4). CNR: London.

CCSR (The Cathie Marsh Centre for Census and Survey Research). (2010). *The Samples of Anonymised Records (SARS)* [online]. Accessed June 8, 2010. Available from http://www.ccsr.ac.uk/sars/2001/hhold/variables/

Cho, Y. (2004). Who moves and where? A comparison of housing association tenants in London and northern regions. In *Housing corporation sector studies 40*. London: Housing Corporation.

Cho, Y., Lyall Grant, F., & Whitehead, C. (2004). Affordable housing in London: Who expects to move and where? In *Housing Corporation Sector Studies 39*. London: Housing Corporation.

Dieleman, F. (2001). Modelling residential mobility: A review of recent trends in research. *Journal of Housing and the Built Environment, 16*(3), 249–265.

Gibbons, S., & Machin, S. (2003). Valuing English primary schools. *Journal of Urban Economics, 53*, 197–219.

Gjessing, M. (2009). *Interview with René Jordan*. December 11, 2009. Leeds.

Johnston, R. J., Poulsen, M. F., & Forrest, J. (2002). Are there ethnic enclaves/ghettos in English cities? *Urban Studies, 39*, 591–618.

Jordan, R., Birkin, M., & Evans, A. (2011). Agent-based simulation modelling of housing choice and urban regeneration policy. In T. Bosse, A. Geller, & C. Jonker (Eds.), *Multi-agent-based simulation XI* (pp. 152–166). Berlin: Springer.

Kim, J., Pagliara, F., & Preston, J. (2005). The intention to move and residential location choice behaviour. *Urban Studies, 42*(9), 1621–1636.

Laurie, A., & Jaggi, N. (2003). The role of 'vision' in neighbourhood racial segregation: A variant of the Schelling segregation model. *Urban Studies, 40*(13), 2687–2704.

Leeds City Council. (2007). *East and south east Leeds area action plan: Leeds local development framework*. Leeds: Leeds City Council.

Mullins, D., & Murie, A. (2006). *Housing policy in the UK*. Basingstoke: Palgrave Macmillan.

Pancs, R., & Vriend, N. (2007). Schelling's spatial proximity model of segregation revisited. *Journal of Public Economics, 91*, 1–24.

Peach, C. (1999). London and New York: Contrasts in British and American models of segregation. *International Journal of Population Geography, 5*, 319–351.

Phillips, D. (1998). Black minority ethnic concentration, segregation and dispersal in Britain. *Urban Studies, 35*(10), 1681–1702.

Phillips, D. (2007). Ethnic and racial segregation: A critical perspective. *Geography Compass, 1*(5), 1138–1159.

Power, A., & Mumford, K. (1999). *The slow death of great cities? Urban abandonment or urban renaissance*. York: York Publishing Services Limited.

Schelling, T. (1969). Models of segregation. *The American Economic Review, 59*(2), 488–493.

Schelling, T. (1971). Dynamic models of segregation. *Journal of Mathematical Sociology, 1*(2), 143–186.

Strand, S. (2002). Pupil mobility, attainment and progress in Key Stage 1: A study in cautious interpretation. *British Education Research Journal, 28*, 63–78.

Tu, Y., & Goldfinch, J. (1996). A two-stage housing choice forecasting model. *Urban Studies, 33*(3), 517–537.

Tunstall, R. (2003). 'Mixed tenure' policy in the UK: Privatization, pluralism or euphemism? *Housing, Theory and Society, 20*, 153–159.

Yin, L. (2009). The dynamics of residential segregation in Buffalo: An agent-based simulation. *Urban Studies, 46*(13), 2749–2770.

Zhang, J. (2004a). A dynamic model of residential segregation. *Journal of Mathematical Sociology, 28*(3), 147–170.

Zhang, J. (2004b). Residential segregation in an all-integrationist world. *Journal of Economic Behavior & Organization, 54*(4), 533–550.