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Title Page

1.0 Introduction

Urban communities are not formed by chance; they are a complex combination of social worlds (Timms, 1971). Focusing on recovering and renewing lost vitality in the physical and social landscape of a community, regeneration policy is a combination of projects or schemes such as adult education programmes, the provision of additional green spaces, mixed tenure housing developments along with older policies such as retrofitting residential dwellings in need of repair. Such improvements can make a community more attractive to investors and with new businesses established, more jobs become available over time for those within the regenerated community (Trueman, Klemm, & Giroud, 2004). In this context, urban regeneration policy target community development in a holistic way, equipping households with the tools necessary to improve their life chances; that is, social mobility, education, and life expectancy among others.

In this paper, the East and South East Leeds (EASEL) case study area is first introduced and residential mobility behaviour is discussed (Sections 1.0 and 2.0). Section 3.0 presents a discussion on Spatial Modelling Techniques while a specific model of residential mobility is then described (Section 4.0). The model is executed in Section 5.0 and then used to explore the impacts of urban regeneration policy, specifically the creation of mixed-tenure housing communities (Section 6.0). Model results are presented followed by a discussion on the policy implications and further work (Section 7.0). The model is also referred to as the CHAIRS model; **C**reating **H**ousing **A**lternatives **I**n **R**egenerated **S**ocieties. This work builds on the earlier work of Jordan, Birkin & Evans (2011) where a methodological framework is presented.

1.1 The EASEL Case Study Area

Leeds is a metropolitan area located in the northern region of England. The city has become a major hub for finance and other professional services in the North. Its balanced economy combines affluence with deprivation, as well as a mixed age structure with a very substantial student community.

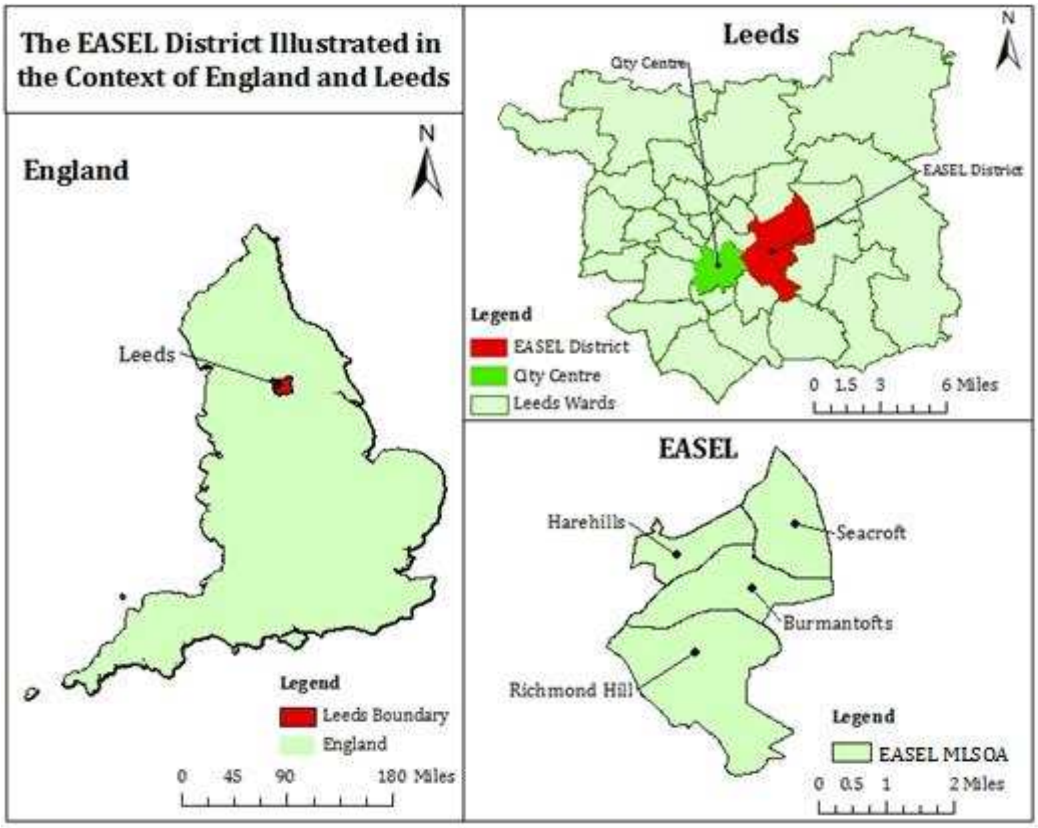


Figure 1: The EASEL District Illustrated in the Context of England and Leeds by Middle Layer Super Output Area (MLSOA)

The EASEL case study area (**Figure 1**) is a prime example of a disadvantaged community within this thriving city. It is home to approximately 78000 people living in 35000 households (UK Census 2001). Note that Middle Layer Super Output Area (MLSOA) is a type of census area geography of approximately 7200 individuals (Leeds City Council, 2007). The figure further divides the EASEL community into four census wards – each area of approximately 20,000 people. The district is an area noted to suffer from high levels of deprivation when socioeconomic variables are assessed as well as the negative effects of crime, violence and antisocial behaviour. EASEL is also home to a large number of social housing tenants. A comparison of key indicators between EASEL and the wider Leeds district is shown in **Table 1**.

	EASEL		Leeds	
Economic Activity				
All Individuals (>= 16)	**53228**	**100%**	**520479**	**100%**
Economically Inactive	22160	41.6%	177,773	34.2%
Economically Active	31068	58.4%	325426	62.5%
Unemployed people	2854	5.4%	17280	3.3%
Crime				
All Reported Crime	**15493**	**100%**	**98320**	**100%**
Domestic Burglary	1219	7.9%	7793	7.9%
Vehicle Crime	1879	12.1%	12826	13%
Criminal Damage	4280	27.6%	22073	22.5%

Tenure				
All Households	**33535**	**100%**	**301623**	**100%**
Owner occupied	12693	37.9%	187645	62.2%
Social Housing: Council	13970	41.7%	63075	20.9%
Housing Association	2683	8%	12990	4.3%
Private Rented	4189	12.5%	37913	12.6%
Households spaces and accommodation type				
All Households with residents	**33520**	**93.6%**	**301614**	**96.5%**
Vacant houses	2285	6.4%	10861	3.5%
Detached	1280	3.6%	46108	14.8%
Semi-detached	13557	37.9%	121394	38.8%
Terraced housing	12953	36.2%	87361	28%
Purpose built flats	7640	21.3%	44179	14.1%
Flat/Maisonette/Shared house	343	1%	13115	4.2%
Temporary Structure	24	0.1%	398	0.1%
Ethnicity Group				
White	44924	84.4%	478320	91.9%
Non-White	8304	15.6%	42159	8.1%

Table 1: EASEL versus Leeds comparative statistics by employment, criminal activity, housing tenure, accommodation type and ethnicity group (UK Census 2001 and the West Yorkshire Police 2005 as referenced by the EASEL Area Action Plan (Leeds City Council, 2007))

Given the high incidences of welfare dependence within low income households, high levels of crime, violence, unemployment and deprivation across the EASEL community, if social inequalities are to be reduced the area will require change (Dorling, 2011). Leeds City Council intended to introduce a greater mix of housing tenures in council owned areas by providing houses for sale and for rent on the private market. It was felt that a greater mix of tenures leads to greater socioeconomic diversity (Leeds City Council, 2007). It is the impact of this mixed tenure housing project that will be analysed in this paper. Housing tenure refers to the ownership of the house. In the UK context these may be owner occupied, council rented, Housing Association (rented) or private rented.

2.0 Understanding Residential Mobility Behaviour

Residential mobility is a process initiated by a decision to migrate and follows on with the selection of and relocation to a new home. In general, it is held that the decision to migrate is the result of a change in circumstance of households which prompts the need to search for a new residence (Rossi, 1955), (Dieleman, 2001), (Rabe & Taylor, 2010). In detail, however, households and individuals move for many reasons. Traditionally, reasons for moving have been strongly tied to changes in the life course or life cycle (Rossi, 1955). However, Clark and Onaka (1983) point out that due to the increasing number of non-traditional households, it is more appropriate to link the decision to move to reasons related to household dissatisfaction rather than the life course. Non-traditional households; unrelated individuals living in shared accommodation.

Changes in household size as well as changes in employment status, neighbourhood quality and/or dwelling quality are likely reasons for a disparity between a dwelling and the household(s) occupying it (Rabe & Taylor, 2010). Partnership formation or dissolution, births and deaths, and children leaving the family home are the principal life course events that alter the trajectory of households and cause them to expand or contract (Clark & Huang, 2003; Mulder, 1996). Employment gains or losses may affect what can be afforded and improvements in neighbourhood quality may be sought after such changes (Böheim & Taylor, 1999). Such changes directly influence the desire for reduced or increased dwelling features – bedrooms, nearby green spaces, access to facilities such as schools and hospitals, and so on.

There exist exogenous factors which can also affect this process; changes in mortgage rates and house prices, the influence of estate agents and the vacancy chain effect among others (Pawson & Bramley, 2004), Hickman *et al.*, 2007, Ferrari, 2011). . Exogenous factors like these are not included in this model, instead the model presented focuses on residential mobility behaviour.

The spatial pattern of destination selection has been the subject of a variety of modelling approaches, for example spatial interaction modelling (Clarke, Eyre, & Guy, 2002), discrete choice models (Benjamin, Johnson, & Hui, 1996) and the simulation of vacancy chains (Ferrari, 2011). Though there are models of other residential mobility issues highlighted in the wider literature (Alonso, 1964, Torrens & Nara, 2007b) among others these are thought to be less critical to our purpose. The use of agent-based models to highlight segregation behavior is commonly traced back to Thomas Schelling (1969) whose major contribution was to stress the impact of neighbourhood level interactions, both amongst individual households and between individuals and their local environment. Specifically, Schelling's insight was to demonstrate the importance of ethnic preferences in neighbourhood selection and that relatively weak individual preferences can give rise to very strong patterns of segregation at the neighbourhood level.

Table 2 compares and contrasts other agent-based residential mobility models documented in the extant literature. As can be seen, most models fundamentally concentrate on the Schelling segregation issue.

ABM Models	Geographic Data	Behavioural Rules	Calibration/Validation Methodology	Model Results
Laurie and Jaggi (2003)	50*50 edgeless torus of artificial agents; blacks to white ratio randomly determined	*R*-neighbourhood used to determine dissatisfaction in current and potential neighbourhood. *R* could be substituted for any value.	No calibration or validation against real world data	Segregation increased as the *R*-neighbourhood increased.
Bruch and Mare (2006)	500*500 grid of hypothetical agents; 50% black, 50% white	Move to areas where there are others of the same race. Move to areas where there are others with similar incomes.	No calibration; Resultant trends compared to trends in the 1978 and 1992 Detroit Area Study using absolute proportions	Residential mobility behaviour based on income decreased segregation while mobility behaviour based on race increase segregation.
Zhang (2004)	N*N lattice torus; ratio of agents vary but representative of two ethnicity types	Move to cell where the utility gained is more favourable than previous location.	No calibration or validation against real world data	Residential segregation could persist in a society even if individuals prefer to live in integrated neighbourhoods.
Aguilera and Ugalde (2007)	2D lattice grid where size = 1	Move to cell where house price matched social class.	No calibration; Validated using Massey's segregation	Segregation increases as inequalities across a

	to n; n*n agents		versus inequality theory and using Theil's inequality index	neighbourhood increase.
Benenson (2004)	Israeli Census of Population and Housing 1995; ~40,000 individuals; GIS coverages of streets and houses	Arabs avoided block houses and oriental architecture. Jewish householders preferred newly built block houses. Arabs and Jews avoided neighbourhoods primarily comprising of households of the other type.	Calibrated by changing the coefficient related to non-correspondence in the validation dataset and by altering agent attitudes of Arabs and Jews toward unfamiliar housing types and neighbourhoods Validated against proportion of Arab/Jewish population; level of segregation using the Moran index; variation of the population when compared to the architectural style of buildings; annual fraction of households leaving Yaffo	Segregation could still occur if only one household group had strong preferences to live in neighbourhoods with like residents.

Table 2: Summary of agent-based models of residential mobility and segregation

Even when other existing models are observed, these same trends are realised; limited behaviours are used to recreate residential mobility behaviours and few models use real world data applied to actual geometric spaces to analyse residential mobility behaviour (O'Sullivan, MacGill and Yu (2003); Fossett and Waren (2005); Pancs and Vriend (2007); Zhang (2004); Fossett and Senft (2004); Sethi and Somanathan (2004)).

Seven residential mobility behaviours have been chosen for this model to simulate the choice of a new home. These behavioural rules (**Table 3**), have been chosen based on the availability of supporting descriptive details in the qualitative literature. These areas cover the major issues involved in location choice if one assumes employment is available (Rabe & Taylor, 2010; Clark, Deurloo, & Dieleman, 2006; Kim, Pagliara, & Preston, 2005; Croft, 2004; Böheim & Taylor, 1999).

	Rules
1	Known areas
2	Neighbourhood quality
3	Number of rooms requested
4	Ethnicity preference
5	Transport routes available
6	Socioeconomic status
7	Schools in proximity

Table 3: Behavioural rules used to define household location choice

Full descriptions of each rule can be found in **Section 4.7**.

3.0 Spatial Modelling Techniques

There are at least four contrasting spatial modelling techniques that may be used to explore the residential mobility problem posed. These techniques include spatial interaction modelling, microsimulation modelling, cellular automaton (CA) modelling and ABM. **Table 4** is used to highlight the differences between each modelling technique.

Characteristics	Spatial Interaction	Microsimulation	Cellular Automaton	Agent-based Modelling
Main Purpose	Explanation, Projection	Projection	Explanation and Prediction	Explanation and Prediction
Building blocks	Aggregate	Individual	Individual	Individual
Applications	Store location; retail planning	Policy implications, population prediction	Urban growth; physical analysis	Theory formulation, verification
Investigation focus	Spatial flows	Aggregate trends	Aggregate trends	Emergent behaviour
Communication between agents	No	No	Yes; however, no movement	Yes

Table 4: Comparison between four modelling techniques adapted from *Table 1* in Mahdavi, O'Sullivan and Davis (2007, p. 367)

What is important to note is that spatial interaction modelling focuses on aggregate flows between a source and destination. This type of modelling does not drill down to the individual level and though microsimulation modelling drills down to the individual level, there is no interaction between individuals. This therefore means that the behaviour of one individual does not rely on the behaviour of others. Like microsimulation, cellular automaton modelling drills down to the individual level and there is communication between agents, however, with CA modelling there is no movement of individuals from one location to another. ABM is an individual level modelling technique where communication between agents can be facilitated. Also, individuals can move from one location to another. Governed by specific rules, agents make decisions based on the feedback gauged from other agents and the environment in which they exist (Franklin & Graesser, 1996). Agents are also described as being autonomous and flexible (Jennings, Sycara & Woolridge, 1998), in that they can act on their own volition, learn from past behaviour and alter their decisions based on present circumstances (Castelfranchi, 1998; Bonabeau, 2002).

We use this understanding and the description of residential mobility dynamics to inform an agent-based simulation model of segregation and housing choice behaviour; CHAIRS.

4.0 Methodology

In this section of the paper, we follow the ODD (Overview, Design Concepts and Details) protocol recommended by Grimm *et al*. (2006, 2010) in order to present the structure of our model with maximum clarity.

4.1 Purpose

The motivation for the model has been explained in the earlier sections. Its purpose is therefore twofold: to represent changing patterns of household segregation over time; and to estimate the impact of housing policies on segregation.

4.2 Entities, State Variables and Scales

The basic entities in the model are the 35,729 households within the EASEL area. Other entities include houses, roads, output areas and schools. The entities and locality are used as a prototype for a larger scale model and as such a second generation model could be extended and embedded within a more comprehensive spatial domain. The state variables are defined for each entity in **Table 5**.

Entities	State variables
Household	Accommodation type Family type Tenure Number of cars Number of dependents Age group Number of rooms Rooms required Ethnicity Socioeconomic group Output area Household migration indicator
House	Vacancy status Tenure Accommodation type Output Area Number of rooms
Road	Access Type
Output Area	Shapefile
School	Name Building Type

Table 5: Entities and State variables defined

Each household is located to a specific property in one of 55 output areas within the EASEL area. The location and related attributes (tenure, number of rooms) of each household are updated on an annual basis, started from a baseline in the year 2001. This is further described in **Section 4.5** Initialisation.

4.3 Process Overview and Scheduling

The first stage in the model is to construct a synthetic list of households which represents the population of the EASEL area. Then at each cycle of the model, a list of households is traversed in such a way that each household is assessed to determine whether a move is desired. If a move is desired then a new house must be located.

The model is executed for 20 iterative cycles; in each cycle the rate of moves is set as equal to the 12 month average for households in this area as defined by the 2001 Census. If a household's propensity to move is greater than a randomly generated number then this household is allowed to move in the model. Thus each cycle is thought to be equivalent to an elapsed time of one year. This is thought to be reasonable particularly because local area changes are more noticeable over longer time periods. For example, the fact that one British White household moves to a predominantly East Asian area is not thought to be significant until several British White households do the same. Such an event is not likely to be realised for some time, in this case, this time period is limited to 1 year.

The simulation of household characteristics is described in the section on **initialisation (Section 4.5)** and the determination of which households move and how they choose new dwellings are explained in the section on **sub-models (Section 4.7)**.

4.4 Design Concepts

Grimm *et al*. (2006, 2010) suggest the enumeration of model design concepts under no fewer than eleven further sub-headings:

i. The **basic principle** of our model is that different types of households have specific location preferences, which includes (but is not limited to) a preference regarding the ethnicity of neighbourhoods.
ii. The model demonstrates **emergence** in the sense that the character of each neighbourhood changes over time in response to the location decisions of different household types through the course of the simulation.
iii. Household behavior is also adaptive as part of a positive feedback loop; for example, as more high status groups move into a neighbourhood the quality of the neighbourhood rises which makes it increasingly likely that more high status groups will move in.
iv. The **objectives** of the households are to find more satisfactory properties based on seven criteria which have already been previously outlined in **Table 3** (i.e. number of rooms required, transport, schools, local knowledge, ethnicity, neighbourhood quality and socioeconomic group).
v. The agents in the model do not show any capacity for **learning**.
vi. The capability of the agents for **prediction** could be described as naïve – their choices are based on the current composition of neighbourhoods and the associated infrastructure (i.e. roads, schools, housing) rather than any assessment of the future state.
vii. The way in which agents are able to **sense** their environment is determined by the seven criteria already presented.
viii. The **interaction** between agents is based on an exchange of property – each time a household moves then a property becomes vacant and is therefore available for occupation by another agent.
ix. The model has an element of **stochasticity** as behaviours are selected according to a Monte Carlo process. For example, if a household has a probability of 0.1 to move in a particular time period, then random integers would be drawn between 1 and 100. If the integer selected is greater than 90 then a move would be simulated. This stochastic element is pseudo-random within any single run of the simulation, so that each run can be exactly reproduced by applying the same random number stream. For the 20 year model projections and policy simulations which are presented, one

thousand model runs have been executed under alternative random number streams and the results include both the mean and the upper and lower confidence intervals i.e. the appropriate model result at the fifth and ninety-fifth centile.

x. The households in the model do not exhibit any **collaborative** behaviours.

xi. Further **observations** of the state of the system at time t+6 are used as a basis for the validation of the simulation. This process is described in more detail in **Section 5** which follows.

4.5 Initialisation

As earlier mentioned, the starting point for the simulation is to construct a synthetic list of households which represents the population of the EASEL area in the base year of 2001. This list is generated using the 2001 Census of Population and Households (Census Area Statistics or CAS) and the Household Samples of Anonymised Records (HSAR) through a process of microsimulation.

The 2001 Census data areas accessed for neighbourhoods are known as Output Areas (OAs). In the EASEL area with just over 35,000 households there are 150 OAs with an average size of 125 households and 300 residents. The Census provides aggregate counts in each OA of tenure, household size, economic activity, age, marital status and a wide variety of other social, demographic and economic indicators which will be crucial to understanding household movement patterns. However, when this simulation was created, census data for the UK was last captured in 2001 and as such all CAS data used in this paper relates to this base year. CAS provides compositional data about areas rather than individual profiles which also restricts its value as a foundation for ABM.

The HSAR is a 1% sample of household records, also drawn from the 2001 Census. Each household is built up from the records of individual family members. Therefore the HSAR provides a complete profile of individuals, but not only are these data sampled, and therefore incomplete, they do not contain geographic references for the purpose of confidentiality. In order to create a complete population of individuals and their groupings into households for the ABM, a microsimulation modelling (MSM) technique is deployed. The MSM is also used as a basis for updating the population of individuals from census date 2001 to the model base year 2007.

MSM uses population reconstruction and dynamic modelling techniques to synthesize populations for the techniques involved, see Townend *et al.*, 2009. Individual records from the HSAR are reweighted to reproduce known characteristics from the CAS. For example, students will be weighted heavily in areas close to the university area while elderly residents will be favoured in retirement towns. A variety of secondary data sources are fed into this process, including vital statistics births and deaths for small areas, household formation and marriage rates, and profiles for both domestic and international migrants (Townend *et al*., 2009). The microsimulation model used is a component of the Flexible Modelling Framework (FMF) created by Harland and described in Smith, Clarke and Harland (2007). The model is deterministic in nature as it matches individuals from the sample population found in the household SAR to a specified geography from a census-defined population of the 2001 Census by re-weighting individual records based on chosen census variable constraints (Smith *et al*., 2007).

Using the synthetic population, each household is then profiled according to their key characteristics of tenure, housing type, household size and output area in order to match them with a suitable house in their known output area. Each time the model is initialised, households are distributed to the same output area though the actual house may vary.

4.6 Input Data

The model does not use input data to represent time varying processes.

4.7 Sub-models

The model simulates household movement patterns as a two stage process – first, household movers are identified; second, new housing units are selected by each mover. Thus CHAIRS has two major sub-models which are described below. The housing selection process in the second sub-model is in itself the product of seven different choice processes, which are discussed in more detail at the appropriate point below.

4.7.1 Determine which households move

Overall, a household's desire to move is determined by comparing the household's likelihood of moving with a randomly generated number. If the household's likelihood of moving is greater than the random number, then the household will be allowed to move in the model.

The likelihood that a household would desire to move is determined within a sub-model. This model was initially generated using the Chi-Squared Automatic Interaction Detector (CHAID) tool in SPSS which results in a decision tree model. Essentially, the CHAID tool analyses a set of categorical data; household data, such that this data is partitioned into separate but distinct groups based on some dependent variable; the *household migration indicator* which is a flag in the HSAR of households which have relocated within the last twelve months. The result of this analysis is a hierarchical tree which shows the relationship between household characteristics and the household migration indicator. The resultant decision tree is shown in **Figure 2**.

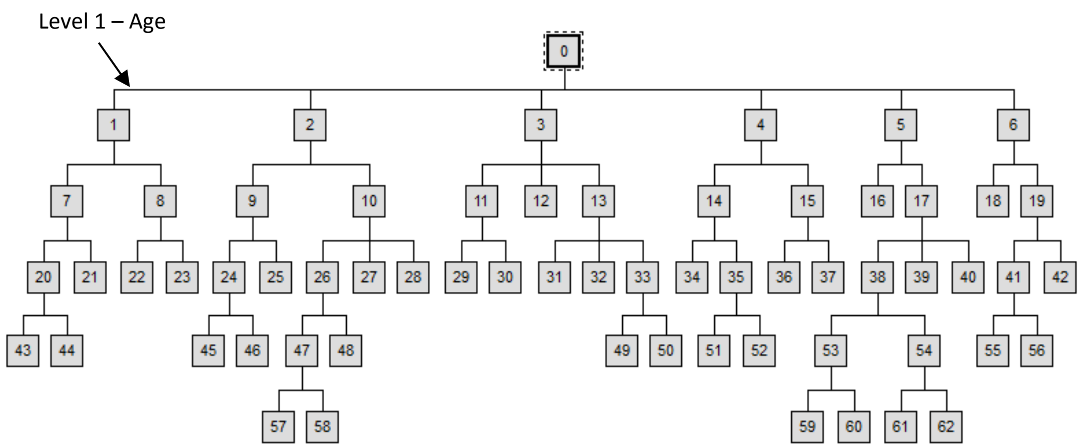


Figure 2: Decision Tree generated using CHAID analysis

The tree is derived by taking the household characteristic with the greatest influence on the propensity to move and using this to split the households into groups using the variable with the highest chi-square value. Each group is represented by a branch on the decision tree. For this sub-model, the household characteristic with the greatest influence on the propensity to move is age group, represented at Level 1 of **Figure 2**. This variable is divided into the categories 16-25, 26-35, 36-45, 46-55, 56-65, >65 and summarily numbered nodes 1 through 6 respectively in the same figure.

Each branch segment produced in the decision tree is mutually exclusive and represents a set of conditional probabilities (Magidson, 1993). The decision tree is allowed to grow to its maximum depth which in this case requires at least 100 households to be available for analysis at the parent node (node 0) and 50 household records at each successive child node. Statistical significance is set to 0.05 and the variables with the highest chi-square values are added to the tree. The branch is complete if a child node cannot be added above the significance threshold, or if it can only do so with less than 50 cases. In this way, the tree is simplified showing only the most significant variables affecting the decision to move for each age group.

In the decision tree above (**Figure 2**), there are six primary branches on the tree with up to five levels. Level 1 of this decision tree is further detailed in **Figure 3** while **Table 6** highlights the details for the decision tree branch with nodes labelled 1, 7, 20, 21, 43, 44. Note that the bracketed percentages highlight the likelihood that each household would be desirous of moving. Given a household with these characteristics, it is the probability that such a household would wish to move.

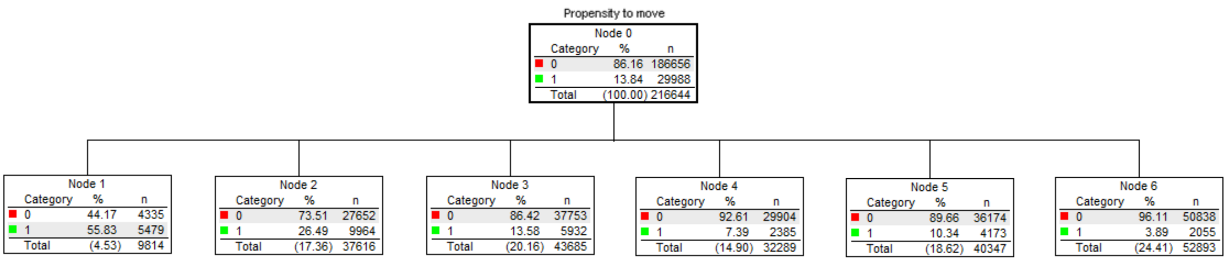


Figure 3: Level 1 of the Decision Tree showing Age Category

Age	Tenure	Family Type	Number of residents in house
16-25	Private Renters	Married Couple no children, Cohabiting couple no children, Ungrouped Individuals	<=2 (*1.13%*)
			> 2 (*0.47%*)
		Lone parent, Married couple with children, Cohabiting	

		couple with children (*0.37%*)	
	Owners, Social Housing Tenants	Cohabiting couple no children, Cohabiting couple with children, Ungrouped individuals (*1.48%*)	
		Lone parent, Married couple no children, Married couple with children, Cohabiting couple with children (*1.09%*)	

Table 6:16-25 Decision Tree Branch

Note that the average rate of moves is 13% for the entire population. This represents annual move probabilities as noted in Section 4.3.

4.7.2 Understanding the Behavioural Rules

In reality, when trying to find a new housing unit, households search a list of vacant houses amassed from various sources such as letting agencies. The choice of a new house is limited by information which the household has at its disposal, that is, the notion of bounded rationality. Added to this, the movement of households in and out of the EASEL district is not simulated in this prototype. To replicate this process in the model, a list of 50 empty houses are randomly selected (the model starts with 6% empty houses as indicated by the 2001 Census). Note that one alternative to this would be to rank the list of all vacant houses by order of most suitable for each household wishing to move. This proved to be computationally expensive. Additionally, although the number 50 is debatable, it is thought that households are generally guided by letting agencies and other media when trying to find a new house, this guidance often amounts to a small number of housing options. Once chosen, however, these 50 houses are examined based on their attractiveness to the household. Attractiveness is determined by traversing each of the seven behavioural rules. A house is then chosen from this order list (see below).

Programmatically, a function is created to execute the behavioural logic for each of the seven rules highlighted in **Table 3**. Each function returns a value ranging from 0 to 1, where 1 indicates that the house under observation is very attractive while 0 indicates that the house under observation is not very attractive. The attractiveness value is a result of the conditions within each function. It is defined generally as follows:

$$Attractiveness = 1 - \left(\frac{|x - y|}{y}\right)$$

Here x and y represent the observed and desired values respectively. These values include, for example, the number of rooms desired by a household as well as distance measures from local schools and main roads. In this way a house with the required characteristics is marked as more attractive than the house which does not meet the required characteristics.

The behavioural rules are executed simultaneously and the house with the highest summed attractiveness value is the house that is chosen out of the 50 houses selected for observation. Thus, every household desirous of moving is relocated though some moves may prove to be more optimal than others. This is thought to mirror similar sub-optimal activity in the real world.

Check Known Areas

The known areas rule simulates a household's knowledge of the community. More practically, household A has knowledge of neighbourhood B if it is within two miles of its current home or a previous residence. The latter replicates the knowledge of householders buying houses in areas they previously rented (Rabe & Taylor, 2010). If the newly found house falls within a known neighbourhood then the house is thought to be attractive. The model assumes a general knowledge of the area.

Check Neighbourhood Quality

Based on the notion that households generally move to improvement (Dieleman, 2001), this rule assesses whether the new house is located in a neighbourhood (OA) that is better than the neighbourhood of the previous house. OAs are compared based on the Index of Multiple Deprivation (IMD). The IMD is a formal measure of deprivation used to assess neighbourhood quality. It encompasses neighbourhood characteristics based on housing quality, crime, income and other features (Leeds City Council, 2007).

Check Room Requirements

Here the rooms required variable contained within each household record is used to determine if the newly found house has an acceptable number of rooms out of the list of 50 houses selected. If a house is found with the same number of rooms required then this is the best house. However, if a smaller or bigger house is found, the house with the number of rooms closest to the number of rooms required will be selected as the best house. The authors have inferred this logic based on the literature on moving to improvement earlier noted.

Check Ethnic Mix

The ethnicity rule attempts to relocate households to an area where there are a high percentage of households of similar ethnicity (Phillips, 1998). During the execution of our model simulation, ethnicity proportions are generated by OA at the beginning of each year. The general assumption used here is that changes in the population are more noticeable over significant time periods rather than shorter time periods. In this case, calculating proportions on a yearly basis is thought to be more useful than monthly calculations. A house is most attractive if the proportion of households in its OA is greater than or equal to some preference level when compared to the proportion of households of the generalised ethnicity group of the household under observation. If the proportion is lower than preferred, the highest calculated proportion is used to select a new house. Segregation is common across the UK, and Leeds is no exception, albeit changes over time in the city have been complex (Stillwell & Phillips, 2006). Note, during model calibration it was determined that households preferred to live in communities where at least 90% of the existing households were of the same ethnicity (see **Section 5.0** for the methodology used). This preference level needed to be high as there were very few non-white ethnicities in the area and the communities were already very segregated, therefore the rule is only effective when a high preference level starting point is used. This is unlike Schelling (1969) as he started with a more even population and a random spread.

Check Transport Routes

This rule is important for those households who do not own cars. The authors have assumed that for a household without a vehicle, a major road must be located within 1 mile of the new house. Based on the transport networks in the UK, this is a reasonable proxy for public transport access. If the new house is at least 1 mile away from a major road then the new house is thought to be more attractive than a house farther away. Using this rule, only households without cars will be processed by this algorithm. A new house found within 1 mile of a major road is regarded as suitable and therefore is assigned the highest attractiveness value. In lieu of this, the house closest to a major road is selected; this may be further than 1 mile in distance.

Check Housing Tenure

This rule simulates upward mobility on the housing ladder (Kemp & Keoghan, 2001). An owner is more likely to search for another house which can be bought and least likely to become a social housing tenant though they may opt to go on the private rental market. In a similar way, a private renter is very likely to either continue on the private market or purchase a home, though social housing may be another option. Finally, a social housing tenant is more likely to continue in social housing, and less likely to purchase a home, though such a tenant may opt to go on the private renting market.

Check Schools in Proximity

This rule assesses whether there is a school within close proximity to the new house. A 3 mile distance radius is used to determine how attractive each vacant house would be. This distance is based on the statutory walking distance rule reported by the government (School Access Services, 2011). Using the statutory walking distance, children under the age of 8 years old, living more than 2 miles away from their school qualify for free transport to and from school. The same applies to children over the age of 8 years old living more than 3 miles away from their school. This suggests that in general, distances between 0 and 3 miles of a school are preferred.

5.0 Execution, Calibration and Validation

In order to demonstrate the robustness of the behavioural rules within the simulation model, the execution of the model was divided into two distinct phases. To initiate the model, households were distributed across the EASEL district based on the 2001 Census distribution and the total period for the simulation was set as 20 years. In the first phase of the simulation, which runs up until 2007 (year 6) various alternative rule sets were evaluated, and the best performing rule set was selected based on a comparison between the model outputs and an empirical view of change in the EASEL area over the same time period. This empirical view was based on data from Acxiom's Research Opinion Poll (ROP) for 2006 and 2007 (Thompson *et al.*, 2010).The ROP data was reweighted to reflect census proportions. Comparing the model runs and the ROP at 2007 allows an element of calibration, to the extent that the best combination of rules can be selected for modelling purposes; and an element of validation, because it provides reassurance that the model is able to represent actual change over a substantial time period. In the second phase of the simulation, the model was executed for the remainder of the 20 year period.

In total, there were 127 rule combinations i.e., $2^n - 1$; where *n* represents the seven (7) rules. Each rule set combination was traversed multiple times providing a practical and systematic approach to the calibration exercise. Using this approach, the deviation between results for model runs from the same rule sets were thought to be negligible highlighting the notion that though some elements of the rule set definitions were stochastic, the results were sufficiently consistent. Considering this, it was not necessary to resort to sampling the space to optimise and validate the model, for example using a greedy algorithm, as is done in many other simulation models (Shooman, 2002).

For this model, the execution/calibration/validation procedure progressed as follows:

Step 1: All possible rule set combinations were generated and run to the year 2007 for every combination.

Step 2: Each set of model results as at 2007 was compared with the ROP results for the same year. The level of error was assessed using the total absolute error (TAE) and standardised absolute error (SAE) statistics generated for each OA. These values were observed for the accommodation type and tenure type variables; that is, total resident occupying accommodation type *x* and tenure type *y* for a specific rule set.

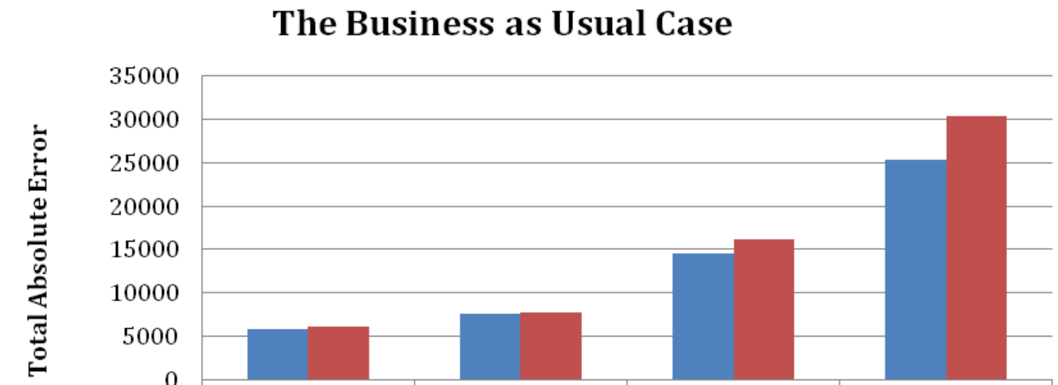
Step 3: The rule set with the smallest total deviation when compared to the ROP results was chosen.

Step 4: Additional parameters contained within the chosen rule set were optimised by running the model with a range of variable values for each parameter. For example, values for distance measures used within the model.

Step 5: The final results were generated using the optimal/optimised rule set.

Out of the 127 rule sets, the rule set made up of the *Ethnicity*, *Socioeconomic Status* and *Transport Routes* rules produced the least error total. In effect, these three rules were able to recreate the population distribution of the EASEL area in 2007 with the smallest total deviation when compared to the ROP. In lieu of additional datasets it is currently impossible to examine the model for over-fitting to the 2007 data however the errors were not so low that this is especially likely; on average a maximum error of 8% was reported for the accommodation type variable and a minimum error of less than 1% for the tenure variable. These were the variables used for calibration.

In the absence of a model of comparable functionality, the performance of the model at the 2005/2006 period can be compared to a 'business as usual' case, taken as the inactive case, to the performance of the model at 2001 when no rules were applied. Such a comparison indirectly tests the effectiveness of the behavioural rules. Here the 2001 census data is taken as the 'no change' model results and validated again the 2005/2006 ROP micro data to generate an error statistic. This is compared with the error statistic generated by comparing the proper model 2005/2006 simulation results with the 2005-2006 ROP micro data. The model producing the least sum of errors is thought to be the model which is a better predictor of the population distribution in 2005-2006. In general it is hoped that a dynamic model will generate better predictions than doing nothing.



	Ethnicity	Tenure	Age	Accommodation Type
2005-2006 CHAIRS	5977	7627	14666	25408
2001 Census	6135	7769	16187	30426

Figure 4: The Business as Usual Case using the Total Absolute Error

In **Figure 4** above, the 2005/2006 CHAIRS results are compared to the 2001 Census results. Both sets of results have been compared to the ROP validation dataset and the total absolute error recorded for each of the validation variables. Using these validation variables, the 2005/2006 CHAIRS results produce consistently lower errors when compared to the validation dataset than the 2001 Census. The ethnicity and tenure variables produce a better fit when the CHAIRS results are compared to the ROP validation dataset. Also, when the age and accommodation type variables are observed, the difference in error is noted to be higher than when the ethnicity and tenure variables are observed. Despite this, the results suggest that the behavioural rules in the CHAIRS simulation model have made a difference when the chosen rule set is used; the CHAIRS simulation produces a somewhat better fit to the validation dataset than the 2001 Census and is plainly replicating some of the system dynamics across the modelled years.

Note that these results capture all error at the EASEL area level. Examining the results at a lower geography, the differences between the CHAIRS results and the national Census are more apparent. **Figure 5** highlights this; the CHAIRS simulation is shown to provide a better match to the ROP validation data than the census when the semi-detached category of accommodation type is analysed. Here, the CHAIRS model produces consistently lower errors than the 2001 Census. A similar pattern of difference can be observed for the other validation variables used.

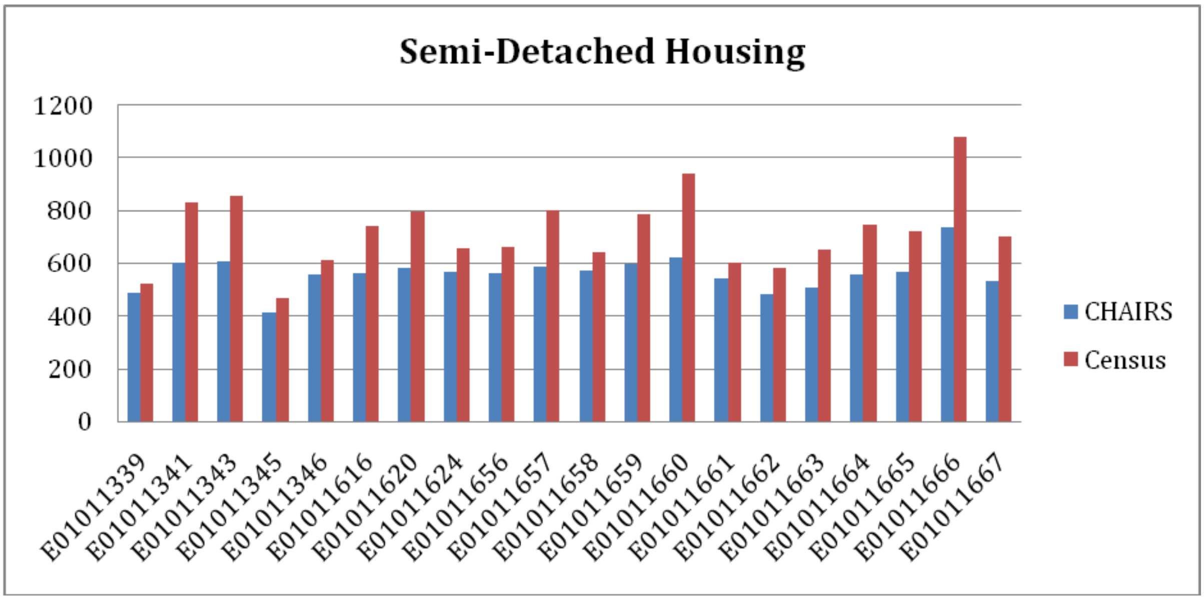


Figure 5: The Business as Usual Case using the Total Absolute Error at the LSOA Level for Accommodation Type

Observations such as these seek to instil confidence in the CHAIRS model and by extension its results.

6.0 Results

Thus far the challenges faced by the EASEL area have been discussed while housing-led urban regeneration policy and residential mobility have been presented as it relates to the case study district. Recall that this paper seeks to explore the impact of housing-led regeneration policies on the case study area. In particular, the paper examines the impact of a new mixed-tenure development in the Gipton area of the EASEL district using the methodology as presented in **Section 4.0**.

Figure 6 highlights the case study area Gipton, one of the areas within the EASEL district where regeneration changes are planned. More specifically, a new mixed-tenure housing development is to be built in this area.

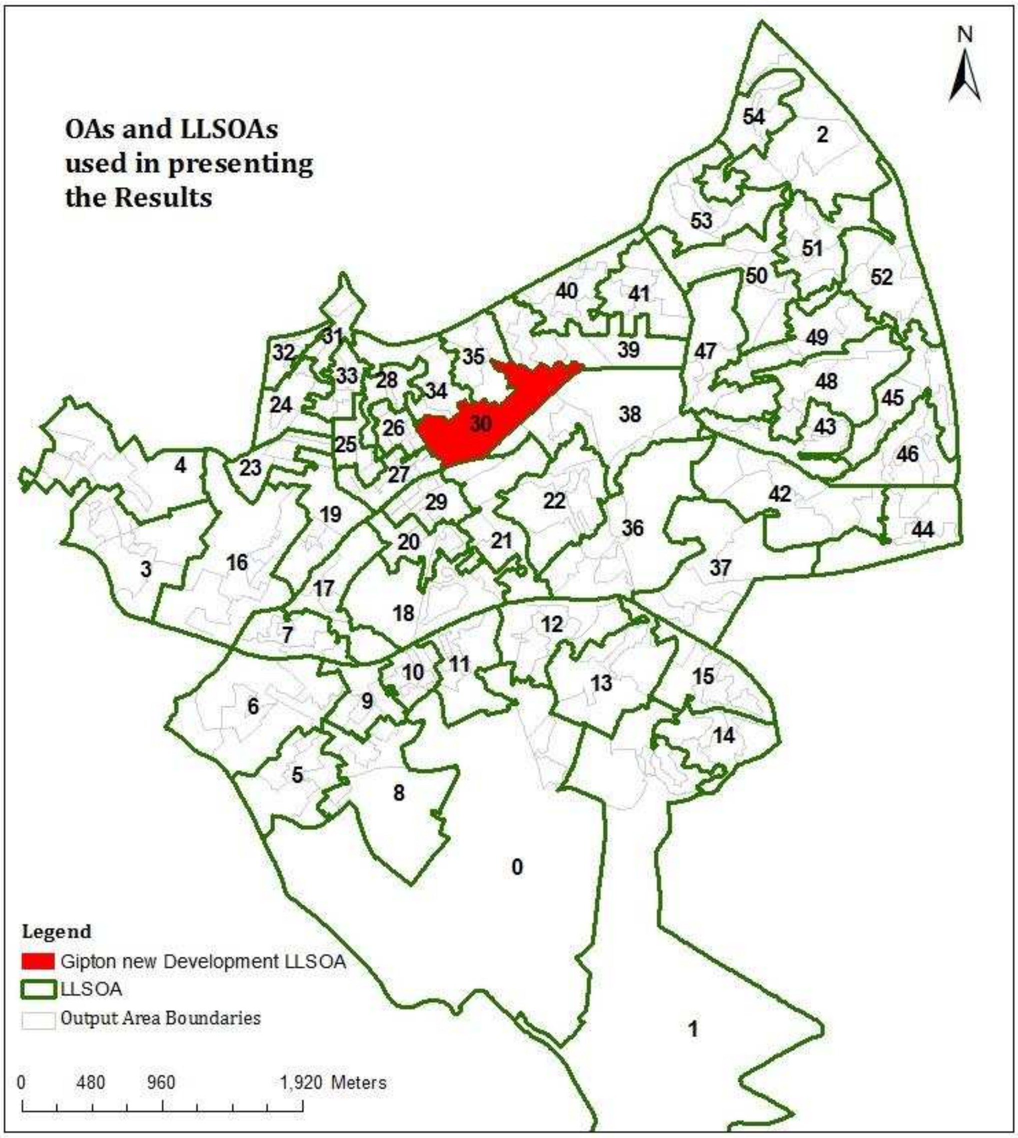


Figure 6: Lower Layer Super Output Areas (LLSOAs) illustrated in the context of OAs for the EASEL district highlighting the Gipton new development area. LLSOAs contain between 1000 and 1500 residents. LLSOAs labelled by generic identifier. A full list of LLSOA codes and titles can be found in the **Appendix**.

Note that the Diversity Index (DI) is used extensively in this section to bring clarity to the results. This index indicates the percentage that two randomly selected households would be different based on some predetermined factor (Brewer & Suchan, 2001). In this case, this difference is measured using the ethnicity or socioeconomic group reported for each household. The index is calculated as follows where **n** is the total number of ethnic/socioeconomic groups, **P** is the proportion of households in area **i**:

$$\mathbf{DI_i = 1 - \sum_{s=1,n} ((P^s{}_i / P^*{}_i)^2)}$$

The DI is therefore a ratio of difference and can also be expressed as a percentage. As a ratio, values closer to 1 indicate greater diversity while values close to 0 indicate greater segregation. We first look at the results if the model is simply allowed to run on the current housing stock. **Figure 7** shows the diversity index (DI) for Gipton. Notice that there is a trend towards reduced diversity if no regeneration policies are implemented over the 20 year model period.

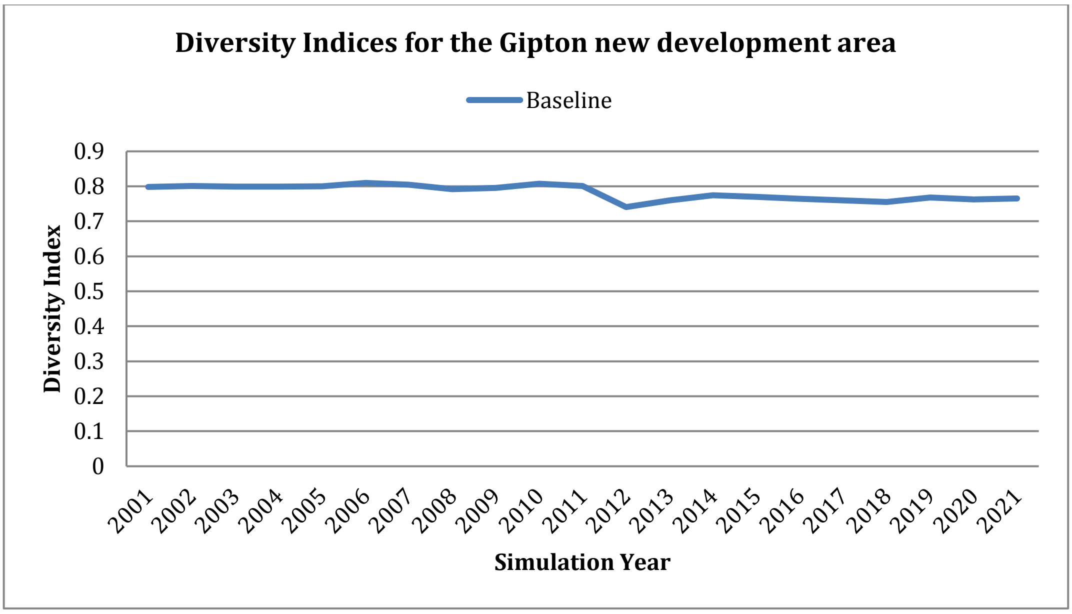


Figure 7: Diversity Indices for the Gipton new development area at the baseline over the 20 year simulation period

Also, the trends in the model are subject to fluctuations rather than a smooth progression. There appears to be a dip in the index between 2011 and 2012 which is indicative of a large number of low income households entering the area in 2012. The area is one which already has an unusually high level of low income households and as such this increase further reduces the level of diversity.

When the socioeconomic categories are examined more closely, **Table 7** shows an increased amount of households in most socioeconomic groups for this area. However, the '*Intermediate Occupations*' and '*Small Employers*' categories decrease by 3-4% over the 20 year simulation period. Note that, '*Other socio-economic groups*' comprises various low income occupations and the continued growth of this category points to the deprived character of this OA.

	Percentages		
	2001	**2011**	**2021**
Higher Managerial	0	0.8	0.8
Lower Managerial	6.4	9.1	8.8
Intermediate Occupations	6.4	4.1	3.2
Small Employers	7.9	3.3	2.4
Lower Supervisory	7.1	6.6	7.2

Semi-Routine Occupations	15.9	15.7	11.2
Routine Occupations	14.3	15.7	16.8
Never Worked, Long Term Ill	5.6	9.1	8
Other Socio-Economic Groups	36.5	35.5	41.6

Table 7: Distribution of households in Gipton by socioeconomic status at the baseline

The population change in Gipton is drawn from elsewhere in the EASEL district. Plainly speaking the hope of the council is that the population distribution will change as a result of the execution of regeneration schemes. However, in the worst case scenarios, the available housing will be taken up by the local community. Given the difficulty in predicting the national or even city level response of the population changes in the housing market, these worst case scenarios are a pragmatic first stage in modelling the regeneration, and show the baseline from which the council needs to strive by increasing opportunities.

As part of its regeneration programme, Leeds City Council has proposed to build a new mixed tenure housing development in the Gipton area. Though Gipton is known to be an area affected by high incidences of crime, antisocial behaviour and other social problems, the DI for the chosen OA is noted to be approximately 79% in 2001; it is an area which is already relatively mixed by socioeconomic class.

In total, there are to be 140 new homes built in the development area. The houses will be of varying accommodation and tenure types; terrace houses, semi-detached and detached homes as well as purpose-built flats (the exact distribution of each has been withheld from this paper). To simulate the regeneration, the model was adjusted to inject 140 new homes with a 60-40% split in tenure as planned. The general layout used in the model simulation is shown in **Figure 8**.

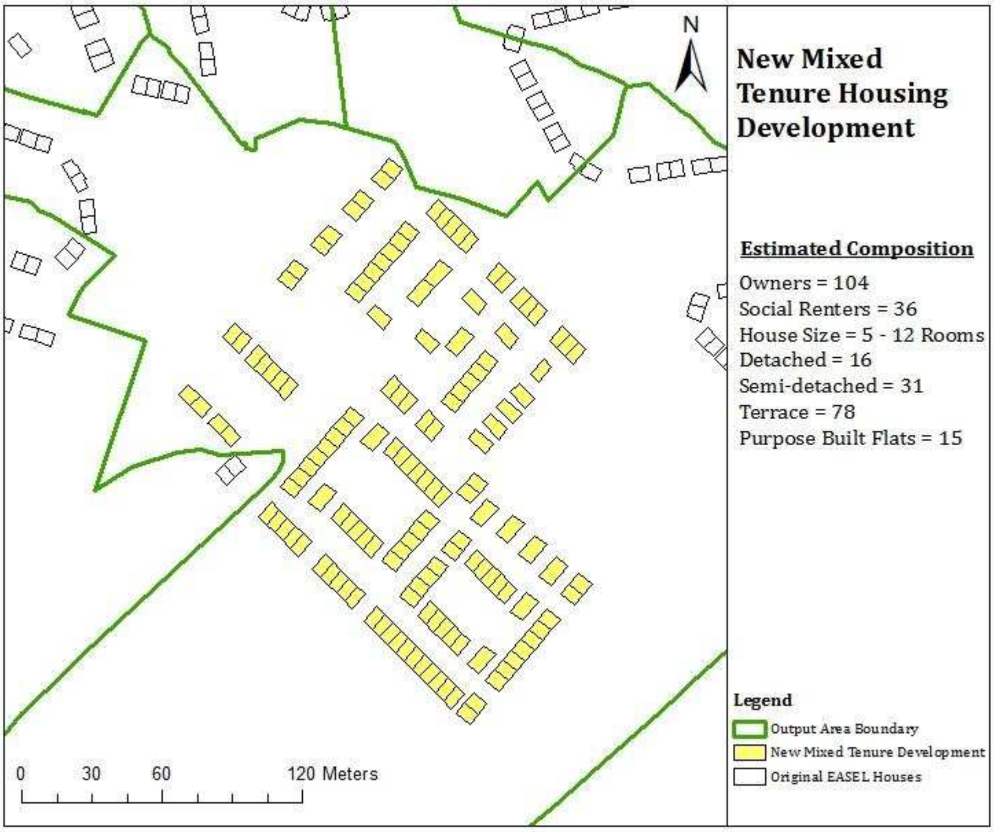


Figure 8: New Mixed Tenure Housing Development in the Gipton area

The graph in **Figure 9** compares the results of the baseline situation with the results of the model when the new mixed tenure housing development is built. With the addition of 140 houses, the results show a higher level of diversity in the Gipton OA over the 20 year period. Such a trend suggests that the new development area is able to attract a more diverse set of households as a result of the increase in mixed tenure housing. This is, again, a worst-case scenario, as the population is still drawn from the rest of the EASEL area, however it still compares favourably with the baseline non-policy situation, above.

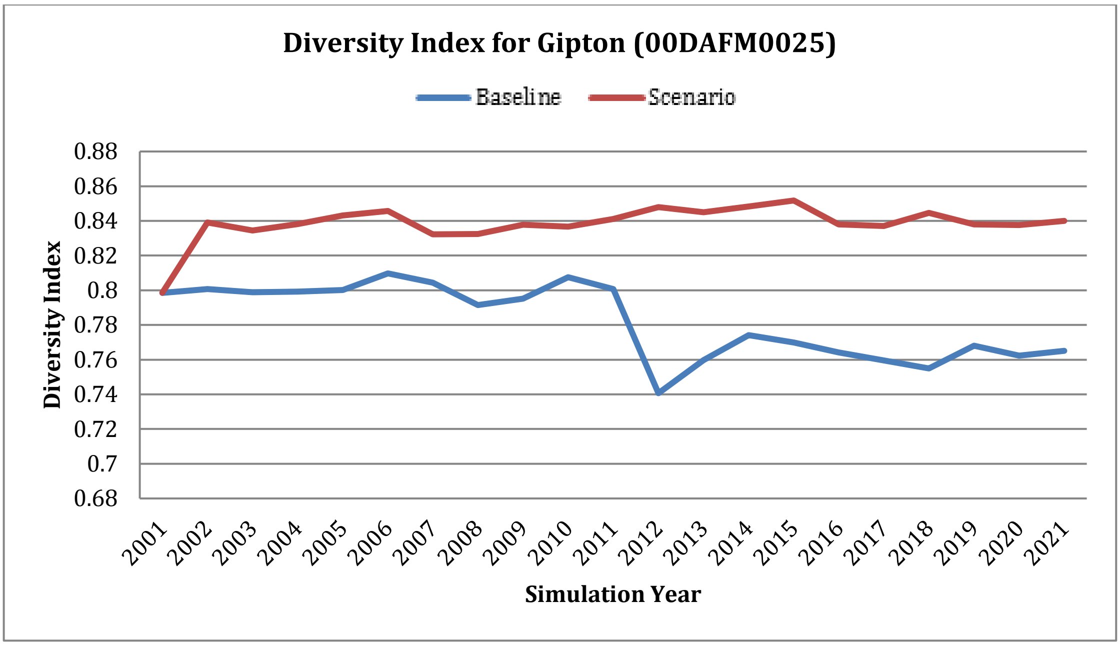


Figure 9: Diversity indices for Gipton area after the development scenario implementation

Table 8 is used to illustrate the types of households that have moved to the Gipton new development when the scenario is simulated. The table shows that moving from a total number of 0in 2001, as a result of the new development, 19 of the *Higher Managerial* households occupying the Gipton area moved to the new development in 2011. This can be contrasted to the *Other Socio-Economic Groups* group who in 2001 amounted to 46 households rising to a total of 68/67 households in 2011/2021 respectively. Of this group, 22/21 households moved to the Gipton new development.

	Baseline	Gipton Output Area		Gipton new development only	
Socioeconomic Code/Class	2001	2011	2021	2011	2021
1 Higher Managerial	0	19	15	16	12
2 Lower Managerial	8	31	34	23	25
3 Intermediate Occupations	8	14	11	9	7
4 Small Employers	10	17	15	10	8
5 Lower Supervisory	9	24	38	16	26
6 Semi-routine Occupations	20	46	35	21	19
7 Routine Occupations	18	38	40	20	17
8 Never Worked, Long Term Ill	7	12	10	3	3
9 Other Socio-Economic Groups	46	68	67	22	21

Table 8: Counts of households by socioeconomic status in Gipton new development area Development Scenario

Figure 10 and **Table 6** are used to further explain the trends shown in the previous graph, **Figure 9**. Using the socioeconomic class variable, there appears to be a reduction of poorer households over the course of the simulation run when the 2001, 2011 and 2021 statistics are compared. For example, there are fewer households in the '*Never Worked, Long Term Ill*' and '*Other Socio-Economic Groups*' categories as compared to most other categories where there are an increased number of households. Over time, the area loses almost 10% of those households thought to be in the more vulnerable socioeconomic categories illustrated in **Table 9**. This may suggest that this already diverse area does not favour poorer households. Such a claim may be further supported by the increased number of households in the higher socioeconomic groups; most notably the '*Higher Managerial*' category which jumped from 0% in 2001 to ~4.9% in 2021.

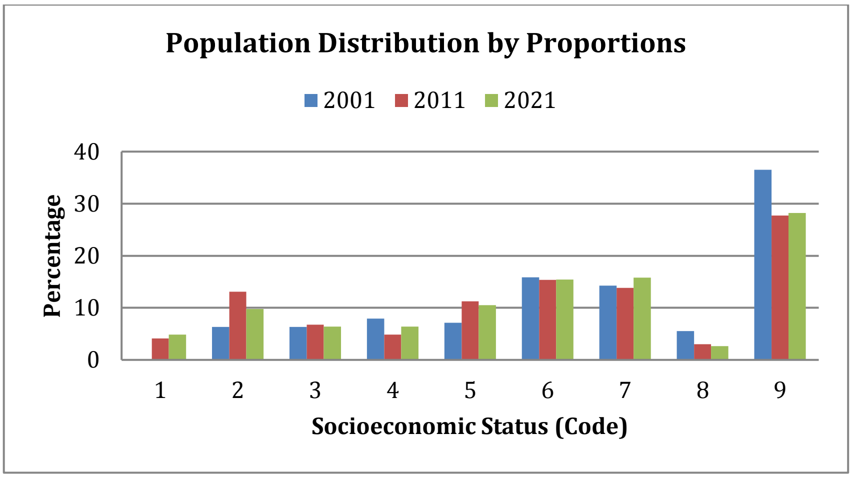


Figure 10: Distribution of households by socioeconomic class by proportions in the Gipton new development area using the development scenario

	Percentages		
Socioeconomic Code/Class	**2001**	**2011**	**2021**
1 Higher Managerial	0	4.1	4.9
2 Lower Managerial	6.3	13.1	9.8
3 Intermediate Occupations	6.3	6.7	6.4
4 Small Employers	7.9	4.9	6.4
5 Lower Supervisory	7.1	11.2	10.5
6 Semi-routine Occupations	15.9	15.4	15.4
7 Routine Occupations	14.3	13.9	15.8
8 Never Worked, Long Term Ill	5.6	3	2.6
9 Other Socio-Economic Groups	36.5	27.8	28.2

Table 9: Distribution of households in Gipton by socioeconomic class using the development scenario for the years 2001, 2011 and 2021

On the other hand, **Table 9** illustrates the possibility that a regeneration policy such as this can reduce or thin out deprivation in deprived areas; noting the reduction in households from socioeconomic class 8 and 9 over the 20 year simulation period compared to the increase in the socioeconomic class 1.

7.0 Discussion

Overall, on the basis of this model, the introduction of a new mixed tenure housing development appears likely to be successful in improving the socioeconomic mix in the Gipton new development area. Such an improvement could make the area more attractive to investors and by so doing provide job opportunities for the unemployed. This in turn could lead to a more productive community, reducing deprivation and the incidence of crime and police costs (Uitermark, 2003).

While the houses added are new homes, and therefore the demographic changes do not entirely represent the exclusion of the poor from the area, the magnitude of the changes suggests that gentrification may be a by-product when new mixed tenure developments are built in this community. It may additionally be the case that such changes are too large, indicating the potential for Forrest and Kearns' (1999) prediction that regeneration projects involving tenure diversification have the potential to exacerbate social differences, potentially increasing social tensions as different social groups not sharing the same core values are brought together in one community. Thus it may be in the council's best interest to consider mitigating policies that could combat these negative effects should they occur. For example, the Leeds City Council may consider increasing the number of social housing options available in the new mixed tenure developments. **Figure 11** and **Table 10** highlight the results of the model when the number of social housing options is increased. Here the model has been executed by implementing the development scenario with 60% social housing options and 40% ownership options; the reverse of the original scenario. **Figure 11** suggests that over time there is still an increased level of diversity.

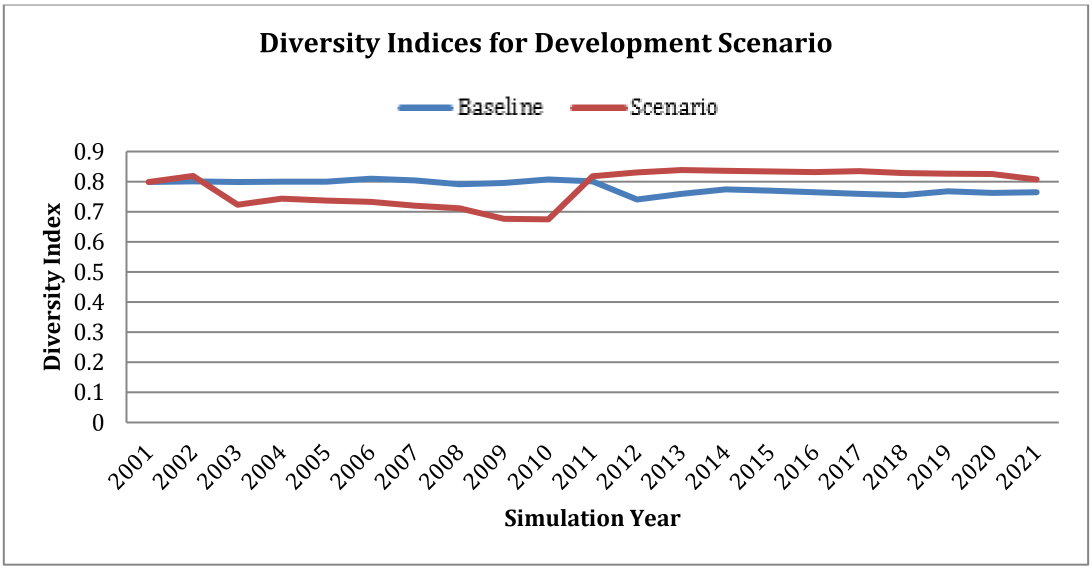


Figure 11: More Council houses allocated in new mixed tenure development

Unlike the original scenario however, where the number of households in the low income socio-economic groups in Gipton were reduced over time, **Table 10** shows that this is not the case when more social housing options are available. The table shows an increased number of households in higher socio-economic groups but the reduction of households in low income socio-economic groups is not as apparent. Thus it appears that with additional social housing options, the diversity of a neighbourhood could be improved without having to suffer the negative impacts of gentrification.

	Percentages		
Socioeconomic Class	**2001**	**2011**	**2021**
Higher Managerial	0	3.1	3.6
Lower Managerial	6.3	9.4	6.8
Intermediate Occupations	6.3	7.5	4.8
Small Employers	7.9	6.7	5.6
Lower Supervisory	7.1	7.5	8.8
Semi-routine Occupations	15.9	11.8	13.5
Routine Occupations	14.3	14.5	17.1
Never Worked, Long Term Ill	5.6	5.1	4.8
Other Socio-Economic Groups	36.5	34.5	35.3

Table 10: Distribution of households by socioeconomic status in the Gipton new development area (Development Scenario adapted; more social houses)

In addition, it is worth noting that the original regeneration scenario favours relatively higher-earning owners across the new mixed tenure development. Higher income households are the ones to occupy the new private homes and not low income households. Though the council hopes that by providing more opportunities for ownership, these mixed tenure developments would give low income households the opportunity to enter the private market, albeit that this is a model and not the real world, such an outcome is not evident in this model. By altering the ratio of social housing options available in the new mixed tenure development, the number of households in low income socio-economic groups is at least increased within the area. Therefore, it may be in the council's best interest to consider such an alteration to the regeneration project in order to reduce the negative impacts of gentrification.

With regard to residualisation, the model does not show high levels of residualisation. Instead the population appears to be more evenly distributed across the whole district when regeneration is implemented. Areas with low diversity indices in 2001 improve in diversity by 2021 as shown in **Table 11**. Though highly integrated areas lose some of their diversity in this simulation period, the gains of integration in low diversity areas appears to explain this loss. Thus it cannot be said that the new mixed tenure housing development leads to residualisation of low income households instead – to some extent disadvantage is thinned out.

		Baseline		Development Scenario
LLSOA Name	**Output Area**	**2001**	**2021**	**2021**
Seacroft	00DAGE0048	0.37	0.40	0.48
Harehills	00DAGF0069	0.45	0.49	0.54
Gipton	00DAFF0047	0.45	0.54	0.54
Seacroft	00DAGE0011	0.49	0.6	0.5
Harehills	00DAGF0066	0.50	0.6	0.52
Richmond Hill	00DAGB0045	0.51	0.6	0.61

Richmond Hill	00DAGB0015	0.52	0.6	0.55
Gipton	00DAFF0023	0.54	0.63	0.58
Seacroft	00DAGE0012	0.6	0.61	0.6

Table 11: Change in diversity indices comparing the baseline and the development scenario results

Thus, housing-led regeneration projects appear to be a viable mechanism for mixing communities by socio-economic status in Gipton and the surrounding areas However, the trend of gentrification emerges; as the Gipton new development area becomes more diverse, there is also a reduced incidence of the number of households in the more vulnerable socioeconomic groups – despite there not being a reduction in the amount of housing traditionally occupied by these groups. Though gentrification may be viewed as being positive for those living within the gentrified community, households of vulnerable socioeconomic groups are forced together because of their lack of economic power. This type of segregation can have adverse effects: proliferating poor quality housing, high rates of unemployment, high incidences of crime and antisocial behaviour all clustered in the same area.

Further work for this model include further reducing the effects of gentrification, an individual, rather than household-based model could help to improve decision-making and a more detailed model of demography could be included to account for mortality and fertility and other natural phenomena. Consideration could also be made to changing the order in which the rule sets are implemented.

8.0 Summary and Conclusion

In this paper we have presented a model of household migration and housing choice that can be utilized to explore urban regeneration policies. It builds on previous models of urban diversity, but includes a wider range of decision making fields, from transport desires and house size through to local knowledge and ethnicity. The model is applied to a case study based around a deprived district of the city of Leeds, UK, and is used to examine planned regeneration changes. It is the intention of the authors to revisit these results when the policy is implemented.

The model suggests that the development of mixed-tenure housing in the EASEL district can attract a more diverse community to an area however, it is clear that this process is partly one of gentrification. Regeneration has the potential for beneficial effects in creating communities mixed by socioeconomic tenure. However, this may be is at the expense of low income households; those households which regeneration policies are thought to specifically target. The model also suggests that a relatively small adjustment to the plan may go a great way to mitigating against these effects.

Acknowledgements

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Appendix

Note that the ID field in this table is related to the Ids noted in **Figure 6**.

ID	LSOA	Name	"Name" of area	Wards
1	E01011338	Harehills	Haselwoods / Rigtons	Burmontofts
2	E01011339	Gipton	Oaktrees / Beech Mount Oakwood Lane	Burmontofts
3	E01011340	Gipton	Coldcoat Avenue / Kitcheners / Bullers / St Albans	Burmontofts
4	E01011341	Seacroft	Veritys / Dunhills	Burmontofts
5	E01011342	Gipton	Brander Road / South Farms / Coldcotes	Burmontofts
6	E01011343	Seacroft	The Oval	Burmontofts
7	E01011344	Harehills	Bellbrooke Avenue / Kimberley Road / Comptons	Burmontofts
8	E01011345	Seacroft	Crossgates	Burmontofts
9	E01011346	Gipton	Wykebeck Valley Road / Branders / Gipton Approach	Burmontofts
10	E01011347	Harehills	Cliftons / Nowells	Burmontofts
11	E01011348	Harehills	Torres	Burmontofts
12	E01011349	Harehills	Glenthorpes / Gargrave Place / Brignall Garth	Burmontofts
13	E01011421	Gipton	Hollin Parks	Harehills
14	E01011422	Harehills	Markham Avenue / Brookfield Avenue / Roundhay	Harehills
15	E01011423	Gipton	Lawrences / Ambertons / Fearnvilles	Harehills
16	E01011424	Gipton	Hetton Road / Amberton Road / St Wilfrids Crescent	Harehills
17	E01011425	Gipton	Grange Parks	Harehills
18	E01011426	Harehills	Gathorne Terrace / Hares Avenue / Pasture Road	Harehills
19	E01011427	Gipton	Easterly Grove / St Wilfrids	Harehills
20	E01011428	Harehills	Harehills Road / Conway Drive / Luxors	Harehills
21	E01011429	Harehills	Spencer Place / Blankside Street / Shepherds Lane	Harehills
22	E01011430	Harehills	Darfield Road / Sandhursts / Dorsets	Harehills
23	E01011431	Gipton	Foundrys / Thorn Drive / North Farm Road	Harehills
24	E01011432	Harehills	Chatsworth Road / Berkeleys / Strathmore Terrace	Harehills
25	E01011433	Harehills	Comptons / Ashtons / Cowpers	Harehills
26	E01011434	Harehills	Ashtons / Conways	Harehills
27	E01011615	Halton Moor and Osmondthorpe Area	Dawlishes / Skeltons	Richmond Hill
28	E01011616	Halton Moor and Osmondthorpe Area	Carden Avenue / Oak Road / Partage Crescent	Richmond Hill
29	E01011617	Halton Moor and Osmondthorpe Area	Rookwoods	Richmond Hill
31	E01011619	Richmond Hill	East St / Upper Accommodation Rd / Lavendar Street	Richmond Hill
32	E01011620	Halton Moor and Osmondthorpe Area	Halton Moor / Ullswater Crescent / Rathmell Road	Richmond Hill
33	E01011621	Halton Moor and Osmondthorpe Area	Ings Road / Nevilles / Osmondthorpe Lane	Richmond Hill

ID	LSOA	Name	"Name" of area	Wards
34	E01011622	Halton Moor and Osmondthorpe Area	Neville Road / Wykebecks	Richmond Hill
35	E01011623	Richmond Hill	East Park Drive / Glensdales / Raincliffes	Richmond Hill
36	E01011624	Halton Moor and Osmondthorpe Area	Halton Moor / Kendal Drive / Cartmell Drive	Richmond Hill
37	E01011625	Richmond Hill	St Hildas / Copperfields / Gartons	Richmond Hill
38	E01011626	Richmond Hill	Corss Green Lane / Easy Road / Dial Street / Dent Street	Richmond Hill
39	E01011656	Seacroft	Boggart Hill Drive / Barncroft Road / Ramshead Drive	Seacroft
40	E01011657	Seacroft	Ramsheads / Limewoods / Monkswoods	Seacroft
41	E01011658	Seacroft	Boggart Hill	Seacroft
42	E01011659	Seacroft	Kentmere Avenue / North Parkway / Easdales Crescent	Seacroft
43	E01011660	Seacroft	Kentmere Approach / Rosgill Drive / Brooklands Lane	Seacroft
44	E01011661	Seacroft	Eastdeans / Seacroft Crescent / Hansbys	Seacroft
45	E01011662	Seacroft	Foundry Mill Terrace / Brooklands	Seacroft
46	E01011663	Seacroft	Tarnside Drive / Foundry Mill Street / South Parkway	Seacroft
47	E01011664	Seacroft	Redmires / South Parkway / Kentmerre Avenue	Seacroft
48	E01011665	Seacroft	Inglewood Drive / Crossgates Avenue / Stocks'	Seacroft
49	E01011666	Seacroft	Hawkhills / Bryan Crescent / Sandway	Seacroft
50	E01011667	Seacroft	Foundry Mill Drive / Hawkshead Crescent / Alston Lane	Seacroft
51	E01011671	Harehills	Cambridge Road / Servias / Meanwood Road*	University
52	E01011673	Harehills	Bayswaters / Gledows	University
53	E01011675	Harehills	Lincoln Green	University
54	E01011677	Harehills	Shakespeares / Bexleys / Bayswaters	University
55	E01011679	Harehills	Little London / Lovell Park*	University