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GEOGRAPHICAL INFORMATION SYSTEMS AND MODEL-BASED LOCATIONAL ANALYSIS: SHIPS IN THE NIGHT OR THE BEGINNINGS OF A RELATIONSHIP?

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1. OBJECTIVES FOR GIS DEVELOPMENT

It is generally agreed that information systems contain raw data and processing, retrieval and presentation capabilities which will transform this into easily-accessible 'useful' information. It is usually argued that what defines something as 'information' is its usefulness in decision-making or planning. Geographical information systems, therefore, should possess these properties in relation to geographical data and information.

It is interesting to note that geographical model builders have long justified themselves in the same way: that their products would be useful in decision-making and planning. For many years, while model-building has obviously enriched academic geography, its usefulness has increasingly, and with justification, been questioned.

A central argument of this paper is that GISs, as conventionally constructed, fail to fulfil their potential. We will show that GIS's and models in geography have largely grown through different cultures and traditions. Both schools have achieved obvious successes, but both have the same kinds of difficulty when it comes to practical application. We believe that model builders are, in part, now beginning to rectify the problems of applicability. As is often the case, this has only been achieved through conceptual and theoretical advances; but also through a more well-defined focus on the real problems of decision-makers and planners (achieved by working directly with them). We wish to argue now that GIS practitioners can learn from the modeller's experience - and indeed through an integration of the two schools, the 'usefulness' problem can be solved. Without such an integration, the GIS school will soon achieve a saturation level of a limited range of application; the modellers will press on, relatively successfully, but without adequate GIS support.

We will also argue that integration involves more than building a connecting interface. For instance, there are types of data which are central to modelling, and particularly to the application of modelling through the concept of performance indicators, which do not figure highly in GIS's: in particular, many kinds of interaction data. On the other hand, a feature of applied modelling is the need to be able to plug into GIS's and to combine data collected in relation to different spatial systems. The skills of the GIS practitioners in developing storage/retrieval and aggregation/disaggregation systems could be crucial here.

In our view, the culture of the GIS community has been too influenced by the technology of remote sensing. This is an important field and there are many valuable applications. But the data banks of this kind, which underpin much GIS development, are not the ones which are most relevant to the locational decision-making and planning tasks of a large percentage of the organisations which make up a modern economy. It is to these needs that modellers have now turned. It also turns out, in proceeding in this way, that modellers can make a substantive contribution to information systems through the calculation of model-enhanced 'data'.

We will pursue all these issues, largely by example, below. First, we attempt to substantiate our case about the overly limited current conception of GIS's through a brief review of the GIS literature and applications (section 2). Secondly, we outline, by example, the developments in modelling and related planning fields, largely within the 1980s, which provide a new focus for modellers and, we argue, potentially for GIS builders also (section 3). Finally, in section 4, we outline some proposals for the beginnings of a programme of integration. We hope that cultural barriers do not totally inhibit such possibilities at the outset.

2.1 Geographic Information Systems: their objectives and methods

We begin this section with a broad definition of an information system due to Lucas (1978, page 5)

> "An information system is a set of organised procedures which, when executed, provides information to support decision-making".

Such a system may be conceived of, in very simple terms, as a set of relationships between seven component parts, as shown in Figure 2.1 (Lucas, 1978, Figure 1.1).

The definition is relatively uncontentious, and we can think of these objectives as shared by those information systems which are peculiarly geographic ie. GIS. In relation to GIS, we would argue that the seven components of Figure 2.1 may be thought of as translating themselves into five kinds of 'elements'. To develop this modified classification, the first two boxes of 'data collection' and 'data' are considered together as a problem of DATA STORAGE AND RETRIEVAL. The third step, of 'processing', we conceive of as a problem of LINKAGE between data sets. As far as 'outputs' are concerned, we will be mostly concerned with the GRAPHICS capabilities of GIS, while the PRODUCTION OF INFORMATION retains its existing meaning. Finally, to inform the user it will be necessary to adopt some kind of ANALYSIS of the previous steps. The objective of the whole procedure is to assist the 'decision' at step seven, as implied in the definition above.

Sections 2.2-2.6 of the paper are then an attempt to present examples of the way in which these five kinds of element are represented within existing GIS. The purpose of the section is to fix ideas, but we will also argue that, in relation to socio-economic systems, a lot more work is needed in certain of these areas. Subsequent sections will attempt to spell out the requirements in more detail. In particular, we will suggest that the potential analytical capability of existing systems is undervalued. This sets the scene for section 3, where some features of a set of models which could be used to expand this analytical capability is outlined. In section 4, we consider the means of integrating such techniques within the umbrella of GIS.

2.2 Data storage and retrieval

An important requirement of any GIS is the ability to store a large volume of different data types at a variety of spatial scales and levels of resolution. This is particularly important in many of the land-use planning systems which incorporates data on a wide variety of physical and environmental attributes. A number of examples serve as illustration. The CORINE/ARC-INFO system described by Green et al (1985) and Wiggins et al (1987), is based on data collected throughout the EEC (in text, vector and raster form) on soils, climate, topology and biotopes, combined to produce a comprehensive database for land-use planning inquiries. Similarly, the Maryland Automated Geographical Information System (MAGI) (described in

Marble et al, 1984) contains a mass of physical, cultural and areal data for state planning in Maryland.

Examples of GIS storage capabilities, aside from land-use planning studies, would also include a number of impressive programmes in the field of economic and social geography. The DOMESDAY project includes most office statistics about Britain (including the Census of Population), a national land-use survey, over 22,000 maps and 40,000 photographs (see Goddard and Armstrong, 1986, Openshaw et al 1986). Another well-known package is the Manpower Services Commission's National Online Information System (NOMIS), which is designed to provide employment, unemployment and vacancy data (primarily) for the whole of Britain, at a wider range of spatial scales (see Townsend et al 1987).

The kinds of spatial data models which underpin GIS are typically either vector (especially in cartographic GIS), raster (especially in remote sensing applications) and quadtree (now especially common in land-use studies). The latter is becoming increasingly popular as a device for increasing the efficiency of data storage and retrieval (Peuguet 1984, Hogg et al 1986).

2.3 Graphics

As in the area of data storage, GIS systems have made impressive strides in the field of data OUTPUT, particularly computer mapping applications. Rhind (1980) makes the observation that the first batch of GIS were often no more than computer mapping procedures, producing many standard mapping packages. Today, there is great emphasis on the role of INTERACTIVE graphics within an overall interactive GIS. Douglas (1982) and Babin et al (1982) explain how the interactive framework helps to operationalise the system without the user needing to 'translate from the world of computer simulation', whilst the mapping facilities help to continually 'humanise' the results of computer analyses and aid the process of pattern recognition.

The expanding field of computer cartography has also allowed GIS users to be more ambitious in terms of the range of presentations. The idea of 'computer movies' in GIS first found fashion in Tobler (1970), whilst Calkins (1984) provides a more recent example of dynamic simulation through computer graphics.

We would hope that it is not too contentious to argue that the main achievements within GIS have persistently come within the domains of data storage and retrieval; and graphic display. It seems that the GIS community has striven successfully to keep abreast of advances in the technology of computation to maximise the efficiency of data handling and presentation within their systems. Furthermore, it is important to state explicitly that these are the kinds of problem which have often been treated most superficially by large sections of the modelling fraternity.

2.4 Linkage of data sets

The main driving mechanism of any GIS is the ability to interrelate data sets. Sant (1982) emphasises

> "Without doubt the transformation matrix is the engine-room of an information system. It is here that the inputs, which mean little by themselves, are interrelated with each other in order to distil the essential picture that is necessary for decision making". (p 88)

In many cases, the primary focus of this manipulation stage is the idea of OVERLAY: of the combining of different maps (or data sets) to help to identify any area having the necessary qualities for 'development' in some way. The best illustrations of the overlay procedure can again be found in the land-use planning literature. Hogg et al (1986) query their information system to identify areas most suitable for 'agriculture': in effect, where regions of brown earth soils, land under 800 feet, areas of grit geology and free drainage coincide. Cowen et al (1983) provide a 27-layer data file for the purpose of minimising land-use conflicts of new route development in Georgetown South (USA), evaluation products which would be 'inconceivable' to generate manually (Cowen et al 1983, p 48). Similarily, Dangermond (1983) uses the overlay procedure for selecting new town sites in Southern California, combining large regional data-bases on a variety of physical and cultural attributes.

In socio-economic systems, as in land-use planning and physical systems, this ability to link data sets is (potentially) crucial (cf Openshaw, 1987). There are two additional problems which need to be considered here, however. One is the so-called 'aggregation problem' which, in this context, implies that rasterisation of socio-economic data bases may be a highly non-trivial problem. The second aspect we can think of as 'functional linkage', which means that the methods may exist to predict the kinds of attribute which are only available at coarse levels of spatial resolution, which are better than simple overlays. Such methods would exploit the functional interrelationships between these variables and others whose distributions are known at finer scales. Suppose, for example, we are interested in the pattern of household incomes across a region. Typically, information will be available at a high level of sectoral detail (in the UK, from the New Earnings Survey) ie. we know income by occupation, by age, by industry and so on, but this data is only presented at a very coarse spatial scale (the Standard Region). It is clear that variations within the regions will tend to be much greater than the variations between them, and it may be possible to pick up much of this heterogeneity by linking income to characteristics like occupation, age and industry, which are available at much finer levels of spatial resolution. This kind of integration may be achieved by the use of synthetic data generation procedures. An example of the approach is presented in section 3.

2.5 Production of information

The fourth kind of GIS element which concerns us is the transformation of data to information. One powerful aspect of this conversion is the use of data-bases in conjunction with spatial data handling procedures to produce maps of various distributions. The ability to store and retrieve efficiently extremely large data bases, and the ability to summarise this data by means of either the hard-copy or virtual map, is obviously a powerful attribute of GIS upon which we have already commented.

Of course, typical capabilities will often extend far beyond this, with the capacity to store a number of maps in parallel, and to window in, overlay, and relate these individual maps to one another. However, the need to extract information from spatial data bases goes far beyond these kinds of mapping procedure, invaluable though they are. In relation to socio-economic systems, we would argue that planning, in either the public or private sectors, requires certain kinds of skills not exhibited by existing GIS, including the ability to transform and inter-relate data in complex ways ('modelling') and thus produce the kinds of indicator of greater value to decision-makers. Furthermore, the update of information to maximise its contemporary relevance is highly desirable. Again, we demonstrate the ability of existing model-based approaches to achieve these kinds of objective in section 3.

2.6 Analysis

Despite the usefulness of the overlay procedure in matching suitable areas of development, it does seem that the amount of statistical or mathematical manipulation of data is very limited in many GIS systems. We wish to argue that what is involved here is partly an imbalance in emphasis, and partly a failure to take on board the kinds of powerful modelling procedure to be discussed in the next section.

One of the dominant analytical activities within GIS has been 'screening', where pertinent spatial characteristics may be overlaid on one another to reduce the set of locations possessing some desirable feature. This process is taken a step further when different weights are attached to different features in the overlay, to derive a gross index of the suitability of different zones for a particular use (Dangermond, 1983). Often this kind of work is undertaken with the objective of obtaining a reduction in the possibility set for some development, on the understanding that final evaluation will take place at ground level. This is the conventional wisdom in the UK with respect to hazardous installations, for instance, when a small number of sites are usually preselected for detailed analysis, following which a decision is taken.

With socio-economic systems we believe it is both possible and necessary to go further than this in the analysis phase. For facility location planning, we may wish to ask: what is the best site, or combination of sites, for future developments? Secondly, can we quantify the impacts of such developments on existing facilities or their users? In section 3 we will discuss a more appropriate set of methods which allow the solution to such problems, and present examples of their use. It appears to us that existing attempts within GIS to cope with issues such as these may be either excessively naive, or not properly integrated within the GIS framework to which they relate. Certain exemptions to this criticism apply in relation to transport simulation planning, which has generally seen the most impressive integration so far of more anlytical methods within a GIS-type framework. For example, the study of la Barra et al (1984) includes not only the ability to store and retrieve large volumes of data (on a macro or micro computer) but also a full suite of calibration programmes, transport and land-use simulation models, impact analyses and evaluation programmes. The potential for integrating model-based systems within conventional GIS frameworks is also recognised by Dangermond (1983), but no practical illustration is offered. Finally, we recognise the significance of attempts to construct information systems around the alternative principle of 'multi-criteria analysis', which aims to evaluate wide-ranging planning objectives from the perspective of conflicting interest groups (eg. Hinloopen and Nijkamp, 1984, Nijkamp and van Delft, 1977, Voogd, 1983). Useful though this may be, it remains necessary to combine it with model-based analytical capabilities.

2.7 Summary

The emphasis in our discussion has been largely on the role of GIS within the kinds of socio-economic system with which we are most familiar. It is probably fair to argue more generally, however, that GIS developments will fail to realise their true potential if their basic role within the decision-making process is inadequately specified. Calkins (1983), for example, argues that

> "the often heard goal/objective of 'supporting decision makers' is inadequate in that it fails to identify how decision-makers would be supported and it does not provide information for any kind of

performance evaluation".

In relation to social and economic planning, the kinds of extension discussed above, in relation to linkage, production of information, and analysis, will probably be necessary to provide adequate tools to assist the takers of decisions. Our next step is therefore to examine in more detail the specific issues in this section concerning such possibilities. The possibilities for an integration of approaches is explored in section 4.

3. CONTRIBUTION OF MODEL BASED ANALYSIS TO GIS METHODS AND EXAMPLES

3.1 Introduction

We have described the main requirements of potential GIS users in the socio-economic arena and have suggested that, as currently perceived, GIS may fulfill only a limited number of these requirements. In this and the subsequent section, we outline how a marriage between model based methods and techniques from GIS can potentially result in a powerful analytic system that meets the requirements of potential users. We illustrate our argument with a range of examples taken from both the public and private sectors. In this section, we ask what types of roles models can perform and how these roles relate to tasks that would enhance a typical GIS.

3.2 Transformation of data

A basic role of models is to provide a framework within which data can be manipulated and transformed. This normally takes the form of simple arithmetical operations that take different items of data and produce information. This is best illustrated by a number of examples. Let us assume that a motor manufacturer has details of sales of his vehicles by postal district and the total sales of all vehicles in each district.

These two items of data can be transformed into an interesting item of information, market penetration by postal district, by dividing manufacturer's sales by total sales. Figure 3.1 represents market penetration by postal district for one Japanese importer in part of southern England. We have plotted on this map the location of this manufacturer's dealerships and a particularly striking feature of this is the very close correlation of market penetration to dealer location.

A more detailed approach to data transformation arises through the comprehensive use of a system of spatial performance indicators. For many services provided, both publicly and privately, two fundamentally different types of performance indicator can be developed. The first can be termed facility based and relates to the efficiency and effectiveness of the outlet in relation to its catchment population. Catchment populations can be considered as the notional number of individuals that a facility is serving irrespective of where these people live. It can be calculated in a number of different ways from spatial interaction data. Once calculated it can be used as the denominator in calculating performance indicators such as the facility expenditure per head of catchment population. The second type of PI focuses on residential districts. Here a typical calculation may involve the notional number of hospital beds supplied to the residents of district i. Through the use of a battery of performance indicators a good picture of service supply and utilisation can be built up. Two examples will help make this point.

Figure 3.2 presents the results of a project in East Yorkshire Health Authority aimed at assessing the current relationship between service supply and utilisation and examining the impacts of proposed changes in supply. In this figure we give, for each residential area in the authority, the hospitalisation rate for Trauma and Orthopaedics, the notional beds/head of population and the average distance travelled to receive treatment. The most striking relationship here is that between hospitalisation rate and average distance travelled, the former inversely related to the latter. Figure 3.3, derived from a study of the location and performance of licensed premises in North Humberside, presents the notional amount of licensed premise floorspace available to the residents of different postal sectors. This could indicate areas of low provision and thereby potential opportunities for new developments.

In our experience this type of model-based data transformation and spatial representation of performance indicators is of enormous value to many managers and planners in that it lets them see data and information in a way they are not accustomed to. Importantly, it provides a starting point for the application of more sophisticated methods in later stages of work.

3.3 Synthesis and integration of data

One of the main points emerging from the Chorley Report is the extent to which data is collected and assembled at different levels of spatial resolution using different categories to classify variables, such as age, social status, and so on. For many variables, such as income, information is not collected at anything like the required level of spatial disaggregation to make it useful. In these cases models can be employed to useful effect - linking and merging data files and making best estimates of missing information. Traditionally, methods such as entropy maximising have been used to estimate variables at the aggregate level. A new way of achieving the same effect but typically incorporating much more detail and a larger number of variables is through microsimulation where households and constituent individuals are recreated from different types of data sets (Census, FES, NOMIS, etc.) and specified at the highest available level of spatial resolution, the enumeration district. These households and individuals can then be readily aggregated to provide cross tabulations of any relevant variables at any upwardly compatible spatial scale. The methodology is underpinned by a procedure known as Iterative Proportional Fitting - (Feinberg, 1970). A system named SYNTHESIS (Birkin and Clarke, 1987) has been developed and tested for West Yorkshire and indicates tremendous potential applications of the methodology.

An example of the application of SYNTHESIS is given in Figure 3.4 where we plot the distribution of households with three or more residents without any income derived from earned sources. This tabulation is not available from any published source.

Finally in this section, we should mention the contribution of data compression methods such as principal components analysis in converting large amounts of data about spatial units into a much smaller number of factors which can be afforded interpretation. Commercially available systems such as ACORN, PIN, SUPERPROFILE and MOSAIC have been used extensively in the commercial sector.

3.4 Updating information

Another clear deficiency of most data sets, particularly the Census, is that they are out of date. How much of a problem this poses will vary according to the context of a particular study. In many cases it will be a serious problem - for example, a good deal of concern is being expressed by the commercial users of the profiling systems mentioned above. Some postal sectors in Milton Keynes, for example, have no households present in the

1981 Census but several hundred addresses on the Post Office Address File (PAF). Since 1981 we have witnessed increasing unemployment, council house sales, counterurbanisation trends and so on. Information is collected on these trends, mainly indirectly, through electoral registers, PAF, and so on, and sometimes directly through, for example, NOMIS, but at a coarse spatial scale. Methods for linking these data sets along with transition rate data generated by OPCS for births, deaths, marriage and so, to allow for an updating of census and related information is clearly an important task. Methods for population updating at fairly coarse spatial scales have been available for a long time (Rees and Wilson, 1977) but techniques that allow for the updating of both household and individual attributes, extending beyond age and sex categories, are in their infancy. Again micro-simulation methods offer much promise and the shell of a systematic micro-level updating procedure has been constructed on an ESRC project (Rees, Clarke and Duley, 1987). Table 3.1 is taken from an earlier study (Clarke, 1986) where the updating was achieved for Yorkshire and Humberside and shows the change in the number of persons per household over the period 1974/5 to model estimates for 1986.

3.5 Forecasting

While updating takes us from the past to the present, an important requirement is to examine how change may take place in the future. This is important in a number of contexts. For example, health, social services and education authorities need not only to know what the future structure of the population is likely to be but also to have a reasonably clear indication of the way this structure varies across space. The same requirement applies in other sectors, such as retailing and financial services.

Any type of forecasting will be model based, even if it is only trend extrapolation. The most well developed methods such as econometrics have paid little attention to spatial analysis, partly through the lack of appropriately referenced data sets. Many of the same methods used in updating can be applied to forecasting, particularly in the demographic area.

3.6 Impact analysis

One of the most popular application areas for spatial modelling has been in assessing the impacts of new plans or proposals on the existing situation. This 'what if' simulation has proved valuable in a number of areas in both public and private sectors. We use an example from each to illustrate the argument.

The development and location of new retailing outlets involves large capital investments. It is therefore appropriate to attempt to estimate the likely revenue that will accrue to a new outlet and to estimate the impact that the outlet will have on existing stores. Spatial interaction modelling is ideally suited to this problem. A study area is divided into a set of residential zones, say postal sectors, and all centres and outlets are identified. The model is calibrated on existing flow data after which the new outlet is introduced and its impact assessed. Although these models have been around for 25 years, only recently as better spatial data became available has their full potential been realised. Again this emphasises the strengths that can arise from an integration of data systems and models. As an illustration we have modelled the impact of a new superstore opening in part of Leeds. Its revenue estimate and an articulation of which areas this revenue is being generated is shown in

Figure 3.5. Modelling can also address scenario testing - we would suggest on the basis of this revenue estimate a smaller store in the vicinity would be forced to close. This can be represented in the model and the results of this are shown in Figure 3.6.

In health care planning a similar approach can be developed for the analysis of new hospital development.

3.7 Optimisation

One of the uses that is commonly made of a GIS is to find locations in a region where several criteria are met, such as say flat land, near a motorway access point and with a population catchment greater than 100,000. A great deal of effort has been applied to generating software for solving this type of problem. In spatial modelling the problem has been addressed from a different approach, that of <u>optimisation</u> (Wilson et al, 1981).

Optimisation methods such as linear programming, attempt to find the best solution to a stated problem subject to a number of constraints being satisfied. They first appeared in the geographical literature through methods such as the travelling salesman problem and location-allocation modelling. Nowadays a much larger class of methods exist, particularly in the non-linear programming area. The great advantage of these methods over GIS systems is the way in which they can handle spatial interaction, for example, in site location problems they can consider a particular solution (say, 50 particular sites chosen from 500 possible ones) and calculate catchment populations and potential revenues very easily. Where existing GIS can help is possibly in identifying local sites. Certainly a marriage of methods will prove invaluable.

3.8 Model based analysis and GIS - the power of integration

We have presented illustrations in this section which show how models can contribute towards the analysis of location problems. We have argued that the link should be made between currently conceived GIS and state-of-the-art spatial modelling. We believe that model based analysis provides the central focus for GIS in the social sciences (it may also be true in the physical sciences) that will enable them to provide the types of information that prospective users require.

4 The feasibility of integration

A number of crucial points have emerged from the argument:

(1) GIS development is crucial for the storage, manipulation and presentation of much geographic data.

(2) Model development is crucial for generating more useful information in a variety of decision-making and planning contexts.

The two approaches, because of differing personnel and histories, have barely come together - though we have found one example (la Bavra et al, 1984) which demonstrates the feasibility of integration in practical rather than merely conceptual terms. To achieve further progress, a number of steps need to be taken:

(1) GIS builders need to recognise the lumpiness and aggregation complexities of socio-economic-geographic data. The appropriate base for such data is not necessarily a grid or roster, though GISs now exist which can cope with this.

(2) A more serious problem is the need to develop the capability within GIS for handling interaction data. La Barra et al obviously solved this problem, but it does not seem to be a common feature.

(3) More generally, GIS software would be much more powerful if it could

be seen as a modelling 'shell'. In other words, it would be more useful if it was possible for the user to add modelling software to the system directly.

(4) If (3) is difficult to achieve, then an alternative is to develop easy-to-use interfaces to connect GISs and models.

(5) Model builders must gain experience of integration with GIS.

On the balance of the evidence, all the technical expertise is available to achieve these objectives. The difficulties are either cultural or practical - different people, different software and hardware systems: it is too much trouble, in an environment of limited resources, to force things together. In the longer run, this situation is bound to change. As an example, we as modellers now feel a strong need for an appropriate linked GIS and we are actively seeking such a system. Others will follow suit and barriers will be broken down. Perhaps what has to be argued is that this process could be accelerated, for the benefit of both fields, if cooperative demonstration projects were funded in the short run. The objective of 'usefulness to decision-makers' would be demonstrably achieved and funding for the whole field might expand more rapidly.

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Figure 2.1 The Components of an Information System

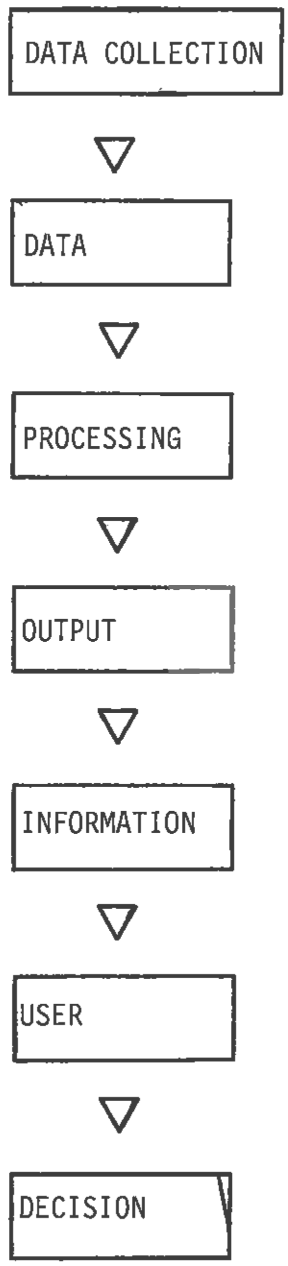


Figure 3.1

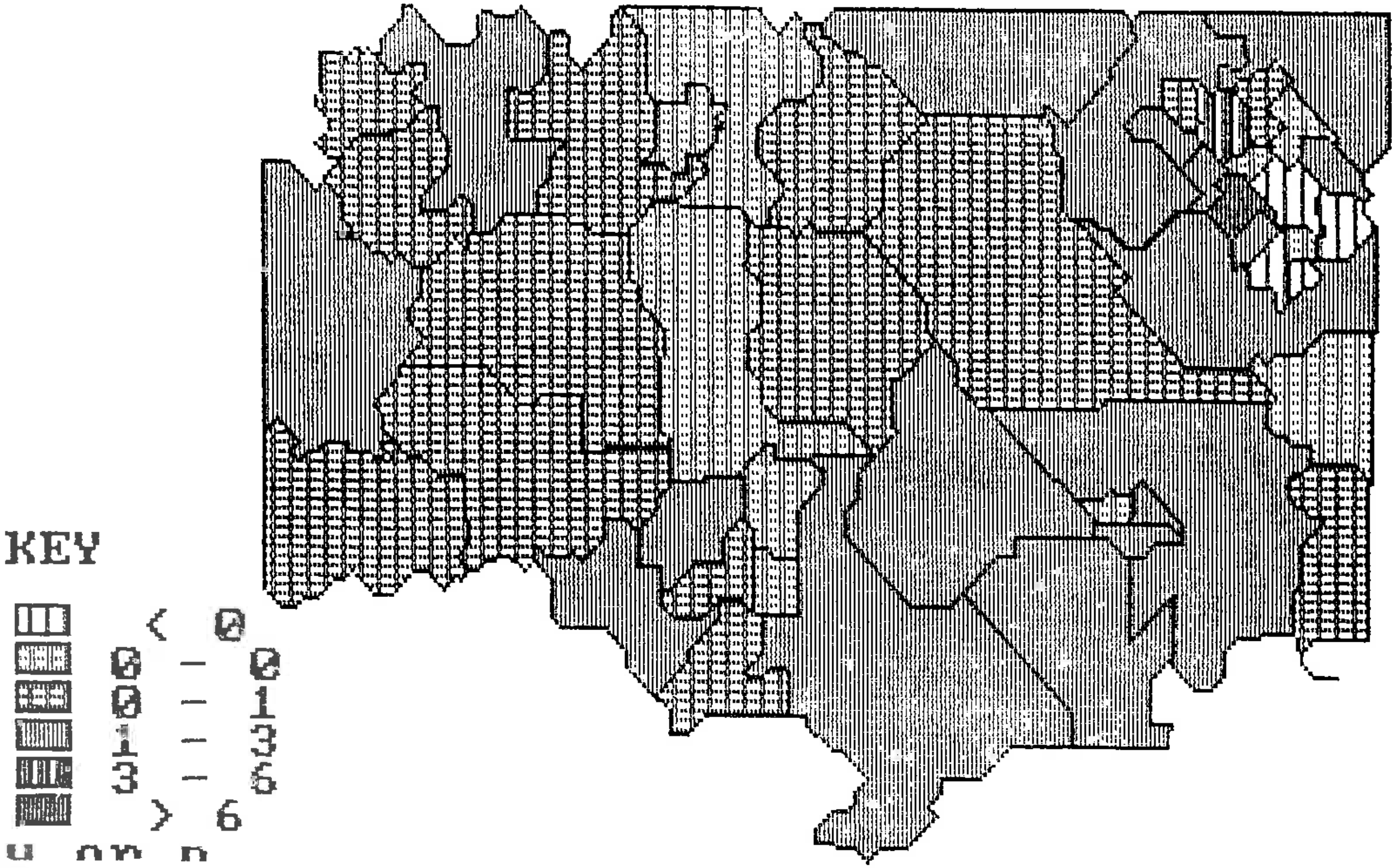
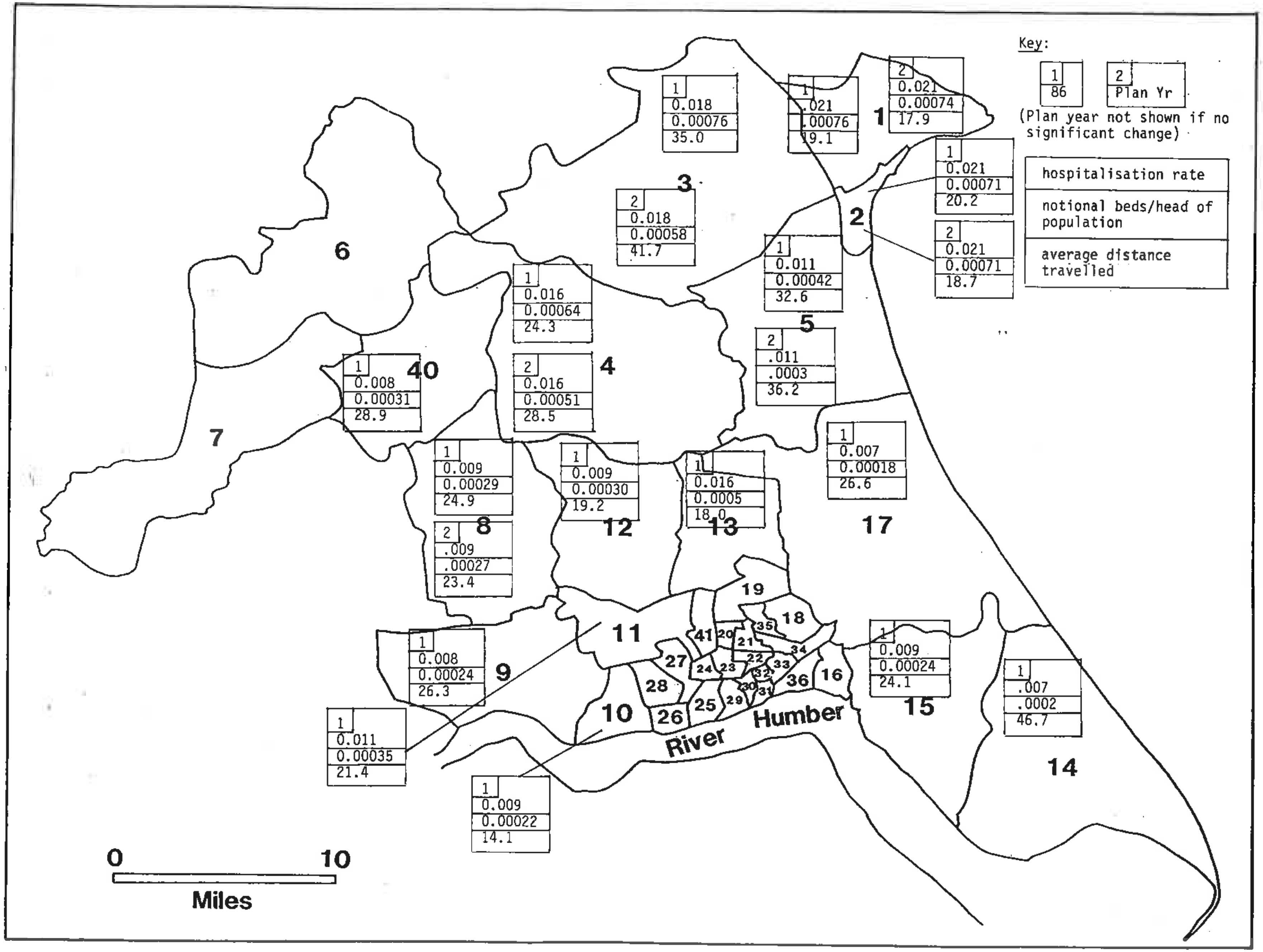


Figure 3.2



Key:
1
86
2
Plan Yr
(Plan year not shown if no significant change)
hospitalisation rate
notional beds/head of population
average distance travelled
1
2
0.021
0.00074
17.9
1
.021
.00076
19.1
1
0.021
0.00071
20.2
2
0.021
0.00071
18.7
2
3
1
0.018
0.00076
35.0
2
0.018
0.00058
41.7
4
1
0.016
0.00064
24.3
2
0.016
0.00051
28.5
5
1
0.011
0.00042
32.6
2
.011
.0003
36.2
6
7
40
1
0.008
0.00031
28.9
8
1
0.009
0.00029
24.9
2
.009
.00027
23.4
9
1
0.008
0.00024
26.3
11
1
0.011
0.00035
21.4
10
1
0.009
0.00022
14.1
12
1
0.009
0.00030
19.2
13
1
0.016
0.0005
18.0
17
1
0.007
0.00018
26.6
15
1
0.009
0.00024
24.1
14
1
.007
.0002
46.7
16
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
41
River Humber
0
10
Miles

Figure 3.3

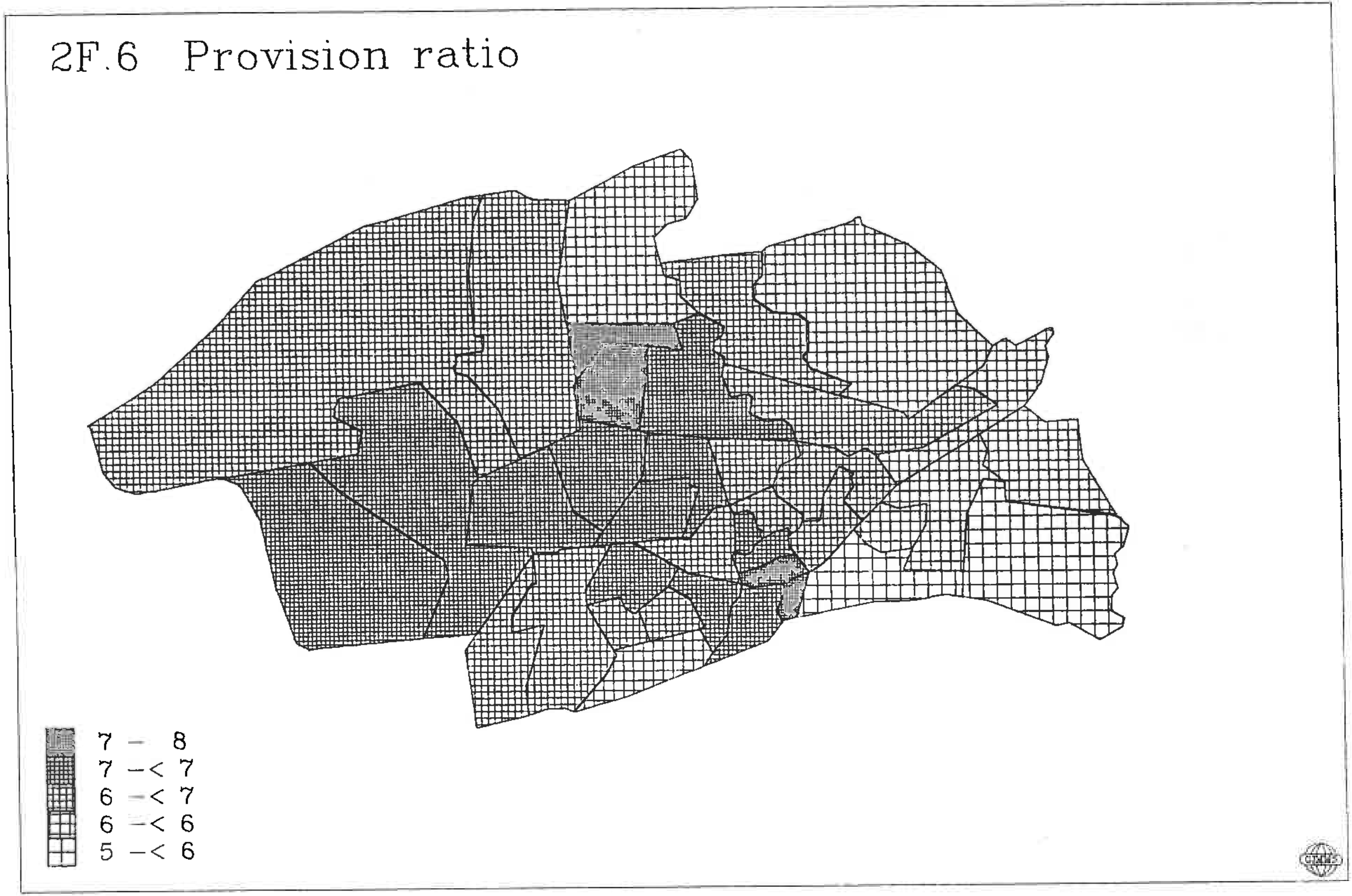


Figure 3.5

Table 10.10 Household type, Yorkshire and Humberside, 1974–5 and 1986.

Household type	Percentages 1974–5	1986
one man, one woman	21.0	23.7
one adult, one child	1.1	1.2
one adult, two + children	1.6	1.9
two adults	29.6	31.7
one man, one woman, one child	11.4	10.4
one man, one woman, two children	14.1	13.8
one man, one woman, three children	5.0	4.6
two adults, four + children	2.8	2.2
three adults	5.9	5.1
three adults plus children	4.9	3.9
four or more adults	1.2	0.9
four or more adults plus children	1.5	0.6
all other households without children	0.0	0.0
all other households with children	0.0	0.0

Source: model runs.

FLOWS OF REVENUE TO NEW HILLARDS FROM SURROUNDING AREAS

TOTAL SALES £328,000 PER WEEK

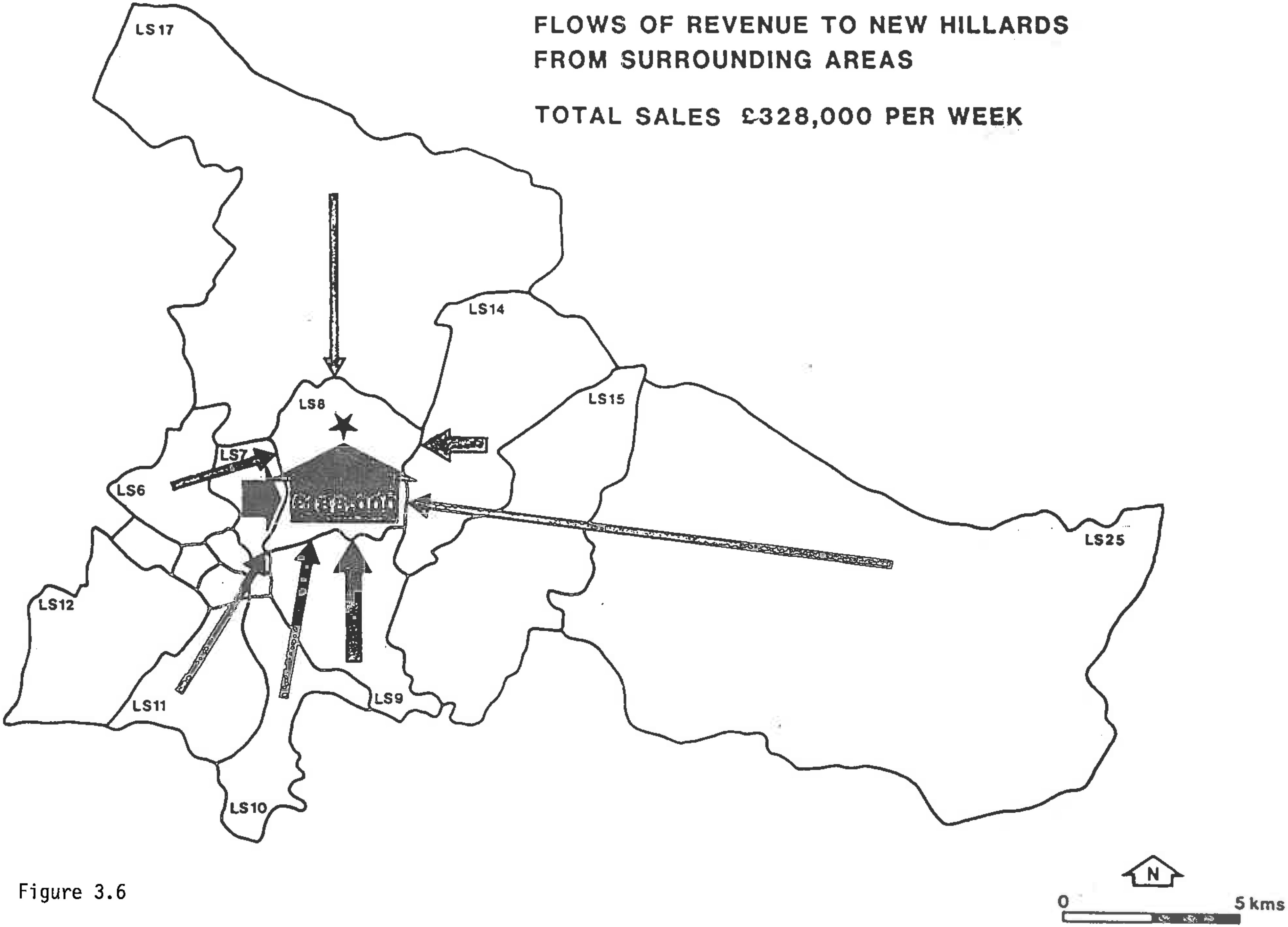


Figure 3.6

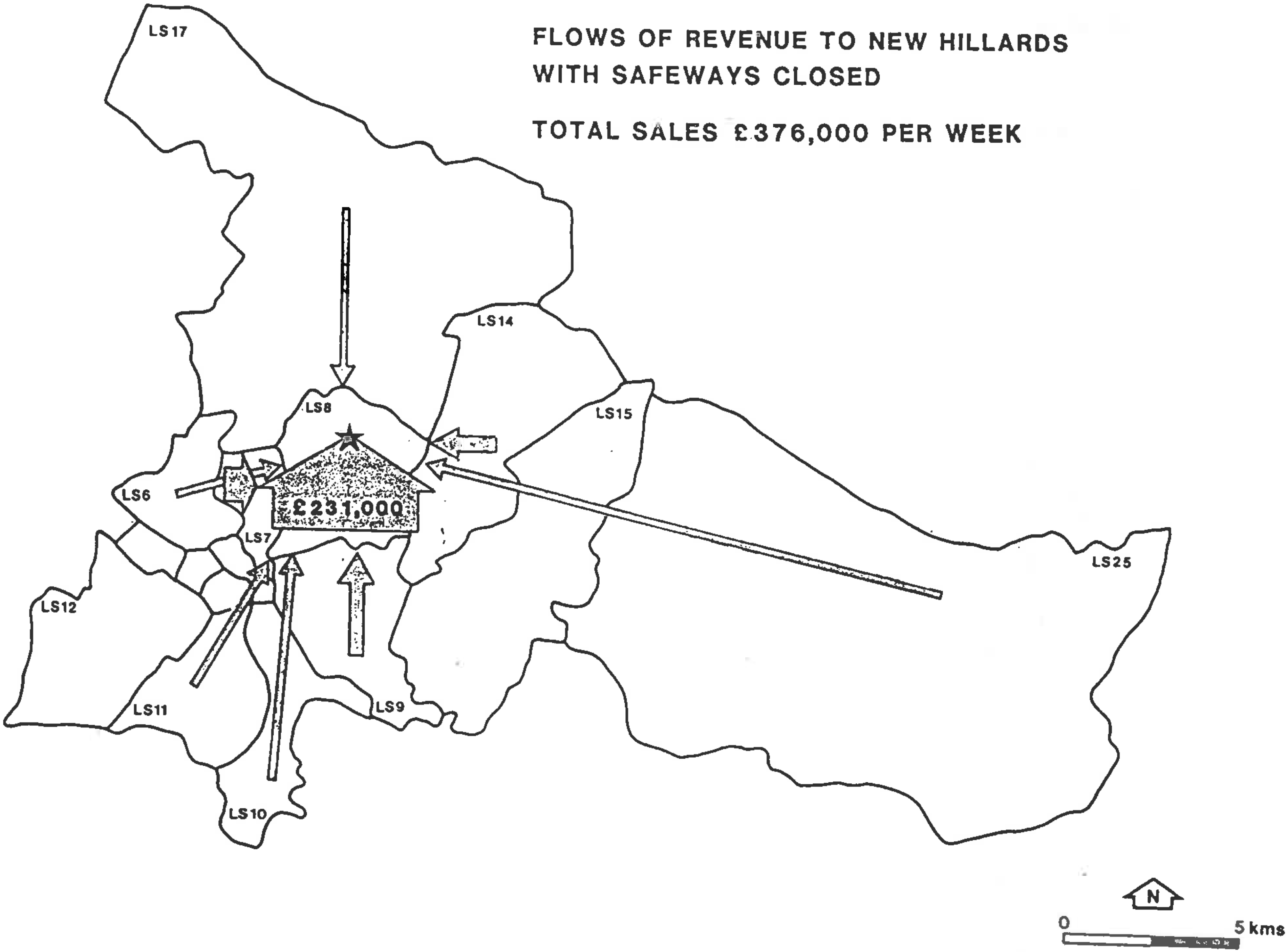

FLOWS OF REVENUE TO NEW HILLARDS
WITH SAFEWAYS CLOSED
TOTAL SALES £376,000 PER WEEK
LS17
LS14
LS15
LS8
LS6
£231,000
LS7
LS12
LS11
LS9
LS10
LS25
N
0
5 kms

Figure 3.7