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ELEMENTS OF A MODEL-BASED INFORMATION SYSTEM FOR THE EVALUATION OF URBAN POLICY

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1. Introduction

In this paper, we reflect on the progress of a research programme at the University of Leeds with a history of nearly two decades of urban and regional analysis. This interest was initially focussed around the application of model-based methods, and this approach always had a strong computational component. This interest in computer-oriented methods has led us naturally, along with many others, into a concern with the use of Geographical Information Systems in the analysis.

We believe, however, that our traditional interests have served to give our applications of GIS a distinctive flavour, with at least two kinds of unusual characteristic. The first of these is that our approach to GIS remains model-based, rather than data-based, as are many such systems. The elements of the modelling approach are reviewed in Section 2 of this paper. Secondly, we are concerned with the development of customised information systems using a variety of software products. This strategy yields greater flexibility and power than the use of single, 'off-the-shelf' GIS packages such as ARC-INFO. Further discussion of this methodology is provided in Section 3.

Much of our theoretical contribution has been elaborated with respect to our local urban and regional economy. Another feature is that much of this work has involved collaboration with various local bodies including the Department of Industry and Estates of Leeds City Council, the Leeds Chamber of Commerce, and the Yorkshire and Humberside Development Association. One of the changing emphases of recent years has been from traditional town planning to a greater concern with urban economic development. This has been reflected in the application areas we have chosen, and in Section 4 below we describe the results of our work in relation to labour markets, retailing, housing and education.

2. Model development

2.1 Strategy

At the heart of our activities has been the development of two kinds of comprehensive model of the urban and regional economy. The first, concerned with micro-simulation, is the most detailed but demands too much data and effort for some applications. The second represents state-of-the-art spatial-interaction based modelling. The models we have built are outlined in section 2.2 and 2.3 below.

2.2 The Microsimulation model

We shall see in the next subsection and section 4 that aggregate model-based analysis is a valuable tool for many kinds of spatial development and evaluation issues in the urban and regional context. However, we may often have a demand for information at finer levels of resolution, in particular to look at distributional effects or impacts as they relate to different types of individuals or households. In order to be able to serve these kinds of needs, we need micro-data on the attributes of individual persons and household units.

One of the problems here is that the kind of micro-data which we need is basically unobtainable for either demographic, social or economic characteristics! However, we can get around this problem by generating this information synthetically from aggregate distributions, that is to produce imaginary but 'typical' sets of individuals generating a population which is consistent with known aggregate distributions. This approach is technically and computationally demanding, but presents us with the basis for information systems of unprecedented power, because it provides us with a framework for linking together a wide variety of data bases that are usually only loosely connected, and often not explicitly related to small areas. The major inputs to the synthetic data generation procedure are the 1981 Census of Population and Households, government surveys (Family Expenditure Survey, General Household Survey and New Earnings Survey), and ad hoc local surveys on shopping behaviour and journeys to work.

An overview of the procedure adopted is provided in Figure 1. Data is generated on a step-by-step basis by sampling from aggregate distributions, initially on the demographic composition of the population, and then moving on to socio-economic attributes and activity patterns. At the end of the chain we are able to introduce income and expenditure to the procedure.

A full set of attributes generated in this way is shown in Table 1. The usefulness of this data can be demonstrated in a number of ways. First, we can reaggregate micro-level data to estimate aggregate distributions which were ot previously known. For example, we can look at a range of household characteristics related to the socio-economic characteristics of their members. The second thing we can do is to generate small area information from spatially aggregate data, especially income and expenditure data. Thirdly, we can combine micro-data with macro-level models, such as a model of retail trip-making. This allows us to produce things like detailed catchment area profiles for shopping centres (or labour markets). Finally, we can use a variety of procedures to 'update' our micro-data to make it more representative of changes since the various data were collected, and to make forecasts about future trends.

We describe a variety of applications of this model in section 4 below.

2.3 Design of an SI-based comprehensive model

Our comprehensive urban model is based on the interdependence between three different subsystems of the urban economy - population and housing, services and the economic base. In relation to each of the three subsystems, there are in turn three separate kinds of focus:

i) an interest in structure - we are concerned with the nature of the housing stock, employment opportunities, or patterns of service provision within small areas;

ii) an interest in activity patterns, which typically means that we want to concentrate on how particular groups of people (such as the residents of a small area in the city) use services, and what kinds of job they have. In practice, this means that we are concerned with processes of <u>spatial interaction</u> within a region. To a large degree, it is these processes which generate the need for a comprehensive approach, because they involve interactions between the subsystems. We are also concerned with other kinds of spatial interaction processes which do not link subsystems, specifically migration and inter-industry trade flows;

iii) we are concerned with dynamics - the way that spatial structures or activity patterns can be expected to develop in time. Some of the dynamics will be generated endogenously within the system: hence we can expect natural growth in the population, coupled with economic responses to supply-side imbalances in the manner of Harris and Wilson (1978). This approach to stock dynamics is equally applicable to the economic base or housing construction as it is to the retail sector (see Birkin, 1990, for instance). A second kind of dynamic process is the response to exogenous change: for example, how does the urban system readjust after a major firm relocates to the city with the generation of 2000 new jobs?

The main structure variables of the model can be described as follows:

H_i^{rs} - housing in zone i, of tenure r and 'type' (size, quality etc) s;

P_i^{abcd} - population in zone i, of age a, sex b and marital status c, social class d;

W_j^k - level of provision of a service type k in zone j;

E_j^{dg} - employment in zone j of persons of occupation d, in industry g;

Then we have the following sets of spatial interactions:

P - W : use of services by the population;

P / H - E : journey to work, and the demand for housing;

P - P : population migration between small areas;

E - E : inter-industry trade flows.

The endogenous dynamics combine the structural and activity components:

population change - is a combination of natural increase and migration;

housing change - is generated by supply/demand imbalances in the housing market, mediated through the price mechanism. Thus where there is pressure on housing stock, there will be price inflation but also a tendency for the stock to expand, and vice versa;

changing service provision - comes about as a response to profitability in provision: where revenues exceed costs then service levels will tend to rise; where costs exceed revenues then levels will contract;

employment growth - can also be related to the economic success of the activity in question, although in practice employment change is more likely to be exogenously determined, by expansion, contraction or relocation. Ad hoc processes will also impinge on the service and housing sectors as developers implement particular decisions for new house builds or shopping centre development. These types of decision are susceptible to impact analysis, as we shall see below, while the more general patterns of growth or contraction in response to supply-demand or revenue-cost imbalances can be used more generally to project changing system structure.

A fourth level of calculations involves the computation of <u>performance indicators</u>. These indicators can be used to summarise the features of complex spatial interaction processes, or may be combines for the evaluation of model outcomes, as we aim to show in Section 4 below.

The comprehensive model operates in three kinds of way - static, comparative static, and dynamic. In static analysis we are concerned with estimating missing information, such as spatial interaction patterns, and the calculation of performance indicators. In comparative static mode, we can assess the impact of changes to the system, such as the opening of a new shopping centre, or the relocation of a manufacturing plant. Finally, we can use dynamics to forecast developments in spatial structure or activity patterns. Where will the demands for new housing be in ten years time?

As we have seen in Section 2.2 above, it is possible to use model-based methods to link together a variety of data sources. However, the comprehensive model can be constructed and calibrated using data which is generally available and easy to obtain. Of course detailed information on population, housing and economic activity are all available from the census (although the business of updating these kinds of data base is a more complex one, and again it may be appropriate to address this problem using microsimulation methods). Patterns of industrial, retail and service supply, can all be established using a variety of directory sources from Yellow Pages to Newmans retail directories or Dun and Bradstreet's industrial directories. The demand for retail and service commodities can be estimated by combining demographic data with Family Expenditure Survey or General Household Survey estimates of household expenditure patterns.

3. Information systems as integrators

3.1. Strategy

We have explained in earlier sections why we have chosen to give a higher profile to our information systems research. Here we need to explain our strategy in more detail.

Consider a number of propositions. We have already indicated that we need to assemble large amounts of data from diverse sources as a basis for model-building. Access to this data is often useful for analysts or planners. Model outputs are another kind of 'data' or - from now on - 'information'. This is particularly true of the micro-simulation model since part of its function is to generate information which fills in 'gaps' in data - say small area income distributions. We can combine elements of data and information in various ways to construct a great variety of performance indicators. Again, analysts and planners need access to these. It is often not possible to pre-specify what the detailed information needs of a particular planning task are - and new needs are identified as the process proceeds. An aim of model-based planning is to be able to run models to generate performance indicators to test the impacts of plans. We often need to do various kinds of statistical analysis - on either data or model-generated information. We need good graphical presentation of the results of such analyses and we need good mapping facilities.

The tasks implied by any one of these propositions as part of a particular planning undertaking are nearly always carried out separately. We have made it a key feature of our research to use the idea of an information system to integrate all these tasks into one comprehensive system. This takes us a long way beyond the traditional concept of a GIS - if only because we want to have on-line access to model-based analysis. We have been able to develop the software to achieve such an integrated system - an IGIS (intelligent geographical information system). It has the structure shown in Figure 2.

The development of this system has been facilitated by the increasing power of PCs (which removes the need for a mainframe for much of the modelling) together with the availablility of software which makes it possible to combine subsystems written in different languages. In the system developed in the programme, we have used DBASE III for the information system, user controller and report generator, graphics and statistical analysis; FORTRAN for the modelling; and QUICKC for the mapping system. It is the overall system which can be described as an IGIS.

3.2 The West Yorkshire IGIS

In the present implementation, the system considers information on five different kinds of urban subsystem: population and housing; the provision of urban services; the utilisation of services; the local economy; and the local labour market. A range of performance indicators can be analysed for each subsystem. Altogether, 44 different performance indicators are considered, but all of these may be disaggregated further - by age, sex, social class, industry of employment, or retail product types, as appropriate.

This 'sectoral' focus is combined with spatial analysis of the West Yorkshire region which can be disaggregated by electoral wards, postal districts, postal sectors or metropolitan areas. There are 127 wards in the West Yorkshire region, and nearly 300 postal sectors.

The combination of spatial and sectoral interests starts to generate a large data base. Access to the data base is controlled by a series of herarchical menus which comprise the information system. These allow data to be retrieved and displayed: for example, Figure 3a shows a list of performance indicators which can be selected for the population and housing sector. The information system also allows the data to be structured e.g. Figure 3b shows a more complex situation in which wards in the Leeds MD have been ranked by the mean journey-to-work distance of employers and managers (in Column 1). (Note that for ease of presentation these illustrations are shown as monochrome tables of data, but would usually appear as multi-coloured computer screens). An important feature of the database retrieval system is that it allows the user to generate his or her own tables as combinations of a large number of performance indicators, which is extremely useful for exploratory data analysis. In systems where the data or information on offer is so rich, it is difficult to offer useful analytical procedures which are more than exploratory, although bivariate statistical analyses such as correlation and regression are available, and multivariate methods could be aded relatively easily if these were seen as necessary.

The database outputs can then be analysed geographically. Figures 4-9 inclusive are all examples of the kinds of maps that can be produced (and again bear in mind that these will usually appear as multi-coloured computer output; and the technology now exists to produce hard-copy colour maps at relatively low cost). These maps can be rescaled or annotated, but it is important to note that the mapping element is not necessarily the heart of our IGIS, as it is with many Geographical Information Systems. Rather, mapping is one of a range of core activities, of which others are the flexible combination of performance indicators, identification of exceptional geographies (through ranking or clustering of the data) and identification of areas with common features (through filtering e.g. filter all areas with between 6% and 7% unemployment).

So far, all the activities we have considered are baseline functions, which relate to the base census year 1981. The modelling capability of the system allows us to add a temporal dimension to the analysis. Thus we can 'project' what is happening to the activities in the system in 1986, 1991 and so on at 5 year intervals. Alternatively, we can change a limited number of activity levels in the system, recalculate the model equations, and look at a new set of performance indicators - a 'comparative static' analysis. For example, we could add a new shopping centre and see what this does for local accessibility to shops (see Section 4). Or we can combine the comparative static and dynamic options to see what happens if we 'fix' some sectors and forecast the others with a free response. So what happens if we build 500 new houses on a development site? Where will the residents find jobs in the short, medium and long-terms, and what impact will this have on the utilisation of local services? What happens if we buid 1000 houses, or develop the land as commercial offices instead?

4. Applications

4.1 Local labour markets

It is clear that the 1980s have witnessed a dramatic restructuring of many local labour markets, with service activities now more dominant than traditional manufacturing sectors. One of the consequences of this restructuring has been a large increase in the numbers unemployed, particularly in certain areas of the city. The aims of our research in local labour market analysis has been two-fold: first to draw upon the micro-simulation Leeds database (in conjunction with models calibrated for the journey to work patterns in the city) in order to breakdown the aggregate picture on (un)employment. This enables us to incorporate attributes such as socio-economic group, age, sex, race and industry type with household structure and composition variables. The second aim is to then focus on the journey to work models and demonstrate the impact of different types of job creation programmmes. In particular, we are interested in how new jobs affect unemployment levels in a certain area rather than merely the balance of migration and commuting flows.

The detailed picture built up on the demand side of the labour market has provided a powerful framework for analysis and put us in a much more effective position to try and make sense of the functional relationships within the local labour market of Leeds. It is useful to conceptualise the interdependencies between the demand and supply sides through suites of performance indicators. The examination of these sorts of indicators is described in Birkin and Clarke (1987). On the residential side these include employment and unemployment rates, average distances travelled, degree of self-containment within areas (that is the degree to which residents can find jobs in their own locality), all disaggregated by age, sex, social class and ethnic status. At the workplace end, indicators include the 'degree of market share' (the number of jobs provided in a particular workplace area as a percentage of the total number of jobs across the whole market), the size of market areas for workplace zones and, once again, the degree of self-containment (the opposite of the previous residential indicator, namely the degree to which a particular workplace zone employs from residents within that zone).

Given such a detailed picture of both the demand and supply sides of the local economy, we are now in a good position to model the impacts of changing either side of the relationship. On the supply side, this might include changes in the housing stock (by locality), local demographics or individual skill levels. On the demand side we are interested in changes to the number and type of job provision, and potential catchment areas for any new jobs created.

We have recently been able to use the modelling and information system to monitor the impacts of a possible 2000 new civil service jobs re-locating from London, in conjunction with the Department of Industry and Estates at Leeds City Council. They estimated that around 500 new clerical jobs would be created for Leeds residents if the city was successful in attracting the jobs (against Nottingham and Manchester). The Department of Health (the body involved) needed to be persuaded that the city could recruit such labour and those residents were well served to the city centre by public transport. It is possible to make a certain amount of progress by using disaggregate census data, such as residential location by occupation and mode of travel to work (Table 47 of the census Small Area Statistics; OPCS, 1982; see Figure 4). We can also use the Special Workplace Statistics to look at gross journey to work flows, and associated indicators (e.g. Figure 5). However, as we have argued above, using a model allows us to do at least two more vitally important pieces of analysis. First, we can fill in gaps in the data, hence make inferences about journey to work patterns for specific occupation groups (by age, sex, industry, or mode of transport if necessary) - see Figure 6. It is this kind of insight which comes from the microsimulation modelling described above. Secondly, we can use spatial interaction models to generate a 'what if?' capability, and actually simulate the impact of 500 new clerical jobs. Figure 7, for instance, shows that more of these jobs are likely to be taken up by residents of the north-western sector of the city than by residents of the deprived Urban Development Area.

4.2 Retailing

For many years the retail model has been the basis of experimentation and illustration in a wide range of theoretical areas (see Birkin et al 1986). The retail model remains an important focus for model development, and recent work has taken three major directions. The first is concerned with the testing of theoretical ideas on patterns of equilibrium and dynamics in the real world retail environment of Leeds. This work draws upon the picture of retail change in Leeds since 1960 (e.g. G.P. Clarke 1986a). The main conclusions of this research are that it is possible to calibrate and fine tune the equilibrium model to reproduce existing retail patterns and structures in a plausible way. Further, when the extension is made to dynamics (in this case using the retail grocery sector) actual system trajectories (or patterns of change) can be broadly reproduced and there is evidence that key parameters achieve critical values beyond which the nature of the structure of provision changes. (see G.P. Clarke 1986a, b, G.P. Clarke and Wilson 1986a, b).

The second approach to empirical work has involved extending the basic model into new areas of retail and marketing geography. These have included the motor industry, financial services and new models for out-of-town retailing (e.g. Clarke and Wagstaffe 1987). Out of this experience has emerged another order of magnitude of improvement in both understanding and usefulness.

The third area of study, and most directly relevant to public policy planning, has been our work on the recent influx of planning proposals for new shopping centres in Leeds. Although the main wave of supermarket, hypermarket and retail warehouses is probably over (although of course they continue to be built), retail planning continues to be faced with issues that cause great problems in terms of impact assessment. The latest in the long line of such trends is the new 'regional shopping centre', or less grandly new retail 'parks' based largely on comparison shopping. Over the last few years in Leeds there has been a large number of planning applications for such new developments. However the impact assessments of such new centres are typically based on simple travel times around largely circular catchment areas. In particular it can be shown that catchment areas are not circular around individual centres and hence the impact on other centres is far more subtle. It is in these sorts of study that our work on performance indicators is also especially important, allowing the specification of residence-based welfare and accessibility indicators alongside centre-specific calculations on changing revenues.

A simple example can be used to clarify ideas at this point. One of the many retail planning proposals for the West Yorkshire region is for the establishment of a large out-of-town centre in the Morley area. The first step in addressing the issues raised by this proposal is to use a performance indicator framework to appraise the existing situation. In Table 2 we present a list of indicators for major centres in the West Yorkshire region, relating to all non-food shopping activities. These basic indicators show that, as one would expect, Leeds is not only the largest centre in this region in terms of its physical size (measured as square feet of shopping space, or 'SQ FT' in the table), but also the largest in terms of centre revenue ('CENREV', in millions of pounds) and catchment population ('CAT'), defined here as the number of households using a centre as their only, or most frequent, destination for comparison goods shopping. Leeds also has the highest density of trading, measured in the retailers' sales per square foot ('SPF', in pounds per square foot). However, Skipton has the most affluent catchment area, with a high proportion of ABs ('CATCOMP' is the percentage of the catchment population for which the heads of household are social class A or B), and the highest sales per catchment household ('SCAT', effectively the average expenditure of households in the catchment of the centre).

The fundamental question to ask now is "what happens to this pattern if we add a new centre in Morley", and for the sake of argument we will assume that 600,000 square feet has been proposed. It is a straightforward matter to add this centre, and recompute the activity patterns and performance indicators, as shown in Table 3. Here we see that Morley generates a catchment of just less than 60,000 households, but this is only achieved with very large deflections from nearby Wakefield. This is, however, a rather sizeable development, and the rate of turnover is low relative to the large urban centres.

Having established the potential for revenue generatio within a planned centre, and hence an evaluation of its profitability, another kind of question that the developer might wish to consider is what scale of development is most appropriate. This will be particularly pertinent if a mixed development of shopping with office space, leisure activities or even light industry is being contemplated. Again, this can be easily tested using the model. Table 4 shows a set of predicted revenues for a varying level of retail floorspace, showing a strong level of scale diseconomies. The implication of this result is that the new retail park has an obvious local catchment area which can be easily exploited, but a larger development will have to cut heavily into the catchment of the large and diverse competing centres of Leeds, Bradford, Wakefield, Halifax and Huddersfield.

For the planning authority which is responsible for the regulation of new developments, this information is all useful grist to the mill. However, additional insights can also be obtained by focussing on suites of residential performance indicators. One kind of indicator which is useful here is simply the average distance which consumers will travel for comparison goods. We present this, in Table 5 (in the column labelled 'Av Dist'), as an aggregate measure, although in a detailed study it might be necessary to break this down and look at the patterns for particular disadvantaged groups, such as the elderly. Table

5 also quantifies the 'effective delivery' ('Eff Del') of retail floorspace to residential zones in the neighbourhood of Morley. This is a notional measure of how much retail space is used exclusively by residents of a particular area, and hence can be a useful measure of the equity of a pattern of retail supply. Another way to look at this is as a provision ratio ('Prov Ratio'), or effective delivery per head of population. Table 5 shows that there are considerable benefits to the local population from a new development in Morley, as one would expect, and as this area started as a relatively poorly provided one, this might be regarded as a significant (and quantifiable) plus by the planners.

It is also worth making the point that this kind of information can also be made available to individual retailers. These organisations will clearly be concerned to generate revenue estimates for a new centre in order to assess the profitability of locating there, but may also be interested in residential indicators such as the variation in their <u>market penetration</u> across residential zones. Many other kinds of residential performance indicator can be developed for either residential areas or supply zones i.e. shopping centres. One of the most interesting is 'group performance', or the comparison for an existing store of the known turnover against a model-based prediction. This is a very powerful tool in the evaluation of branch networks for all kinds of retailers. Note that when a new store or shopping centre is evaluated by simulation, this kind of facility also allows the retailer to assess the deflection pattern within his own organisation. This kind of analysis would typically be frightfully difficult to quantify, but could have a crucial effect on decisions concerning marginal developments in the network.

As an example of this, let us consider an imaginary organisation, 'XL Stores', which sells mens clothing. This multiple chain has three branches in West Yorkshire, one each in Leeds, Bradford and Wakefield. Figure 8a shows the pattern of market penetration which this implies. Although the three locations are the largest in the region, with spatially extensive catchment areas, this pattern of market penetration can be seen to be significantly concentrated around these centres. This pattern changes if we open a new branch in Morley (see Figure 8b). As this is a relatively small centre, this generates big peaks in penetration in the locality of Morley.

4.3 <u>Housing and Household Incomes</u>

The micro-simulation data base has again provided the backbone for our work on housing and household attributes. From SYNTHESIS (see Birkin and Clarke 1988) we can provide a highly disaggregate picture of household structures which provides far more richness than traditional Census variables. Indeed, one of the deficiencies of Census data is that it is almost ten years out of date and a major element of the microsimulation strategy is the updating of household and demographic characteristics. A discussion of progress with this line of research appears elsewhere, in Duley et al (1988), M. Clarke et al (1990). The importance of this work in application terms is to provide up-to-date ward profiles which are of obvious benefits in all areas of our urban and regional modelling work. In particular, it can be linked with our labour market modelling to give new insights into journies to work in the 1990s.

One particularly important application of SYNTHESIS has been in the production of individual and household incomes. Birkin and Clarke (1989) show how it is possible to construct an income generating module based on the industrial sector and occupation of the individual within the SYNTHESIS dataset using the New Earnings Survey. It is important to appreciate that this kind of data is simply not available to the academic or private community at the present time. Traditional proxies for income, such as owner occupation, professional workers or car ownership levels, have been the best we could get. Hence the new work reported here is of immense importance. On the commercial side there are obvious advantages of using incomes data. Academics too would find income data of great use in studies which attempt to understand the relationship between activity variables (i.e. any service utilisation) and measures of wealth/deprivation.

As an example, in Figure 9a we show average earnings for male workers in Leeds wards (in 1981). These estimates are obtained by synthesising data on the socio-demographic composition of wards, and the industrial and occupational composition of the workforce, with detailed data on wages from the New Earnings Survey (DE, 1982) which is powerful but crucially lacking in any small area component. The technique is discussed in more detail by Birkin and Clarke (1989).

The work on income generation is also leading to interesting research on benefits and taxation in general. Since we now have income coupled to household structure and occupation it is possible to apply direct sets of rules to generate state benefits and taxation for each household in the SYNTHESIS data set. This is particularly pertinent given the radical reorganisation of local taxation with the onset of the community charge or 'poll tax'.

As well as being crucially important in its own right, the work on individual incomes also allows us to generate (within the microsimulation framework) household incomes. This information can then be combined with data from the Family Expenditure Survey or other surveys to provide estimates of household <u>expenditure</u> (e.g. Figure 9b). This kind of information is clearly of great value to retailers, as we saw in Section 4.2 above, but is usually only generated by proxy measures involving some kind of clustering or social area analysis.

4.4 Education

An important component of the urban and regional information system is education, and this is one substantive area where extensions of the modelling approach can be envisaged in the future. In many respects, the early 1990s have never been a more appropriate time to undertake such a modelling exercise in cities like Leeds, as the local planning authorities consider radical change. The problem of falling rolls has been particularly significant in the development of plans for the complete re-organisation of primary and secondary education in the city. The most significant proposal is that of removing the current middle tier of education (9-13 year olds) to be replaced by a simple two tier system: (1) primary, 5-11 year olds, (2) secondary, 11-16. Clearly such radical re-organisation, coupled with the perceived need to remove the excess space caused by falling rolls, will result in some school closures and amalgamations. Such closures are bound to cause great resentment amongst parents and the public at large, and it will be interesting to report the results from our simulation exercises on the impacts of such changes. How will accessibility patterns be affected for example? Again, the performance indicator framework will be useful here in defining residence based and facility indicators. The same argument applies to other kinds of subsystem like health, leisure and social services.

4.5 Comprehensive modelling

In our illustrations we have concentrated on static and comparative static applictions of urban subsystem models. The possibilities are still more exciting if we can link these submodels together into a comprehensive whole with a dynamic focus. Thus when looking at a new shopping centre, for example, we are likely to be interested in the employment generated by such a scheme. How will this new employment affect the local labour market, and where is new housing to be found for these new employees?

5. Future research and developments

Three distinct areas of activity can be highlighted here:

i) GIS development - to extend the functionality of the information systems to include a wider range of features such as overlaying and windowing. Of course these features (and many more) are contained within standard GIS packages, but equally these packages lack the kind of modelling capability which we have described above.

ii) Research on particular sectors: many of the commercial applications of the work described above are in retailing, although in a very broad sense of that word. We have been working with clients in newspaper publishing and distribution, motor vehicle sales, and retail breweries aswell as high street and out-of-town retailing. The rapidly changing face of the retail environment (e.g. the demise of the high street and growth of new out-of-town centres; speciality retailing and niche marketing) must be paralleled directly in information systems design and, especially, modelling technology. The methods described in this paper are also being applied to a wider variety of sectors, including health, water resource and energy systems.

iii) Local research - the local area is still the most appropriate point of reference for comprehensive modelling and information system design. The main requirement here seems to be to make local institutions aware of the power and applicability of urban and regional information systems. The institutions concerned might be local planning departments or Chambers of Commerce at the city level, or medium-sized to large businesses with regional interests.

One of the characteristics of this ongoing research program is the diversity of its funding, being sourced as it is by a variety of private and public sector organisations. A second feature which is worthy of comment is that although the local area is still of interest, much of the research programme is focussed on national, rather than regional, issues. As most organisations are nationally oriented, this greatly enhances the number and variety of potential applications of a methodology which is fundamentally spatial rather than regional.

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Figure 1. The sequence of steps in attribute generation

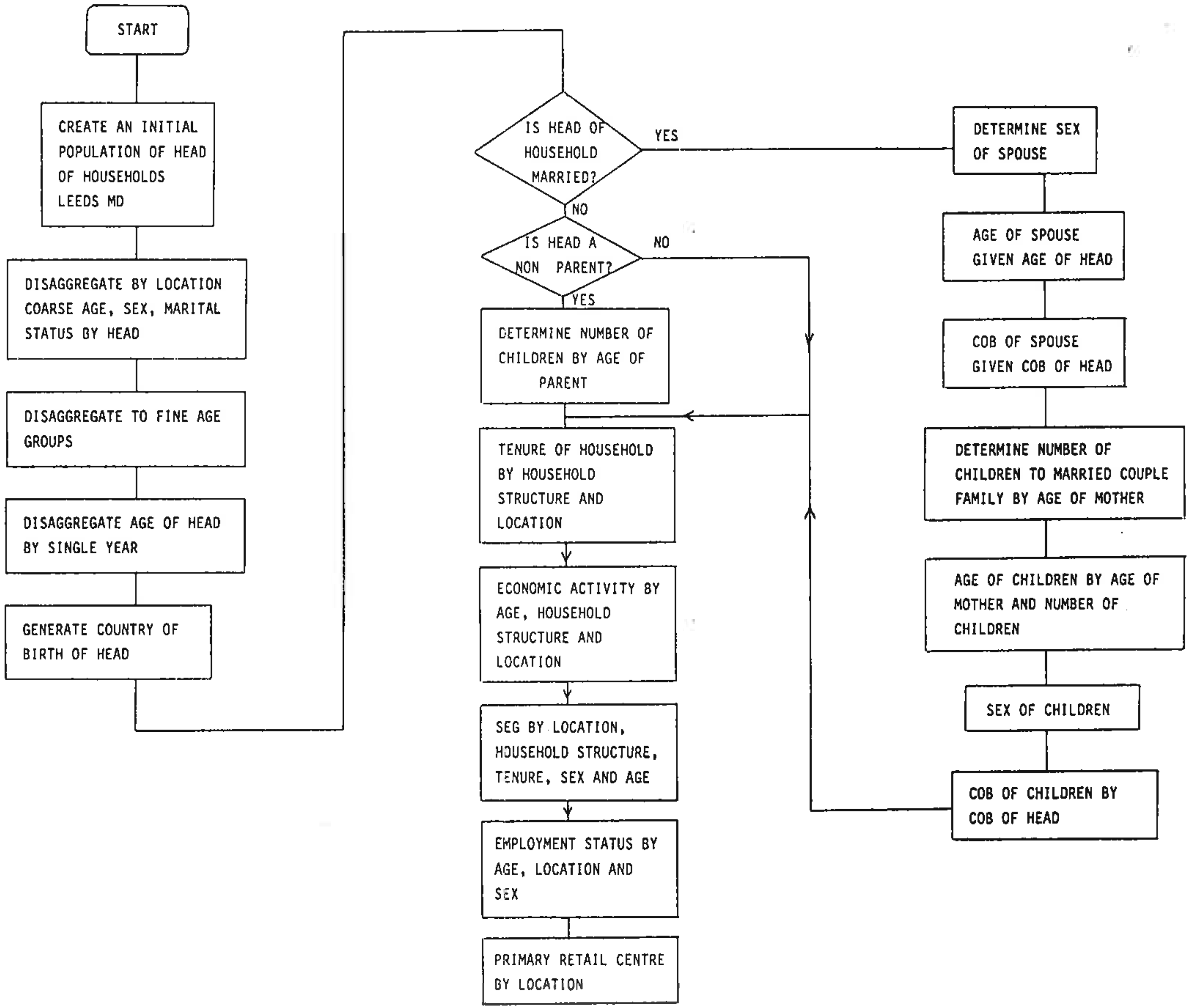

Figure 2. The structure of an intelligent geographical information system

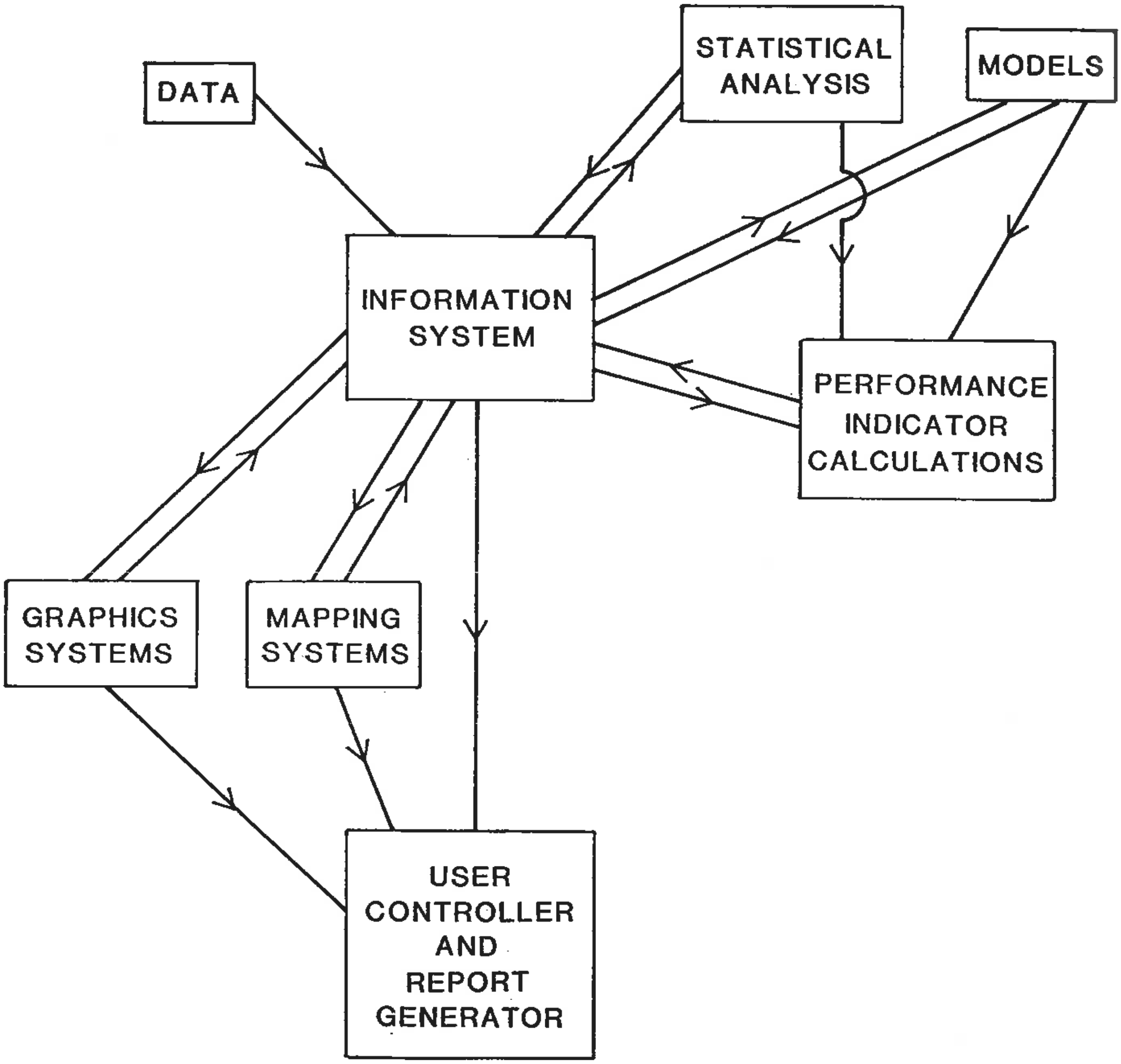

Figure 3a. An example of the West Yorkshire IGIS: Data choice menu

West Yorkshire regional model
**** DATA CHOICE MENU ****

Population/housing	Retail (supply)	Retail (demand)	Industry (supply)	Industry (demand)	Quit

Population by age-sex/marital status
Population by social class
Local net migration rate
Rooms by tenure by zone
Bid rents
Compound accessibility
Population density
Unemployment rate

All choices are further broken down subsequently

Choose population/housing data to display
Total variables to be chosen; 1. Now choose variable 1. F1-toggle info window

Figure 3b. An example of the West Yorkshire IGIS: Some key indicators

West Yorkshire regional model information system
Area is:LEEDS   Model is Baseline (1981)

Ward	TRIP Emps/mang All.ind	TRIP Non-manl All.ind	TRIP Sk.man All.ind	TRIP SS.man All.ind	Hans.acc Emps/mang All.ind	Eff.del SS.man All.ind
Wortley	6.6	4.7	3.7	3.9	4591.9	2942.6
Wetherby	4.0	3.3	3.1	3.0	8725.0	7362.6
Bramley	3.5	3.4	3.0	3.2	9027.7	8062.6
North	3.4	2.9	2.6	2.8	12591.3	11613.5
Cookridge	3.2	3.1	2.9	2.9	13658.6	14891.8
Hunslet	3.2	3.1	3.0	3.0	14752.9	14075.8
Garforth&Swil	3.0	2.9	2.5	2.7	15119.6	15827.0
Middleton	3.0	3.0	2.8	2.8	9682.3	8845.2
Beeston	2.9	2.7	2.8	2.8	12699.1	10872.5
Moortown	2.9	2.6	2.4	2.5	16115.2	16368.8
Roundhay	2.9	3.2	3.2	3.1	11307.5	10347.8
Horsforth	2.8	2.6	2.5	2.5	16002.3	17627.2
Harehills	2.7	2.6	2.6	2.7	16359.2	14753.0
Burmantofts	2.6	2.4	2.3	2.3	12534.7	15539.0
Whinmoor	2.4	2.3	2.1	2.0	11099.5	9973.7
Morley-North	2.4	2.2	2.0	2.0	16771.3	13446.5

Item:1 1-34 of 34   Ward summary:highlight ward, PRESS ENTER
_F1 - full variables, F2 - hotkeys________Pg Up,Pg Dn to scroll, Esc to Escape

Figure 4. Leeds clerical service workers commuting by bus

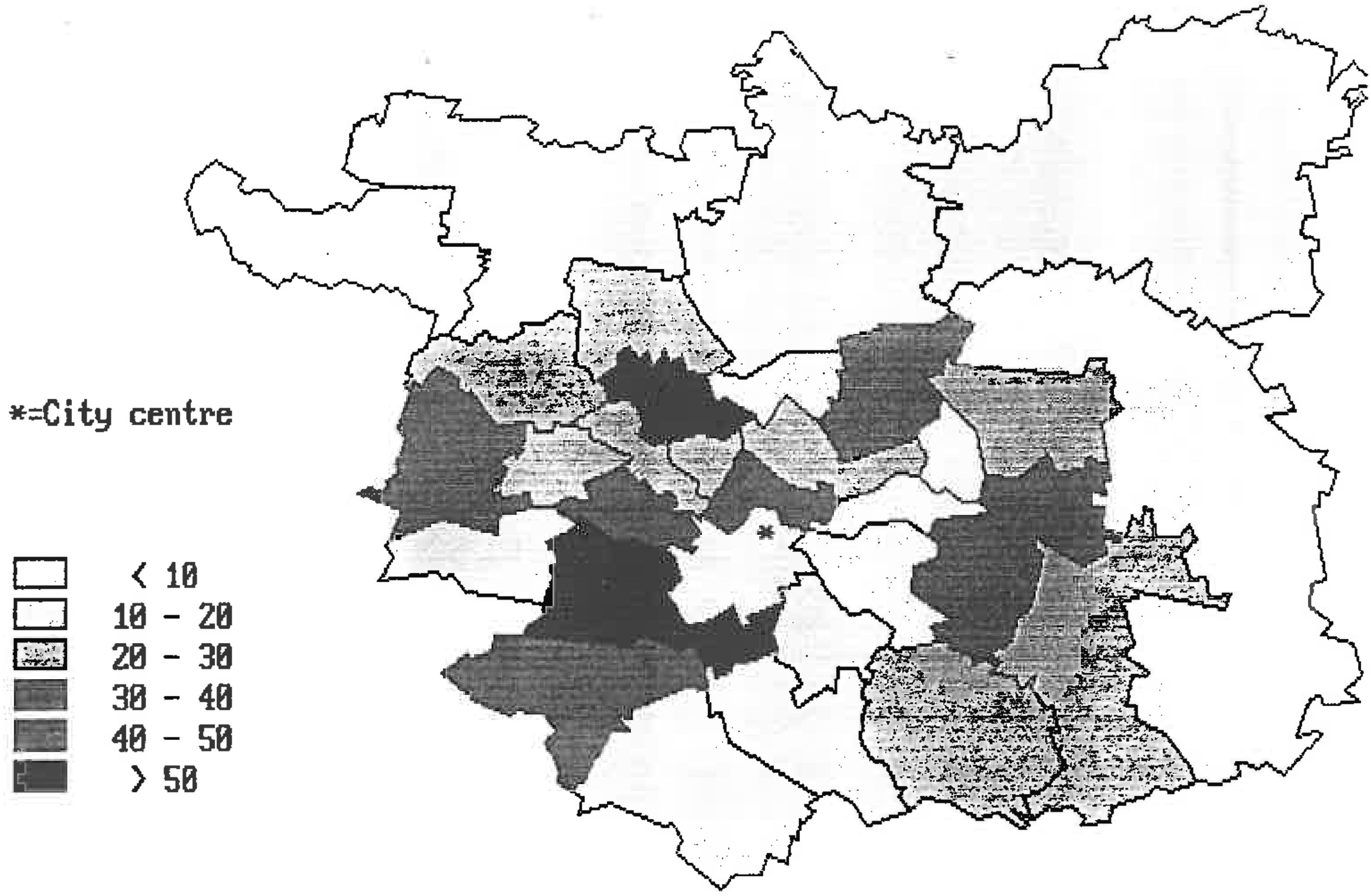

Figure 5. Percentage of city centre workers resident in Leeds wards

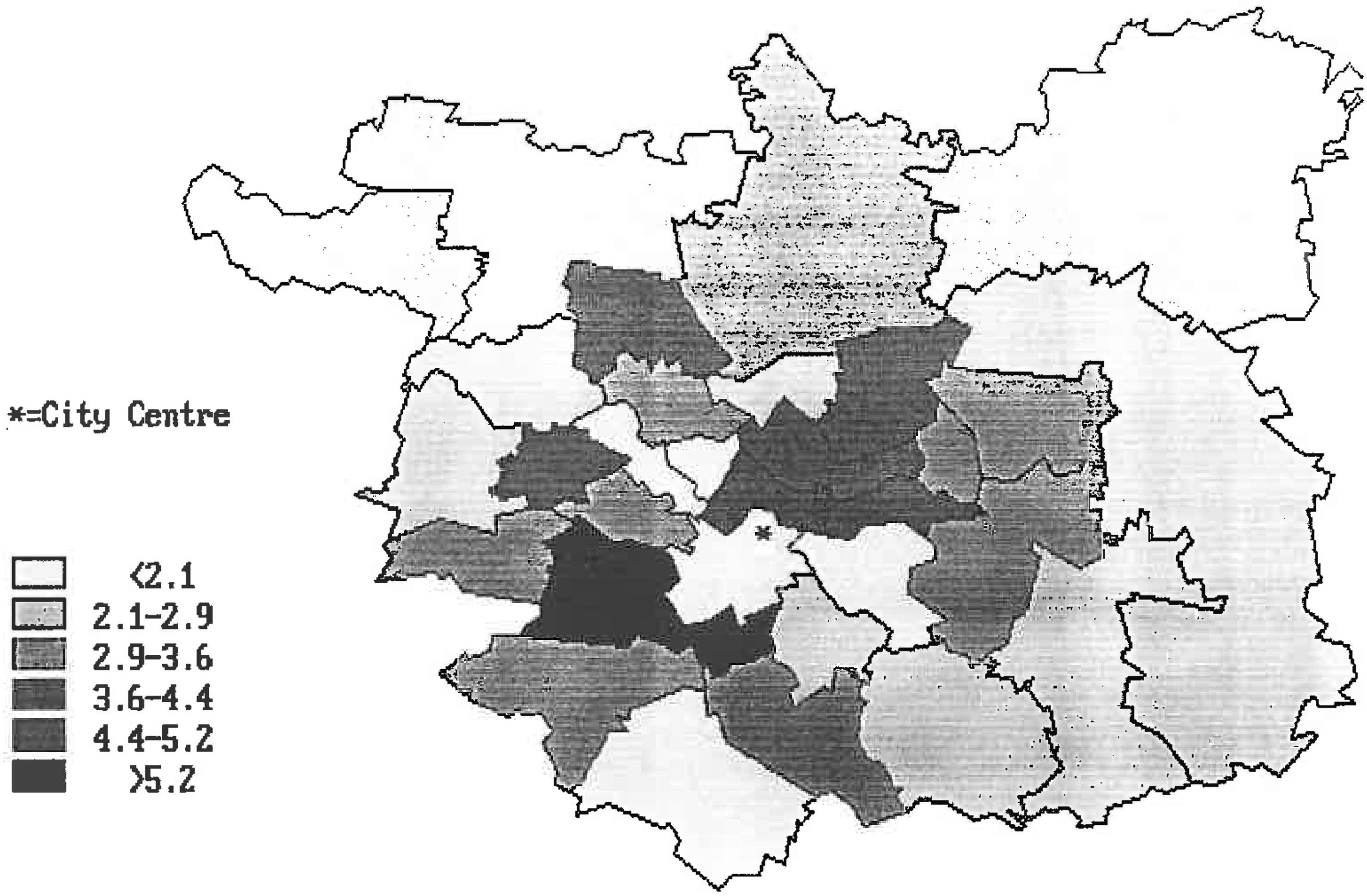

Figure 6. City centre workers resident in Leeds wards: Services - Clerical (%)

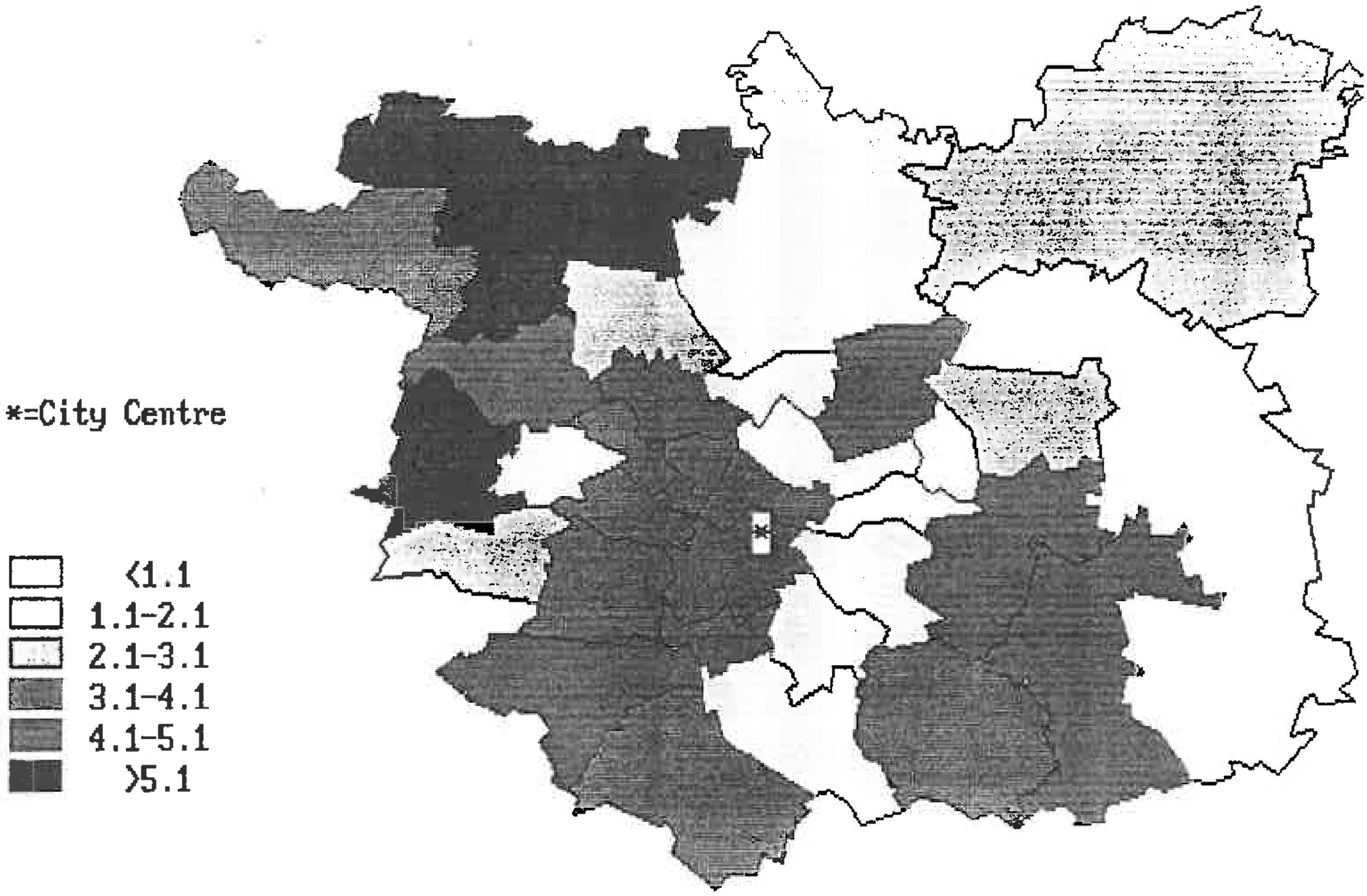

Figure 7. Residence of 500 new clerical service workers in the city centre

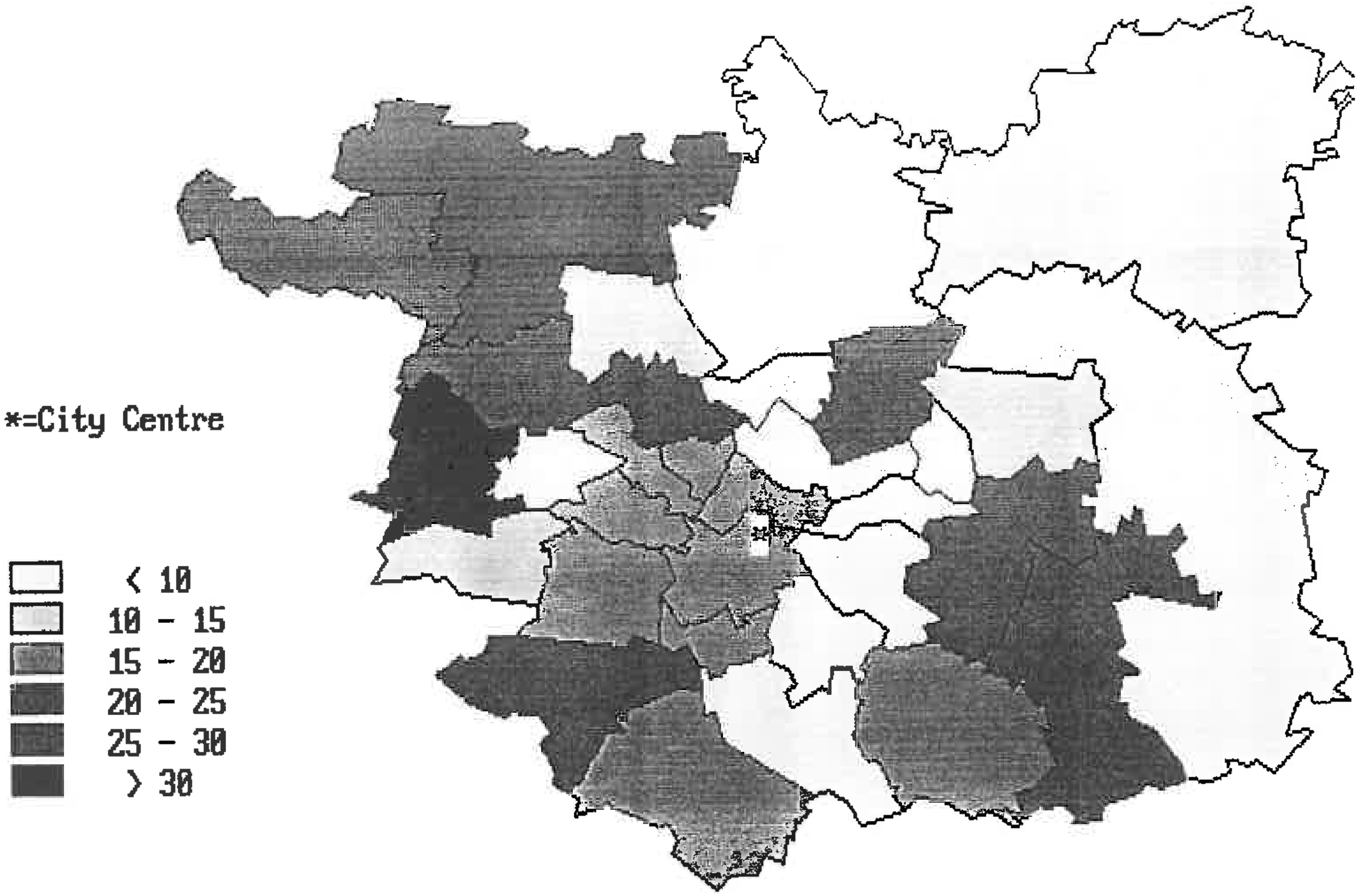

Figure 8a. XL Stores: Baseline market penetration

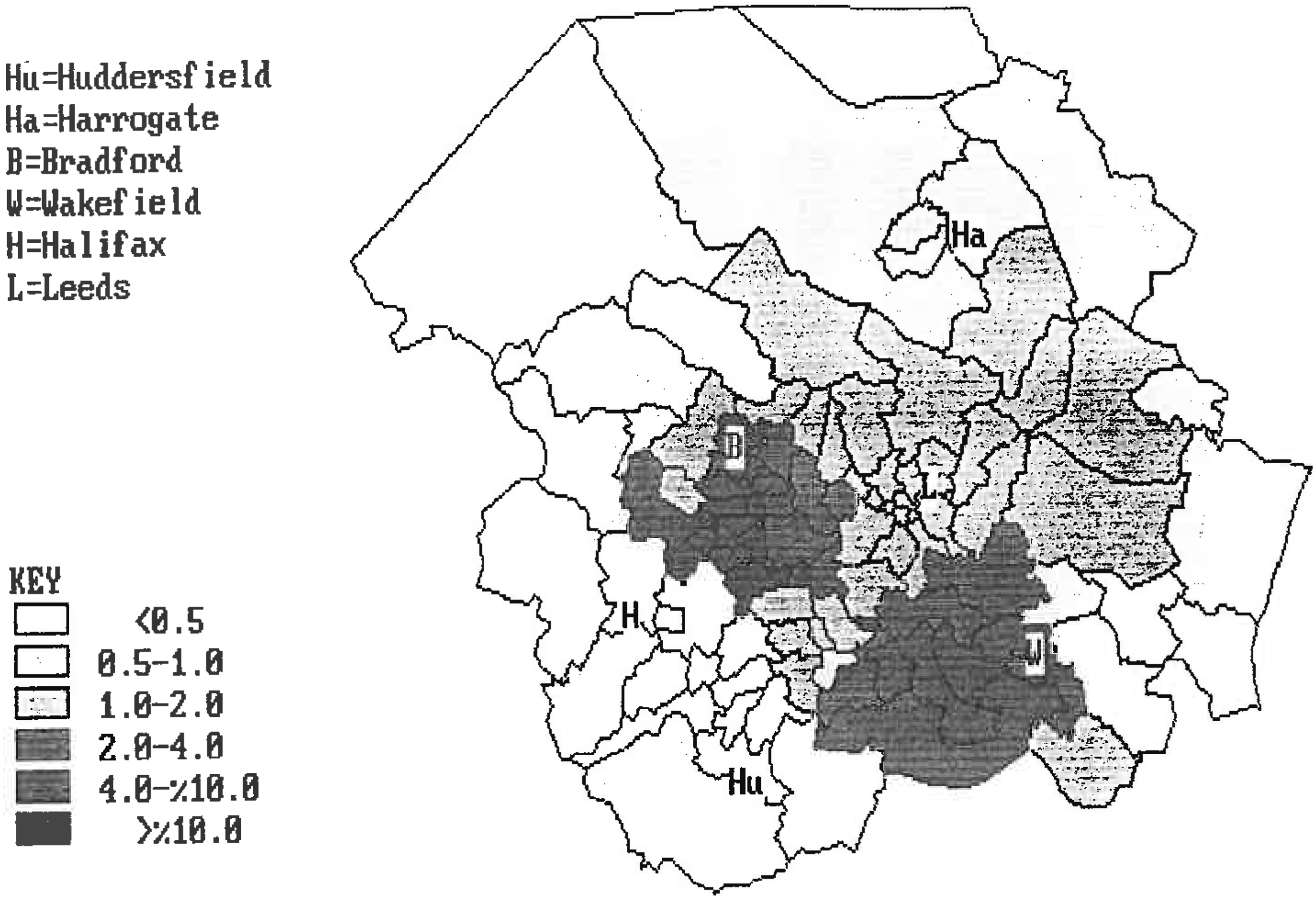

Figure 8b. XL Stores: Market penetration with Morley shop

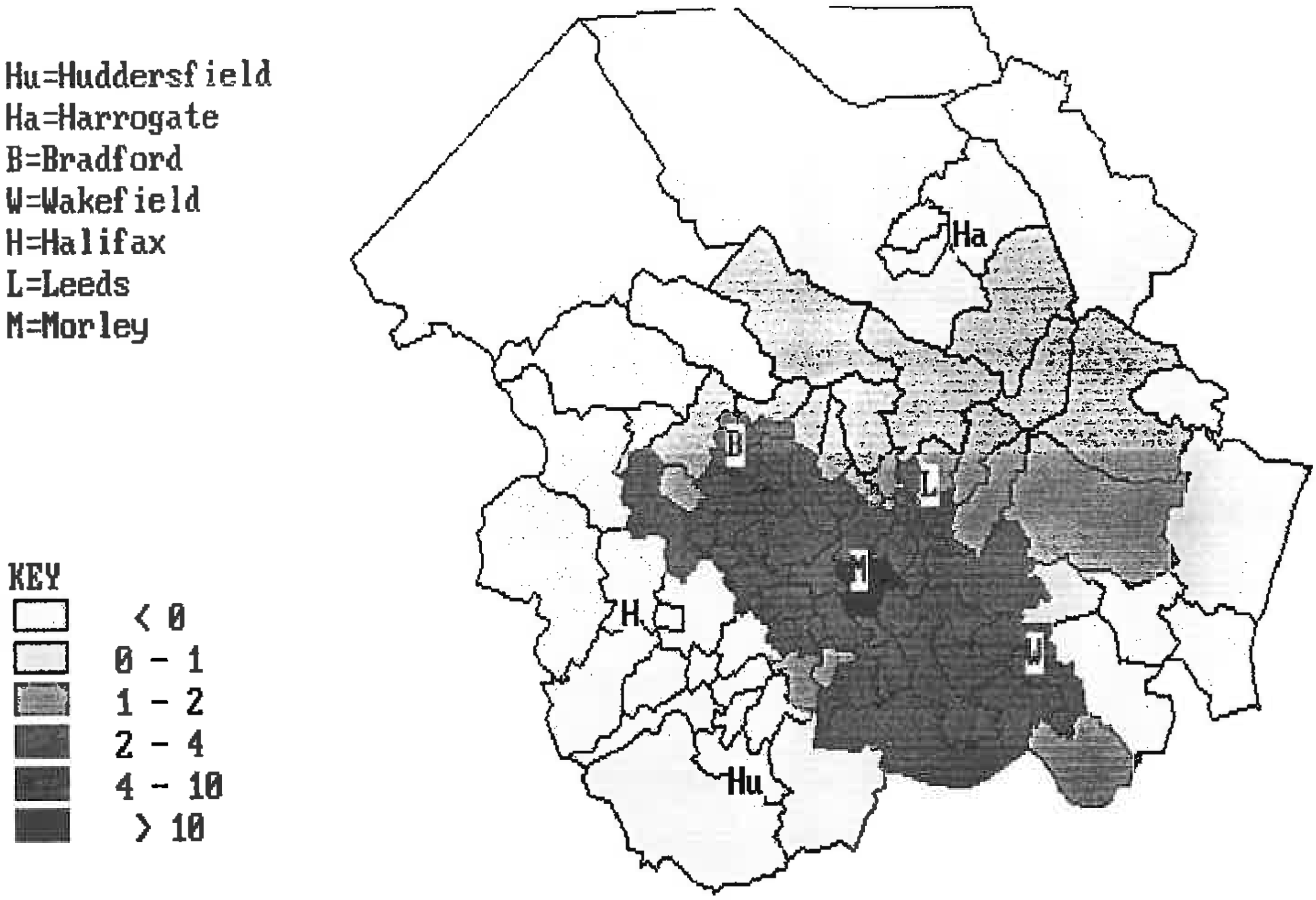

Figure 9a. Average male earnings, Leeds wards, 1981

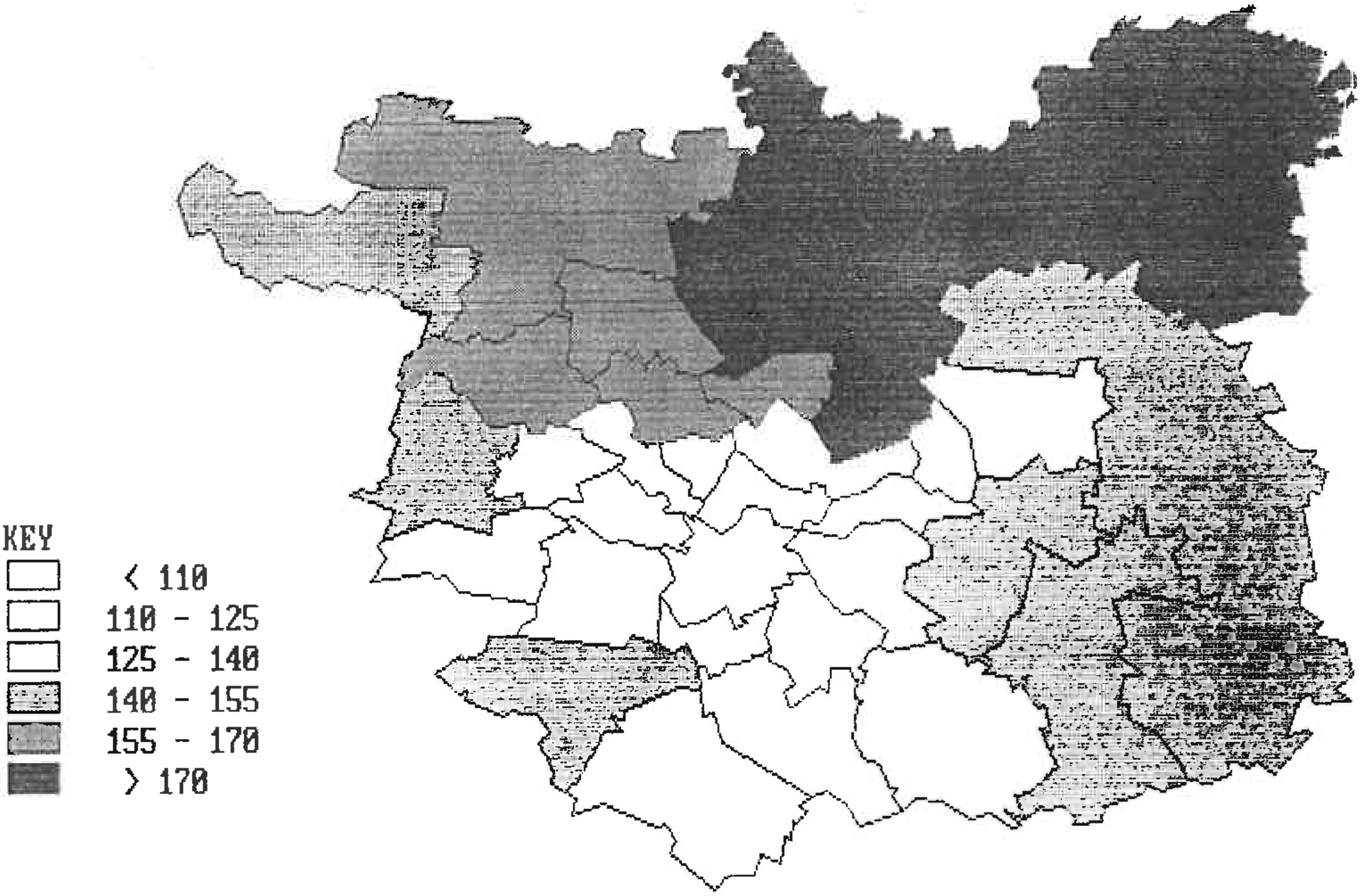

Figure 9b. Average household expenditure on fuel and power, Leeds wards, 1981

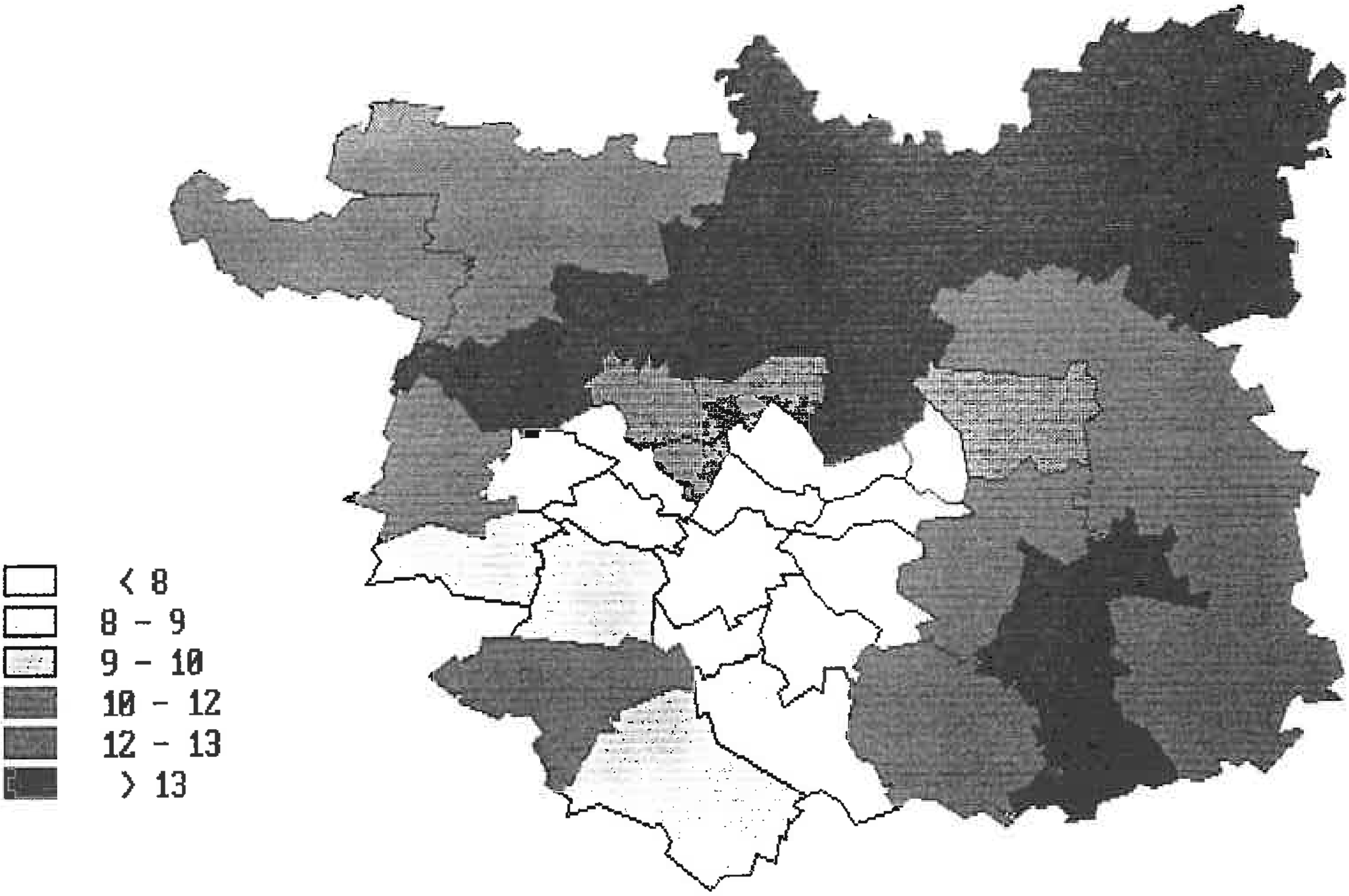

Table 1: Attributes generated in the microsimulation model

Attribute	Number	Details
a) Household attributes		
Location	1565	1 DAAA01 2 DAAA02 ... 1565 DABK47
Household structure and composition	5	1 Single person, retired 2 Single person, not retired 3 Married couple, no children 4 Lone parent family 5 Married couple with children
Tenure	3	1 Owner-occupied 3 Other 2 Council rented
Country of birth of household head	7	1 Great Britain 6 Pakistan 2 Eire 7 Rest of the World 3 New Commonwealth - India 4 New Commonwealth - Caribbean 5 Rest of New Commonwealth
Primary retail location	52	1 Hemsworth 2 Normanton ... 52 Bradford
b) Individual attributes		
Status within household	5	1 Head 2 Spouse of head 3 Child of head 4 Other dependent 5 Other
Exact age	86	0 1 2 ... 85+
Sex	2	1 Male 2 Female
Marital status	3	1 Single 2 Married 3 Widowed/divorced
Economic activity	4	1 Inactive 3 Retired 2 In work 4 Seeking work
Socioeconomic group	7	1 Employers and managers 2 Professional 3 Intermediate non-manual 4 Skilled manual 5 Semi-skilled manual 6 Unskilled manual 7 Other
Industry	7	1 Agriculture 5 Distribution 2 Energy 6 Transport 3 Manufacturing 7 Other 4 Construction
Exact income	1000	0 1 2 ... 999+
Household expenditure by category	8	1 Housing 5 Household 2 Fuel 6 Other goods 3 Food 7 Transport 4 Clothing 8 Services

Table 2: Summary Indicators for the Ten Largest Centres in West Yorkshire

	CENTRE	SQ FT	CENREV	SPF	SCAT	CAT	CATCOMP
1	LEEDS	3075000.	576.0	187.	682	844492.	27.73
2	BRADFORD	1578000.	251.3	159.	752	334168.	25.45
3	HUDDERSFIELD	602000.	85.1	141.	727	116621.	28.33
4	WAKEFIELD	577000.	75.7	131.	761	99518.	25.58
5	HALIFAX	401000.	49.6	124.	670	73653.	24.40
6	KEIGHLEY	307000.	34.4	112.	758	45415.	31.01
7	PONTEFRACT	227000.	20.7	91.	690	30010.	20.14
8	DEWSBURY	215000.	14.0	65.	693	20231.	26.36
9	SKIPTON	224000.	14.5	65.	795	18244.	39.41
10	CASTLEFORD	151000.	10.2	68.	685	14940.	18.97

TABLE 3: Households in the Catchment of the Major Non-food Retail Centres in West Yorkshire

Centre	Catchment Populations		Deflections	
	Without Morley	With Morley	Gross	%
Bradford	334168	161503	8020	2.4
Leeds	844492	266934	17734	2.1
Huddersfield	116621	99022	5831	5.0
Halifax	73653	49677	1399	1.9
Wakefield	99518	77907	23088	23.2
Morley	0	59757	-	

TABLE 4: Performance of Morley with Varying Scales of Development

Size	Turnover	Sales/ft	Catch pop	Sales/head
100000	10000	100	14699	2041
200000	18100	90	26426	2051
300000	24900	83	36297	2058
400000	31700	79	46117	2060
600000	41200	69	59757	2069

TABLE 5: Residential Performance in the Catchment of Morley

Post	Without Morley			With Morley		
Code	Av Dist	Eff Del	Prov Ratio	Av Dist	Eff Del	Prov Ratio
LS27	7.2	2343	20.5	5.5	3300	29.0
LS10	7.0	2443	19.8	6.0	3050	25.8
LS11	5.0	2426	20.5	4.9	2828	23.8
LS12	6.7	2665	24.1	5.6	3148	28.4
BD 4	8.3	1947	18.9	7.6	2312	22.3
BD11	7.2	1423	16.9	6.0	1797	20.7
WF17	7.5	2155	20.5	5.3	2310	26.4
WF 3	6.7	2012	23.8	5.9	2198	25.9