THE POTENTIAL OF GIS AND SPATIAL MODELLING FOR PLANNING IN THE NEW EDUCATION MARKET

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WORKING PAPER 95/10

SCHOOL OF GEOGRAPHY • UNIVERSITY OF LEEDS

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Abstract

The aim of this paper is to evaluate the potential for the application of GIS and spatial modelling techniques in the context of educational planning. It is our contention that such techniques can be particularly effective given the recent changes in the education policy framework; namely the development of a market system to replace the previous producer-led planning environment. We argue that GIS-based techniques can offer only a partial solution to the manifold problems facing educationalists, and that we must look to more advanced spatial analysis tools such as spatial interaction modelling. The paper concludes that a combination of these techniques offers a powerful tool for planners increasingly concerned with questions of the equity of provision.

We would like to acknowledge the assistance of Leeds City Council Education Department for making available much of the data used in this paper.

1. Introduction

The UK has witnessed radical changes in education since the introduction of the 1988 Education Reform Act and the subsequent arrival of a market system where schools now 'compete' for pupils. The traditional roles of local education authorities (LEAs) as planners and policy-makers are threatened as fixed catchment areas are phased out and parents choose the school for their child according to personal preferences. Such an environment of school competition will undoubtedly produce winners and losers, as some schools will inevitably be seen to out-perform their rivals. The winners will be those schools perceived to be performing well, and hence increasing their attractiveness to parents, and the losers will be those schools with poor performance indicators relating to exam success, truancy rates and so on. There is also likely to be a spatial dimension to this success/failure (as we shall argue in depth in section 3). This is because there is a well-known correlation between educational attainment and the residential/social background of pupils (Bradford 1991, Mortimore and Blackstone 1983, Rogers 1986). Thus it is likely that the best performing schools (as measured by exam success) will be in more affluent, suburban locations. The pressure for places at schools in these areas will grow, leaving inner-city and suburban estate schools to 'mop-up' those who are unable to exercise choice (for reasons of cost, transport availability, knowledge constraints *etc.*). We have already seen evidence of this in Scotland, where the market reforms occurred earlier (Adler *et al* 1989, Willms and Echols 1992). It is important to predict and monitor these changes as well as help schools faced with falling rolls to become more attractive in the market. This may be possible through new marketing techniques such as school specialisation and advertising or by the introduction of new performance indicators which might soften 'hard' indicators based on exam success alone.

Given the presence of these sorts of geographical concern in the new market situation there has been an increased interest regarding the potential role of geographical information systems (GIS) in addressing some of the planning issues inevitably raised by the changes. GIS has to date had varying degrees of success in local authority applications. There is evidence of increased efficiency (see Swainston 1993) but also of 'underachievement' in terms of effecting policy change (Worrall 1990, Campbell

1994). Part of the difficulty has been related to the level of analysis present in many proprietary GIS packages. This argument is explored in detail elsewhere (Longley and Clarke 1995, Birkin *et al* 1995), but centres on the contention that GIS should look to marry its obvious advantages of data storage, visualisation and overlay with the added analytical power of traditional spatial modelling. The product of the link between GIS and models, intended to provide more flexible information systems, has been labelled as 'intelligent GIS' by Birkin *et al* (1995), or more generally as 'spatial decision support systems' (SDSS) by Densham (1991) and Densham and Rushton (1988).

The aim of this paper is to explore the potential of such a marriage between model-based methods and GIS for a market era in education. In section 2 we review key elements of the market reforms and look at the changing role of the LEA policy maker in section 3. The spatial dimensions to these reforms will also be highlighted. As many LEAs are currently considering the use of GIS then we hope that section 4 will provide a useful overview of the potential of proprietary GIS for aiding the planning process. In section 5 we review the role of traditional spatial modelling approaches to education planning. A key argument here is that the new age of competition is itself likely to change the sorts of modelling procedures which are most relevant to market situations. The traditional programming and optimisation models (where control lies with the local authority) to balance school catchment areas are no longer as appropriate. What is required are new methods that will explore the consequences of parental preference and the dynamics of change caused by good/bad school performance, whilst at the same time offering new insights into the measurement of school performance. Section 6 concludes by detailing our thoughts on future developments.

2. Market reforms in education

1979 provides a natural break in any consideration of education in Britain. Not only was it the academic year in which school rolls reached their peak, but it was also politically significant in that the present Conservative régime was first brought to power. It was a year, therefore, that heralded considerable changes in education, on a scale which would at least match those of 1944. Legislative changes began to alter the face of education, to a far greater extent than the indecisive to-ing and fro-ing on the comprehensivisation of secondary schooling during the 1970s. From their first Education Act in 1980, the Conservative government sought to redefine education in a 'market' setting which would be defined by the consumer (*i.e.* parents and pupils) rather than the producers (schools and LEAs). The power of the LEAs was slowly reduced by provisions in the 1980, 1984 and 1986 Acts, a process which, to all intents and purposes culminated in the 1988 Education Reform Act (ERA). This Act impacted significantly on the local control of education, and some would say sounded a longer-term death knell for LEAs, despite the fact that many of its policies, such as the local management of schools and to some extent the national curriculum, had in fact started life as local initiatives (Dale, 1989).

The 1988 ERA introduced the centrally-determined National Curriculum and permitted schools to 'opt out' of LEA control altogether by becoming grant-maintained (GM) and receiving their funding direct from the Department of Education and Science. It also forced the delegation of much of the local budget (some 85% by 1995) direct to schools through a scheme known as the local management of schools. Fully open enrolment meant that parents were completely free to choose which school their children would attend, no longer constrained to choose within a single authority, let alone their nearest school. The ERA also fostered the development of the City Technology College programme. These are selective state schools based around a technology-led approach to the National Curriculum, and were intended to be 'beacons of excellence' in inner city areas. They were to be funded partly through sponsorship from private enterprise, which would have fitted with the government's more general intention of involving the private sector in public service provision, although the level of interest has been very disappointing to education ministers (Whitty *et al*, 1993). In addition, OFSTED has recently argued that at least one City Technology College is failing academically (Joseph, 1994).

Since 1988 the rôle of educational legislation has been to decrease the power of LEAs and increase the "quasi-market" (Bowe *et al* 1992, p24). This overall "marketization" (Goodwin 1992, p78) of education has been met with considerable opposition, especially from those who operate at a LEA level. Roy Pryke, Kent's chief education officer, suggests that there is a "serious problem with the policy of schools opting out ... [which] is threatening to undermine the quality of the education service" (1993, p12). For these comments and others, Pryke was branded "deeply lippy" (Dean and Hackett 1993, p1) by John Patten, the then Secretary of State for education, highlighting the very serious nature of the schism between central and local government. Schools are now forced to compete for pupils (since each child is now an 'age-weighted pupil unit' in the complex local management funding formulæ – see section 3) by appearing to be 'different' from each other. As every state school is forced by law to provide exactly the same curriculum, set centrally by the Department for Education, then this is likely to lead to schools trying to show that they outperform their 'rivals' through indicators such as examination results.

It is clear that the ERA and more recent, related, legislation such as the 1993 Education Act (concerning the founding of the Funding Agency for Schools) has had a major impact on education, both in the area of what is taught and on the structure within which provision is planned. The initiative has been largely taken away from the local administrators and left LEAs to contend with the private sector as specialist service providers with a greatly reduced planning capacity (see section 3). This imposition of "undemocratic centralism" (Goodwin 1992, p85) has rightly increased fears for the future equity of provision. To compliment market forces schools are required to publish performance indicators relating to such data as exam scores and truancy rates. These indicators are published as league tables of 'best' and 'worst' schools in an area (for illustrations of this process see section 4) and are intended to inform the process of parental choice. Although parents have traditionally viewed schools with good reputations as an important factor in the decision to move to a new area (see for example Lawson, 1993 on the effect of schools on house prices), the publication of these new performance indicators is likely to mean schools which may already be popular with middle class parents will draw more advantaged pupils (and thus funding) from a wider area, to the detriment of already underprivileged parts of towns and cities. Local planners will be unable to prevent the increasingly inequitable distribution of educational resources and perhaps increased social divisions across Britain's urban areas.

As the 1988 Act becomes fully operational there is an urgent need to monitor the impacts on the education system and, particularly, on outcomes within a particular city. Very little has been written on the spatial implications of the recent policy changes, or on ways in which a geographical analysis can be employed to aid the planning process. The aim of this paper is to put forward some proposals for the construction of an information and modelling system to monitor, predict and make recommendations concerning likely impacts of these changes in an urban area.

3. Planning issues facing local education authorities

The aim in this section is to examine the consequences of the 1988 ERA from the perspective of the local education authority (LEA) and its traditional planning functions, rather than to present a full appraisal of the possible implications of the reforms. The latter can be gleaned from texts such as Maclure (1989) and Bowe *et al* (1992). LEAs have a large number of functions; their major task, according to the 1944 Education Act is "to secure that there shall be available for their area sufficient schools for providing primary … and … secondary education", but alongside this they must fulfil a series of other commitments. The Audit Commission in 1989 described LEAs as information providers, quality regulators, bankers, leaders and partners to schools and colleges. Not all of these have a geographical perspective, of course, and it is the planning function which most concerns us here, although this is to some extent affected by their other rôles, especially as financier. LEAs are expected to plan not only how many schools will be required at various levels, but also, crucially, where they will be required and what demand for transportation there is likely to be. This is clearly a very significant set of tasks, and the sums of money involved every year are huge – local authorities in England spent some £22.7 billion on education in 1991-2 (Craig, 1994).

Perhaps the activity which is of most obvious interest to geographers is that regarding the provision of school places. This is always a thorny issue because of the intense loyalty of the public at a local level to particular schools (Bondi, 1989). It is consequently one of the most demanding tasks a LEA has to carry out. At the same time, a major problem facing LEAs is that of surplus places. The cost of each secondary school place which is surplus to requirements is some £300 *per annum* (Independent, 1994), although it is less for primary schools. At a national level this is reckoned to amount to 1.3 million places, at a cost of some £310 million *per annum* (TES, 1994). This situation also highlights one of the serious contradictions of current central policy. The government's emphasis on parental preference (see section one) has meant that LEAs are constrained to maintain a number of surplus places in all schools in order to allow parents to have an actual choice. At the same time there is considerable financial pressure on the same LEAs to remove surplus places from their schools. The pressure is not just internally generated and financial. The Department for Education (DfE) is also keen to see the large number of places at a national level removed for reasons of efficiency. There is therefore the threat hanging over LEAs that if they do not rationalise their own provision it may be that the DfE will send in a team to rationalise for the authority. The optimum number of surplus places to balance the two needs discussed here is considered to be approximately ten *per cent*, but certainly no more. This gives an authority flexibility not only for parental choice, but also in case of increased levels of migration, emergencies such as fire damage to school buildings, and so forth. The difficulty of LEAs responding to the removal of surplus places is increased by the newly-emerged possibility of schools opting out.

It is interesting to note that one of the main reasons given for opting out has been to avoid local authority reorganisation (some 80% of grant maintained schools in 1989/90, according to Fitz, Halpin and Power, 1993). Although this proportion fell after the first year of the opting-out scheme, by 1991/2 it was still accounting for some 40% of decisions. The explanation for this decline could be that fewer LEAs have been putting forward plans for reorganisation, perhaps for fear of 'losing' schools to the grant maintained sector. As the numbers of schools opting out for reorganisational reasons declined, the proportion of schools opting out for financial reasons increased. The first eighteen GM schools were confirmed in September 1989 (OFSTED, 1993), and by late 1994 just over 1000 were operating (Dean, 1994), meaning that the Funding Agency had a part to play in some 50 LEAs (Budge, 1995). There has recently been concern expressed that the policy of opting out has allowed a large and very expensive number of spare places to be saved in schools which might otherwise have been amalgamated or closed (McSmith, 1994). This highlights the seriousness of the planning crisis facing many LEAs.

A related problem facing LEAs is that they must have an accurate idea of where children are likely to live in the next few years and, perhaps equally importantly, some measure of predicting to which schools these children will travel. This latter has become particularly significant in recent years since there are no longer rigidly defined catchment areas and parents can in theory choose to send their children to any school, in any authority. The increased possibility of inter-authority flows of children also complicates the issue, making it even more complex for any one authority to plan for the provision of sufficient schools within its region. However, authorities do now hold data on all the addresses of all children in their schools, as well as the school which the child attends, so there is a very large database of interaction flows available for analysis (see section 4).

The lack of control a LEA has over grant maintained schools is also a central issue. The LEA has no power to close such schools, or reduce their provision, which complicates the task of rationalisation immensely. The government's newly-appointed quango (set up by the 1993 Education Act), the Funding Agency for Schools, is intended to take over many of the functions of local authorities and central government. Responsible primarily for grant maintained schools, this body will distribute resources directly to grant maintained schools rather than going through the LEAs. It will also, significantly, have powers over the planning of school provision. Once 10% of a LEA's schools have opted out, the two bodies will become equal partners in the planning process, and the Funding Agency for Schools takes over full responsibility for planning once this figure reaches 75%. It is also possible for LEAs to delegate their responsibility to the Funding Agency for Schools before these basic figures are reached. It is important to recognise the fact that the Funding Agency for Schools has no local accountability, in the tradition of quangos, being appointed by and accountable only to Westminster.

As the number of GM schools increases and the Funding Agency takes over the full planning rôle of the LEAs any difficulties which might develop during the phase of shared control should be overcome. However, there will still be a question of the political implications of the Funding Agency for Schools' decisions to close schools. If they decide to rationalise an authority's provision and the grant maintained schools in that authority are left untouched while others close it will be accused of 'favouritism' and bias toward the government's political agenda. This is a potential problem of which LEAs are rapidly becoming keenly aware (Beckett, 1994), although their swift acknowledgement of the possibility of a problem is not without a certain amount of self-interest.

Another key area of LEA planning is the control of funding for schools which remain under their jurisdiction. General funding of schools is by formula. These are derived by the LEAs themselves based on two DfE rules; that a set percentage of total funding must be delegated to schools and that at least 80% of the money which is delegated must be based on the head count of pupils, with each pupil in an age group worth the same as his or her peers (this is the so-called 'age-weighted pupil unit' or AWPU). This amount rose to 85% in April 1994. The specific detail of the formula, which is usually a combination of sub-formulæ, each intended to allocate a different section of schools' budgets (which range from cleaning and maintenance formulæ to basic age-weighted head count funds), is left to individual LEAs to define. Resources for what is known as additional educational need (AEN) is clearly a part of this wider process of formalisation. Such financial planning is therefore also a central issue affecting LEAs. The majority of authorities have a certain amount of money set aside to allocate on the basis of perceived social and/or educational need, usually allocated on a *per capita* basis. There is therefore a requirement to define an index of deprivation and accurate and meaningful performance indicators to measure educational 'need'. At present free school meal rates are the most common proxy for both forms of 'deprivation', but there is certainly some dissatisfaction with this. It is thought that although the number of pupils receiving free school meals is a reasonable indicator of social deprivation the link with educational deprivation is often assumed rather than given. Work to develop indicators of this kind and 'add value' to raw measures of educational performance is ongoing in many LEAs (and can be given a clear geographical perspective through the use of GIS, as discussed in sections 4 and 5). These are largely based on a weighted *per capita* formula of pupils at a school falling into various LEA-defined groupings. The simplest remains eligibility for free school meals, with a straightforward financial sum being allocated on a *per capita* basis. For more information on the wide variety of these measures of educational need, see Lee (1991).

There is also a burgeoning interest in the need for performance indicators to measure the true relative performance of schools at local and national level. The interest has been fuelled by the government's decision to publish annual league tables of exam results and, more controversially, truancy rates, leading to many calls for some accurate method of improving the worth of such tables for actual comparison of schools within an authority. This is clearly relevant both for the allocation of resources based on need, but also for the publication of data likely to influence parental choice – the wisdom being that a school apparently performing well in the league tables will attract the interest of a greater number of parents and thus ultimately more children and more funding. The actual merit of the tables if they are published without weightings is however limited, and in order not to penalise schools which appear low in the unweighted tables it is generally considered (Bertuglia *et al* 1994) to be reasonable to define some form of weighting system and thus new tables of performance indicators rather than tables of raw exam results. There is also the question of defining which schools should qualify for the additional AEN funding available in many LEA formulæ. It may be possible to use new measures of educational 'need', designed for funding purposes, to 'add value' to raw indicators of educational performance, an area of considerable interest to many LEAs at present, and this is therefore an area of interest which impacts on a number of areas of the LEA's operation. The question of performance indicators for schools is discussed in depth by Bradford (1991) and in section 4 below.

There are other issues facing LEAs which have a geographical flavour. There is the question of home to school transport. Enshrined in the 1944 Education Act, and never rescinded, is the law that any child who attends his or her nearest appropriate school and lives more than three miles away by the shortest walking route is entitled to LEA-provided transportation. This policy applies equally to all children, and thus if a child's parents *select* a school further than three miles away which is not defined as the 'nearest appropriate' then the child does *not* qualify for free transport. Even so, this is an expensive business, and the methods of dealing with disputed cases are in most situations still somewhat archaic. Measuring distances on paper maps, and in the most extreme cases actually going out and walking the route with a surveyor's wheel are common. Such a situation is costly in person-hours and there are clearly more efficient methods of dealing with the problem using accurate digital maps and information about addresses of pupils. Another significant rôle of the transport section of a LEA is to provide for pupils with special educational needs who attend special schools or special units attached to 'mainstream' schools. The vast majority of these are provided with transportation to their institution and this creates significant logistical difficulties. The particular difficulty in this situation is devising efficient routes for authority minibuses to collect pupils and then deliver them to their school. Again the use of modern geographical software could help solve this and improve the efficiency of such activities considerably.

To conclude, it is argued that there are a number of issues facing LEAs which are of direct interest to geographical planning. First, and most serious, is the provision of sufficient places. For this LEAs need to know the <u>impacts</u> of reductions in school capacity and perhaps amalgamations, closures and openings. Key concerns are the likely changes to provision and accessibility indicators as well as the changes in pupil flow patterns (or deflection rates, to use a marketing term). Similarly, LEAs need to examine the <u>dynamics</u> of the marketplace in greater detail. For example, what might the consequences of parental choice be and is it possible to predict the likely pressure on places if current trends persist? For these sorts of 'what if?' questions we need a sophisticated level of spatial analysis, since in addition to parental choice, school growth or decline will also be a function of declining or growing local populations and changes in local competition (Ball *et al*, 1994).

A second geographical issue is the definition of performance indicators which are based on residential catchments or pupil backgrounds. Despite the difficulties of measuring this in both theory and practice (Bradford, 1991) it is a key task that continues to merit further consideration. As Schagen (1995) reports, pressure from educationalists is forcing the British government to investigate the possibility of developing 'value added' indicators. That is, can LEAs or schools find ways of 'softening' the raw indicators of examination success, by adjusting for prior attainment or social context, in order to demonstrate that their school(s) might actually be performing well given the intake of students from less well-off environments. For this we need to identify new suites of performance indicators which relate pupils' residential locations to individual schools.

A third geographical or equity concern arises from the possibility of parental choice leading to social, ethnic or religious segregation in British schools. There is increased evidence that a market based on choice serves the middle and upper classes better than the lower or working classes (see for example Judd, 1995). The study of Ball *et al* (1994, pp19-21) in London suggests the following explanations;

a. that middle class parents are better <u>informed</u> and are more able to exploit the market situation
b. that middle class parents are better <u>able</u> and <u>willing</u> to move their children around the system. This argument is based around the greater material resources available to these members of society.

There is similar evidence emerging from elsewhere in the world, where market systems have been introduced in education (see Waslander and Thrupp 1995 for an excellent review of reforms in New Zealand). The implication of this sort of evidence is that schools in middle class suburbia will be generally more attractive to parents from elsewhere in the city. Conversely it is argued that schools closer to more deprived areas may lose their most able students as parents exercise greater choice. We shall explore ways of monitoring this is sections 4 and 5.

Finally, there are a number of other miscellaneous geographical issues that we need to address, such as formula funding for schools in different locations in the city and the traditional home to school transportation problem still faced by LEAs.

4. GIS in education: a review

4.1 Introduction

The development of geographical information systems (GIS) within local authorities as a whole has a chequered history. The principal use has been for the production and maintenance of land use maps, and substantial savings of time and money have been suggested (Buxton 1989, Swainston 1993). However, the general consensus in most review articles (Worrall 1990, Birkin *et al* 1995) is that GIS has not penetrated into more proactive areas of local planning and remains therefore at a low level of policy analysis. Indeed, some are beginning to conclude that GIS is the latest in sequence of IT solutions which have promised much, but delivered little (Allinson, 1993).

The problem lies partly with GIS itself and partly with potential users. First, it can be argued that GIS (for policy analysis) desperately requires greater analytical procedures. This is the primary argument of an increasing number of GIS consultants and one which is developed further below and in section 5. However, a second argument is that planners require greater guidance on how the full potential of GIS can be realised. To this end it could be argued that there is a need for more immediately user-friendly, integrated desktop packages which can be employed quickly and easily by those in the mainstream of planning and policy development. The remaining sections of this paper discuss the potential for inclusion in such a system of a number of techniques taken from the worlds of GIS and spatial modelling.

There are, as we have seen in section 3, a number of planning functions carried out by LEAs on a regular basis which have a distinct geographical flavour. To supplement their more 'traditional' planning methods, a number are now looking to the potential of GIS. At present, most of the authorities which are making use of GIS have access only to packages held corporately rather than packages specifically purchased for education. The rest of this section describes the basic functionality of GIS and offers a blueprint for its development in education.

4.2 Visualisation

At present it would seem that the use of GIS in education departments is still a new, albeit expanding, area. The actual GIS is in many cases peripheral to the main work carried out, being used as a basic mapping tool rather than for analysis. The benefits of displaying data are that often hidden spatial patterns become much clearer to see and one can use such maps as the stepping stone to more detailed investigation. Figure 4.1 for example, 'brings to life' the national performance indicators published in November 1994 (and therefore show results for the 1993-4 school year). The problems in the urban cores are immediately apparent and the maps throw up some more surprising geographical concentrations of both 'good' and 'bad' performance, a pattern which may not be immediately apparent from published tables alone. Although there has been much criticism over possible variations in the measurement of such indicators it does begin to ask a number of questions concerning school performance that require further investigation. The variations are particularly apparent when the scale changes to the intra-urban level. Figure 4.2 shows the variation in GCSE results for high schools across the city of Leeds, in the north of England. By mapping such results it is immediately apparent that schools on the outer (especially northern and western) edges of the city 'perform' much better, whilst there are grave sinks in the inner core and eastern and southern edges associated with areas of high unemployment on so-called 'problem estates' (see figure 4.3). This provides a clear link to the possibility of more complex GIS-based analysis – see section 4.4 below.

Figure 4.1a: National 'performance indicators', by LEA area

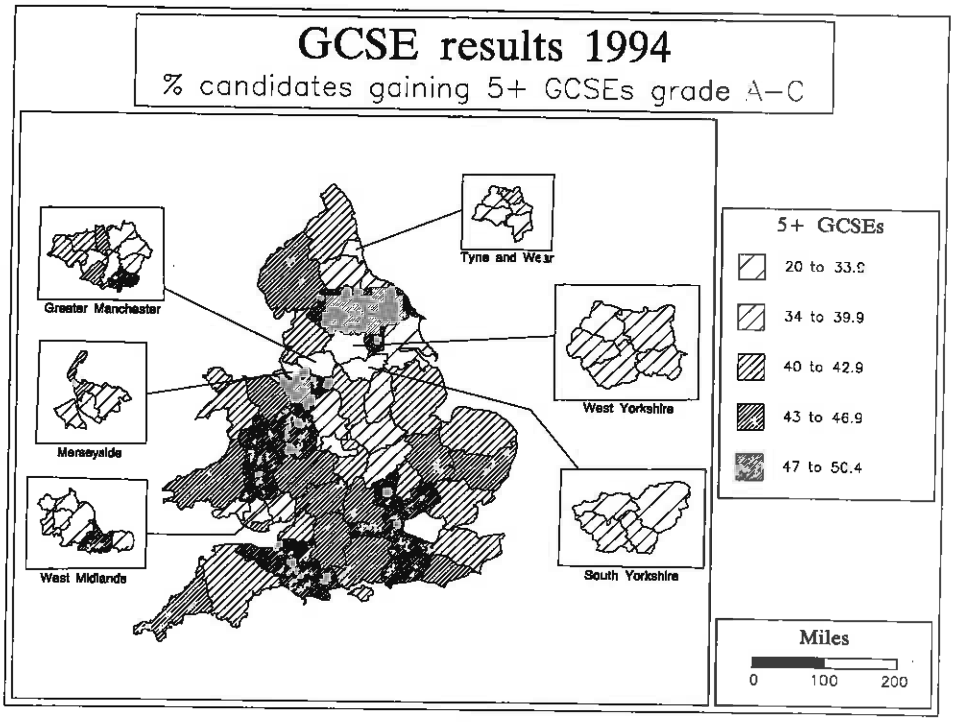


Figure 4.1b: National 'performance indicators', by LEA area

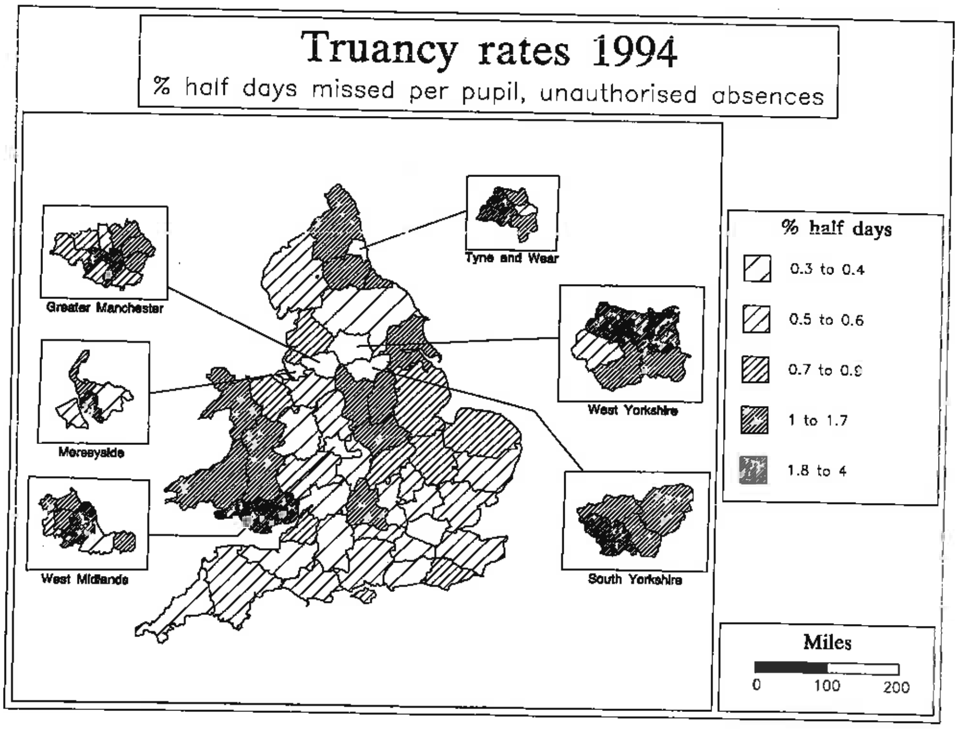
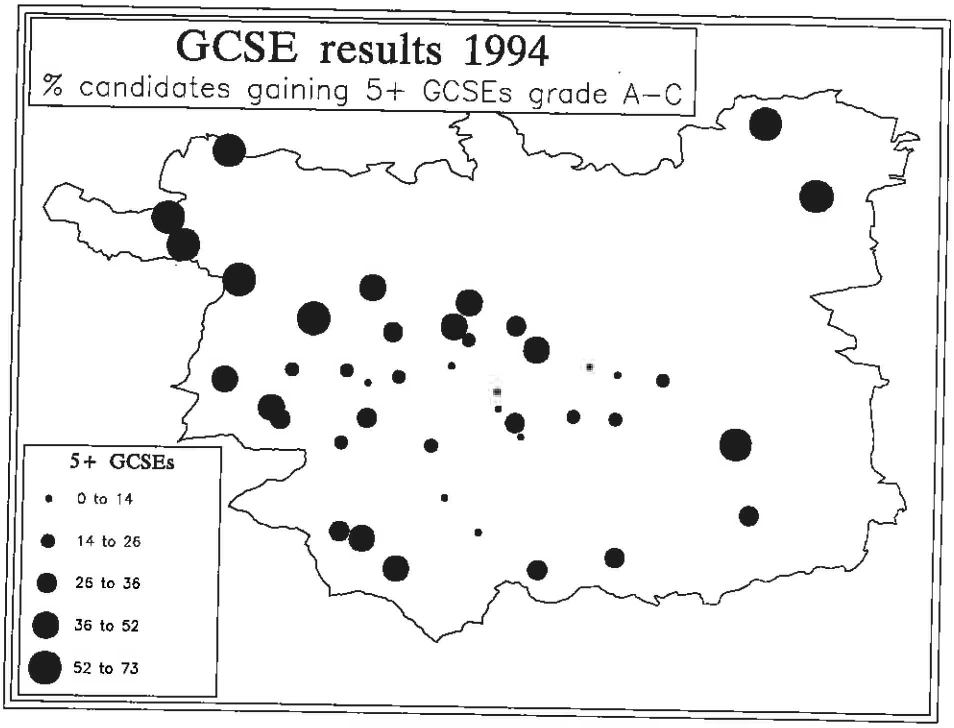


Figure 4.2:Local 'performance indicator' for Leeds High Schools



Given the importance of monitoring surplus places through catchment area analysis seen in section 3, it is not surprising that the most common usage of GIS in education departments is for the definition and mapping of school catchment areas. This is useful for the task of visualising which children attend which schools, and also any changes in catchments effected by parental choice. It is useful to see which areas of a city are served by which schools as an aid to planning for provision. Figure 4.4 shows four contrasting catchment areas for schools in Leeds. It is clear that the schools, the first two of which have high examination scores and the second two of which have very low results, have very different sizes of catchment area and that pupils are drawn from very varying socio-economic areas (compare figure 4.4 with the indicators in figure 4.5). Such a process can also help to define simple indicators based on the number of school places *per capita* for each appropriate age cohort, and hence where new schools might be required because of increasing pupil numbers or where there is an unacceptable surplus of places. Figure 4.6 shows the number of surplus places by high school for Leeds. Comparison with figure 4.2 shows that schools with many surplus places tend to have lower examination pass rates, and *vice versa*.

Figure 4.3: Socio-economic indicator for Leeds

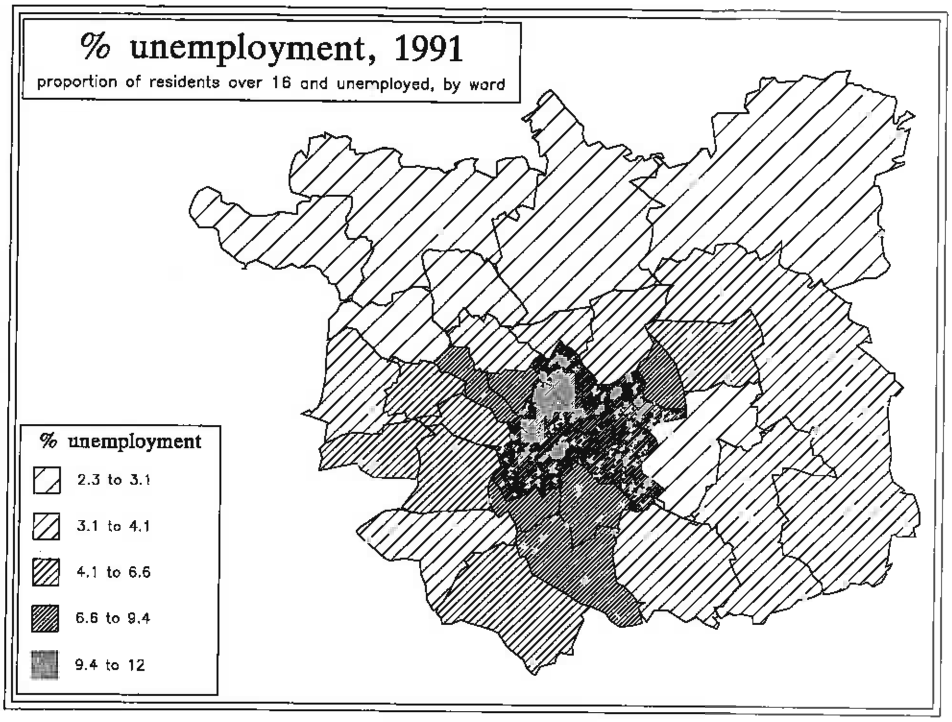


Figure 4.4a: Catchment area, school with high examination results

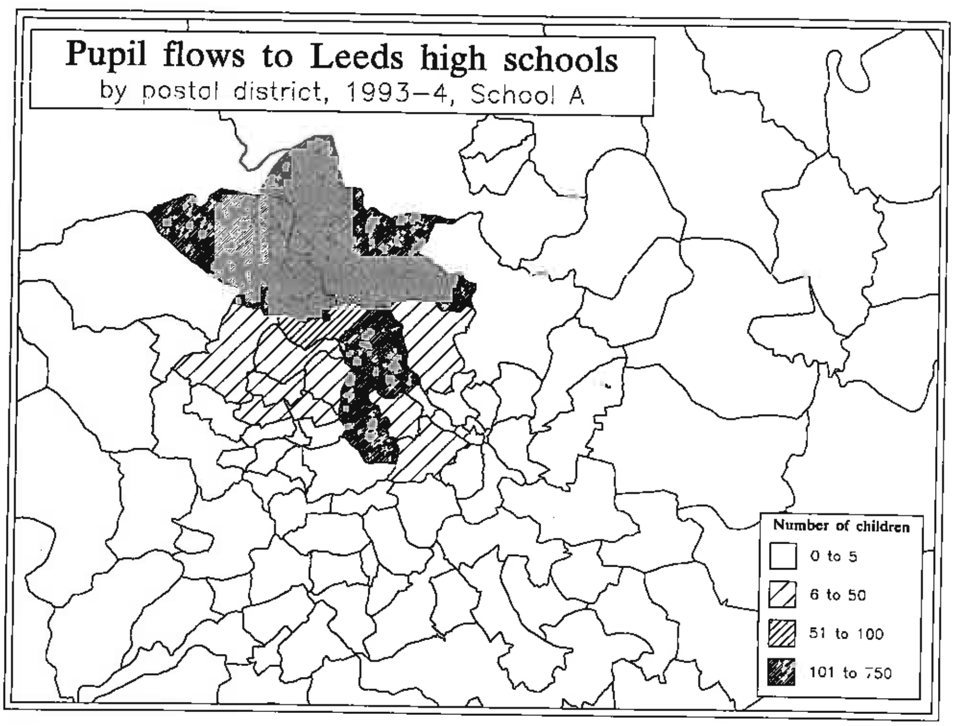


Figure 4.4b: Catchment area, school with high examination results

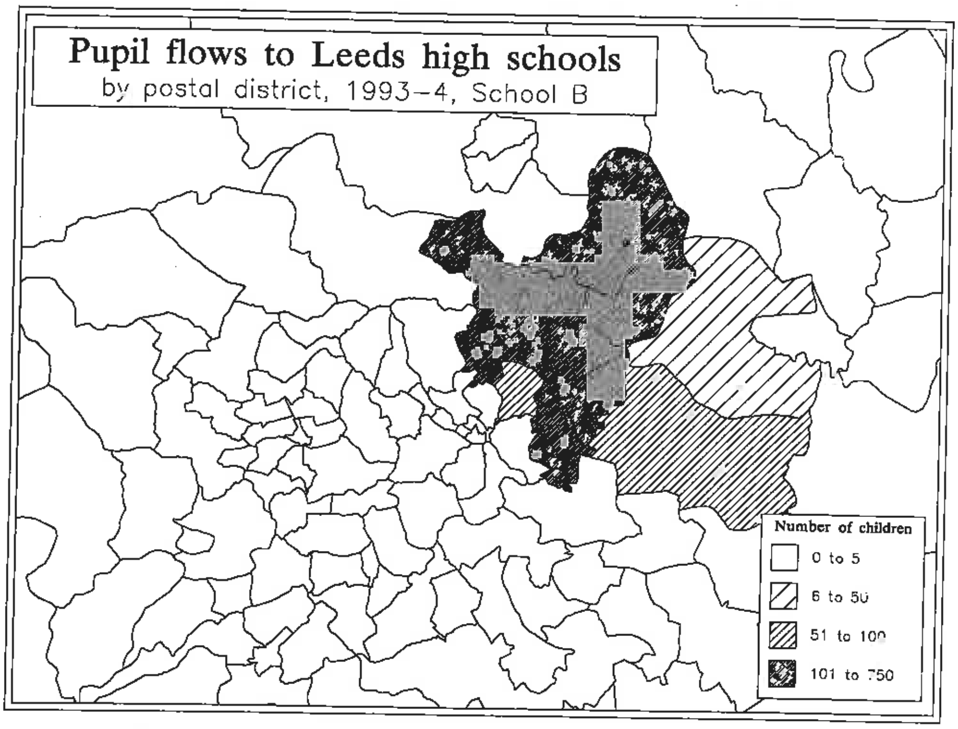


Figure 4.4c: Catchment area, school with low examination results

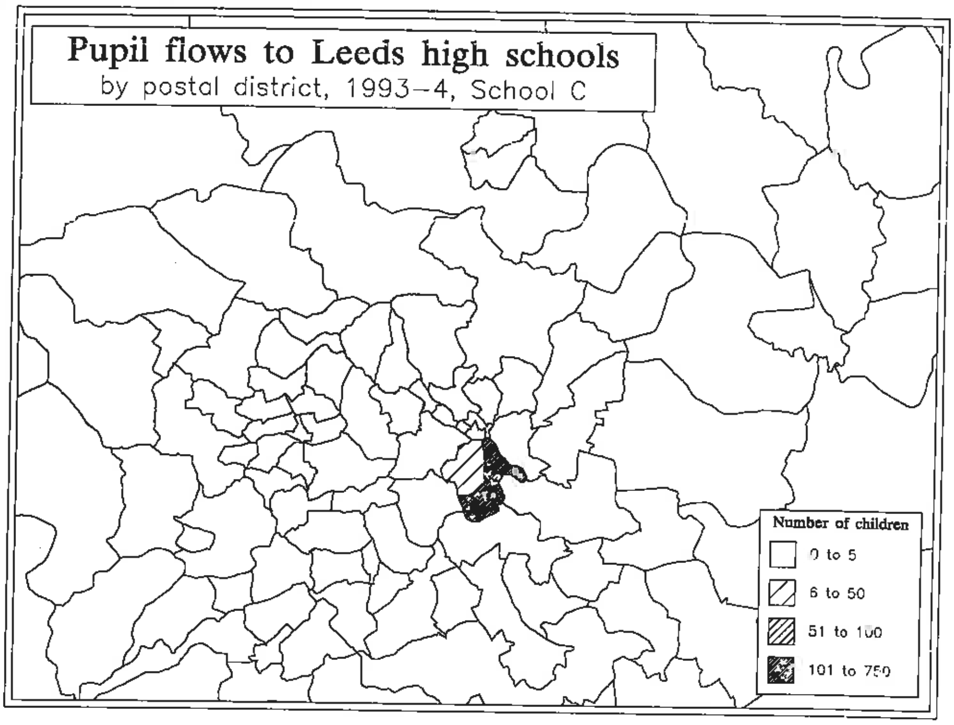


Figure 4.4d: Catchment area, school with low examination results

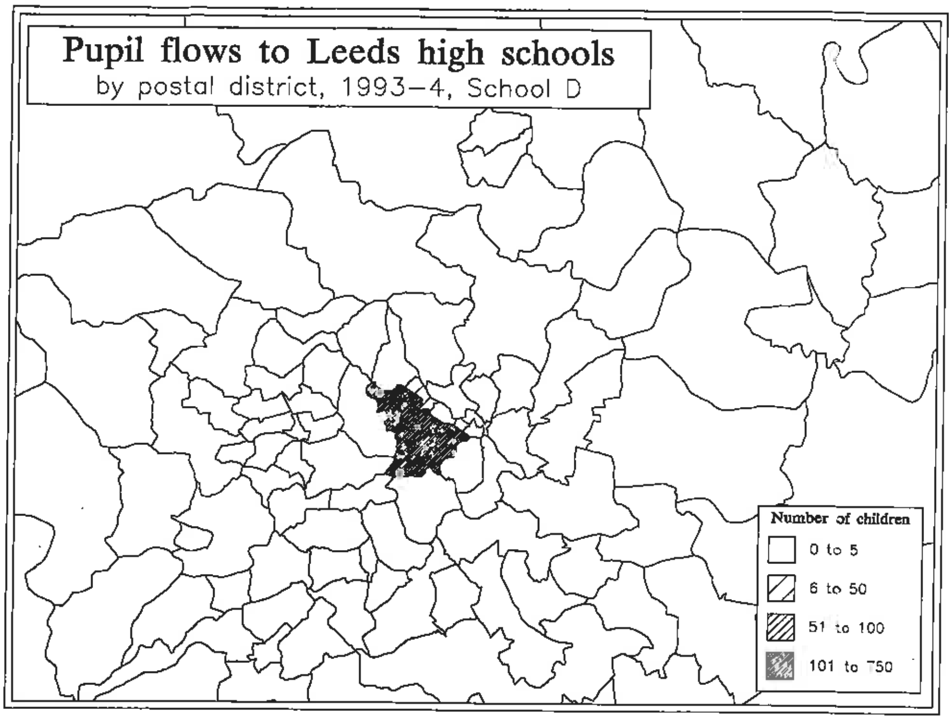


Figure 4.5a: Socio-economic indicator for Leeds

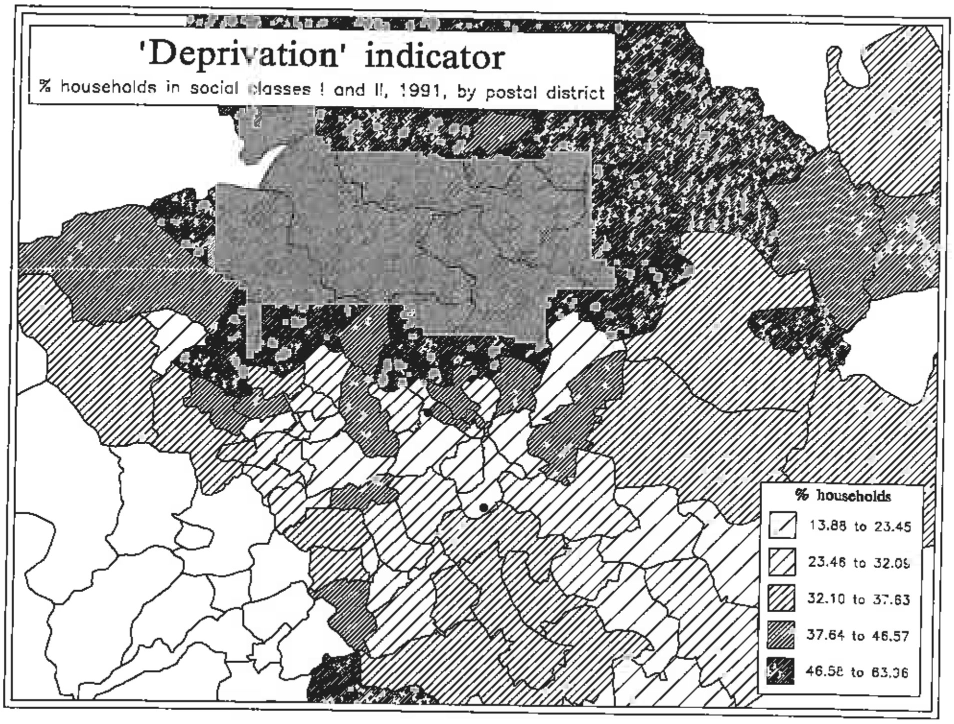


Figure 4.5b: Socio-economic indicator for Leeds

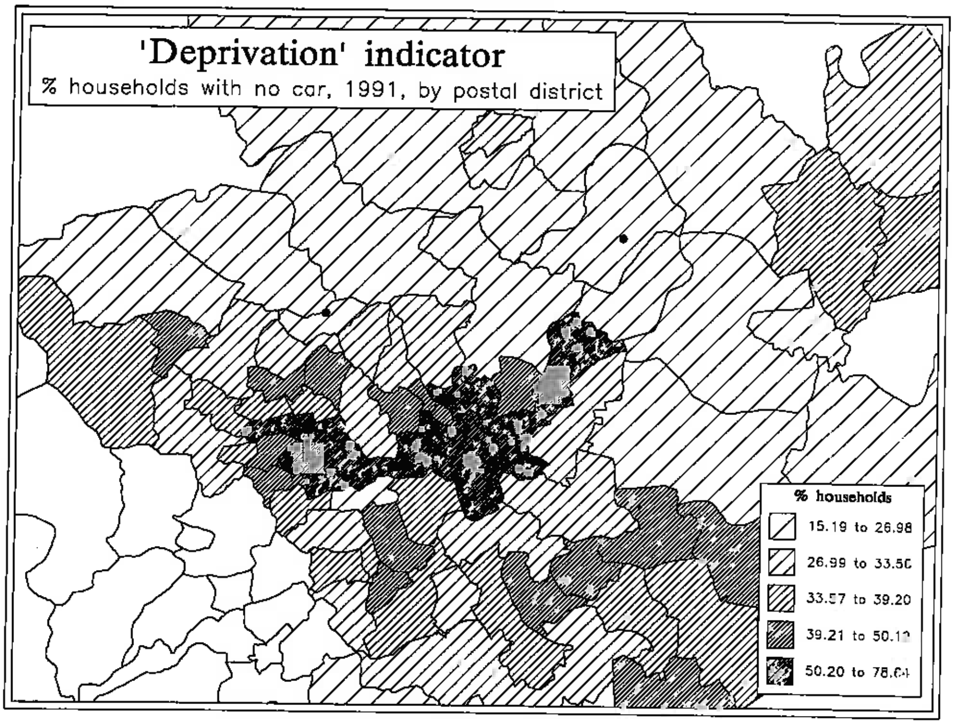
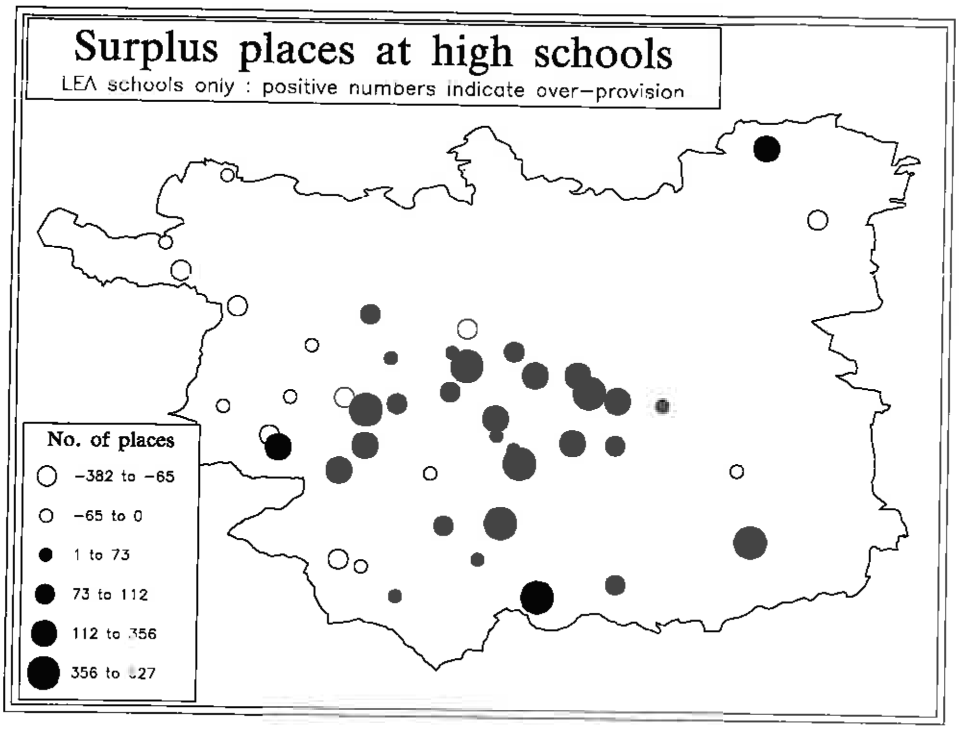
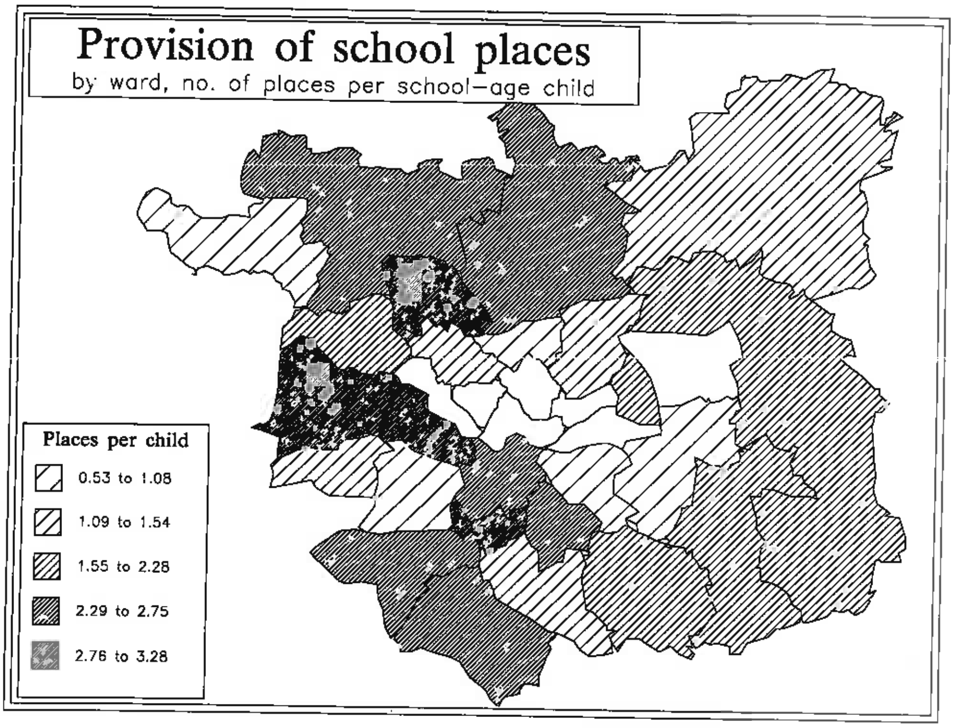


Figure 4.6: Surplus places at Leeds secondary schools, 1993-4



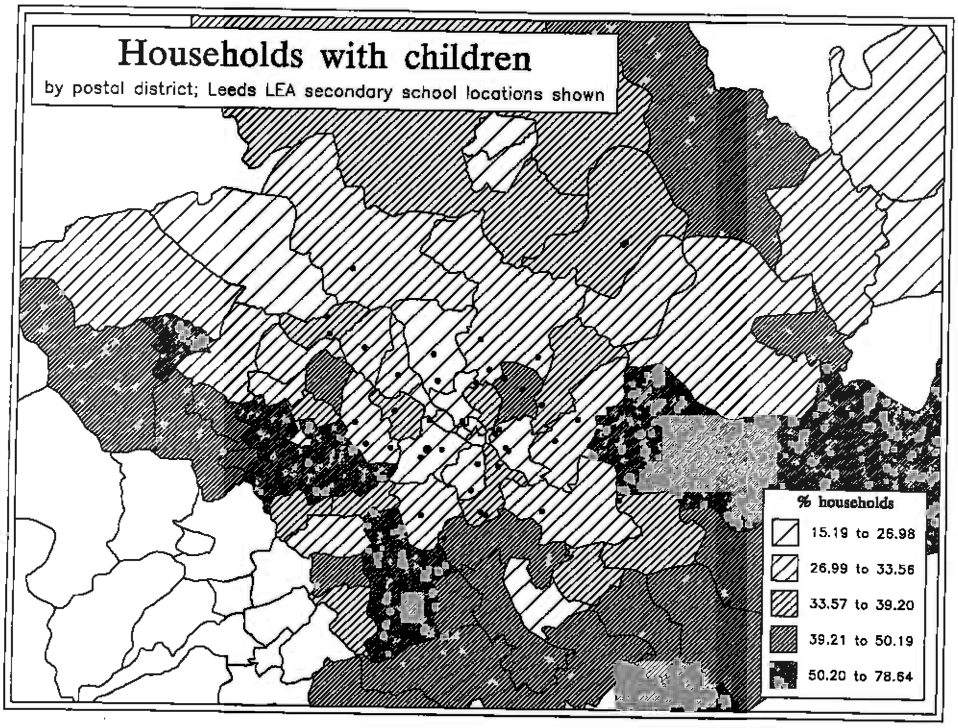
This simple display method would also be able to provide some measure of how *per capita* provision is changing over time, enhancing the planning process overall. Figure 4.7 maps one such simple indicator; the amount of places available in Leeds wards compared to the number of school pupils residing in the ward. This is a common method for the analysis of provision. However, such maps of provision rates can often be misleading. From figure 4.7 it can be seen that the wards of central Leeds look particularly underserved. However, in reality, these areas lie next to wards with high provision, and are reasonably well served by schools on or close to ward boundaries. The major problem here is that school catchments and census wards do not nest accurately. What are required are indicators which take into account the level of spatial interaction between sets of wards or 'catchment areas' rather than looking at relatively meaningless ward rates in isolation. We shall return to this theme in section 5 (and see also Bertuglia *et al*, 1994).

Figure 4.7: Provision of secondary school places per child in Leeds



Authorities could also benefit from the mapping functions of a GIS by using it to gain a measure of future need by plotting families with children (a census variable) alongside a map showing school location (figure 4.8). If this method is used on an

Figure 4.8: A measure of future demand from the 1991 census



authority-wide basis it would be simple to identify general areas of under- or over-provision. More detailed studies, perhaps covering just a few schools, could then be focused on these areas to define exactly where new building or closures should take place. The system can also be used to pinpoint the extra-district pupils who, as mentioned, are becoming more significant to admissions planning than in the past. The admissions sections of LEAs are also interested in utilising GIS in order to help organise the efficient transfer of pupils between schools, using this process. Since the postcode data for each pupil exists it is a relatively simple task to allocate primary children to their closest secondary school when transfer between sectors is required. This is an example of how the most basic form of computational automation through GIS can improve the speed of data processing within a LEA considerably. The on-screen combination of datasets such as this can be a very important tool for the analysis of school provision, even with the very basic level of implementation which is normal at present.

For individual schools the plotting of pupils through a GIS could provide very valuable marketing information which might help it target areas for potential new students. The marketing of schools is becoming an important activity in the new era of competition (see Sullivan 1991, Pardey 1991) and the simple visualisation function of GIS would identify the existing catchment area and areas in which the school was seemingly underrepresented.

4.3 Geocoding

Geocoding refers to the ability of GIS to store attribute information relating to any feature which has a spatial reference, and to retrieve this information when the user highlights such a feature. The spatial reference feature may be a point set (information for particular schools), a line feature (information on routes to schools) or area information such as census tracts. Normally one would expect to see all these operating together. In order to map school catchment areas for example, pupil's home addresses have to be accurately located on a street plan or within a census tract. Geocoding is made simpler when all attributes have a common geographical identity, such as postcodes. However, this is unlikely to be the case when dealing with data sets built by different departments for very different reasons. Table 4.1 shows a selection of the data which may be available to LEA planning officers from various sources and at various scales.

Hence the GIS must be capable of dealing with a variety of spatial identities at a variety of hierarchical scales. Figure 4.9 sketches a simple framework for dealing with attribute data held by individual schools and a LEA. The user would be able to select three spatial routes through the data sets. The primary building block is the census enumeration district, which could be used to aggregate to any of the remaining spatial scales. This would provide a level of consistency throughout the GIS, but recognises that some times the appropriate scale may be postcodes (most likely for relating student addresses to other data sets) or traditional LEA school catchment areas.

4.4 Data linkage

Once the data has been inputted into a GIS the user needs to consider ways in which 'analysis' can be performed. Although the data sets listed in table 4.1 are valuable in their own right the real interest begins to emerge when these are linked. Data linkage is one of the most fundamental methods of adding value to data within a GIS. The first and most basic form of analysis is the use of simple arithmetic operations. For example, flows to each school could be combined with residential information for school-age children to produce simple maps of 'market share' in an area. This would enable schools to approach the idea of targeting areas for marketing in much the same way as retailers might. Figure 4.10 demonstrates this for the four schools shown in figure 4.4. It is clear that there is a very serious dichotomy between the catchment areas of high-performing and low-performing schools. Maps such as these enable schools both to consolidate marketing and/or advertising in areas in which they had a high market share and to step up their marketing campaigns in order to attract pupils from new geographical areas. It is, however, worth noting that such marketing activity, while burgeoning, is not uniform, and in many areas is still seen at a school level as 'ungentlemanly', while other areas are embracing the new environment with more aplomb (see Ball *et al*, 1994).

In most GIS packages the concept of polygon overlay is central to this linkage process. This includes the layering of information within a single map outline. For example, the overlay technique can be used in order to plot pupil distribution in relation to census data, which can allow authorities to build social profiles of individual schools. Such area profiling is common amongst LEAs, which often designate some financial resources to be allocated on the basis of a fixed measure of perceived social or educational need, as discussed in section 3 above. Hence, GIS can be used to help correlate areas of high social deprivation with the exam successes/failures or truancy rates *etc.* of the pupils living within these areas. This could provide a first step towards a new set of indicators of residential disadvantage to be examined in relation to the newly published school-based indicators which supposedly measure school effectiveness (the second step would be to incorporate new model-based indicators, and we return to this in section 5).

Figure 4.9: Possible framework for data-led 'GIS' data display system

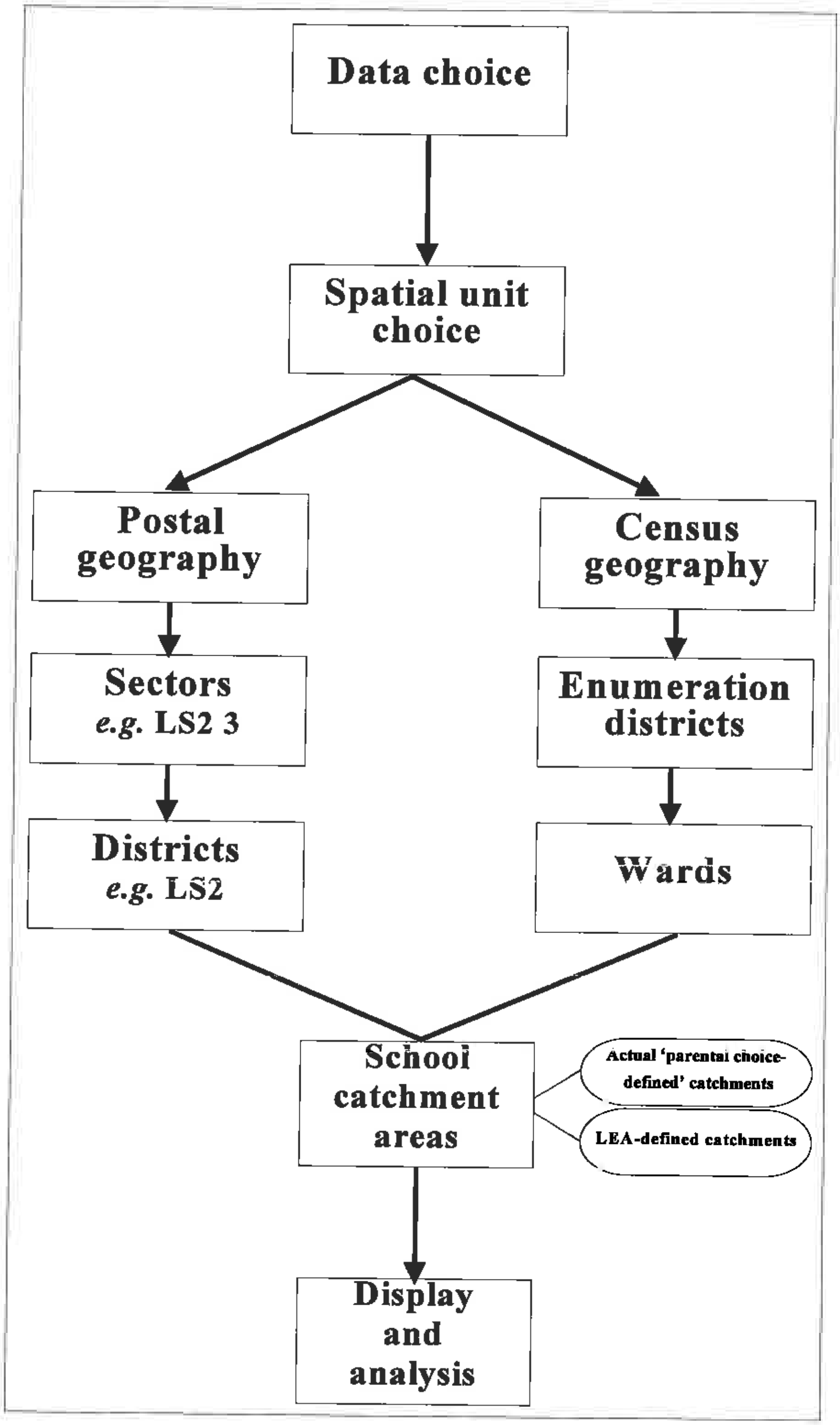


Table 4.1: Data accessible to LEA planning officers

LEA	Child Health Service	Social Services	Police
Free school meals by school	Children with severe learning difficulties, by primary school	Income Support rates, by postcode	Number of offenders by postcode
Ethnic composition by school	Special educational needs, by school (or postcode)	Condition of housing property register, by postcode	Number of crimes by postcode
Vandalism rates by school	Waiting lists of various health facilities	Home Care information, by postcode	
Exam results, SATs *etc.*, by school and/ or by pupil (postcode)	Failure-to-thrive data, by postcode		
Attendance rates and unauthorised absence, by school	Child protection numbers, by postcode		
School rolls, projected rolls and historical data, all by school			
Nursery places			
Teacher/pupil ratios by school			
Teaching facilities by school (*e.g.* computers)			
Teacher service years (total and in authority), by school			

Figure 4.10a: Market penetration, school with high exam results

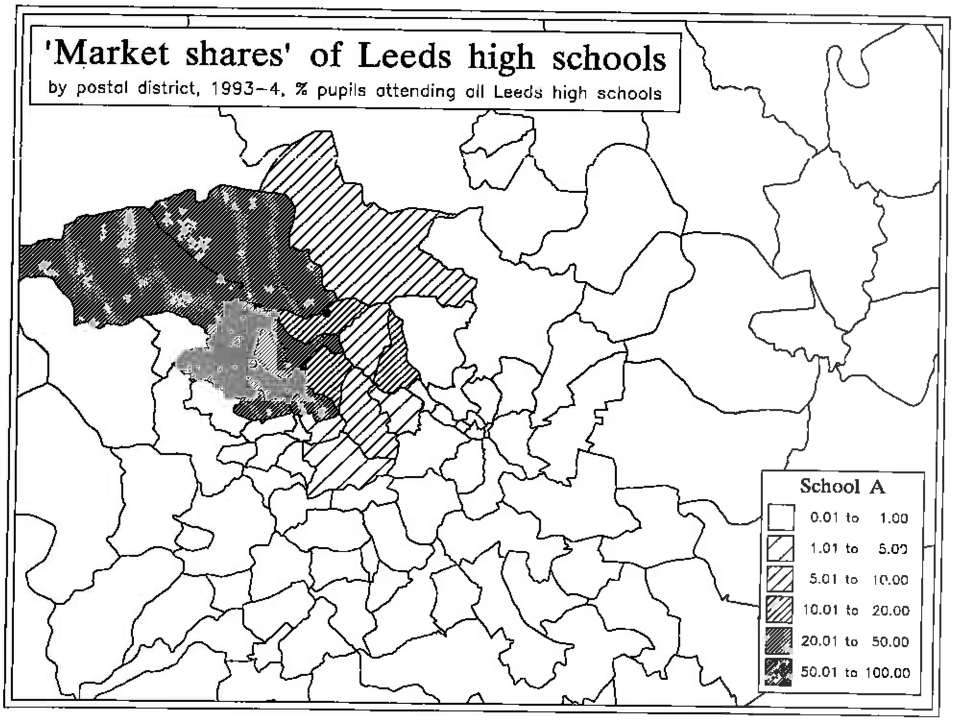


Figure 4.10b: Market penetration, school with high examination results

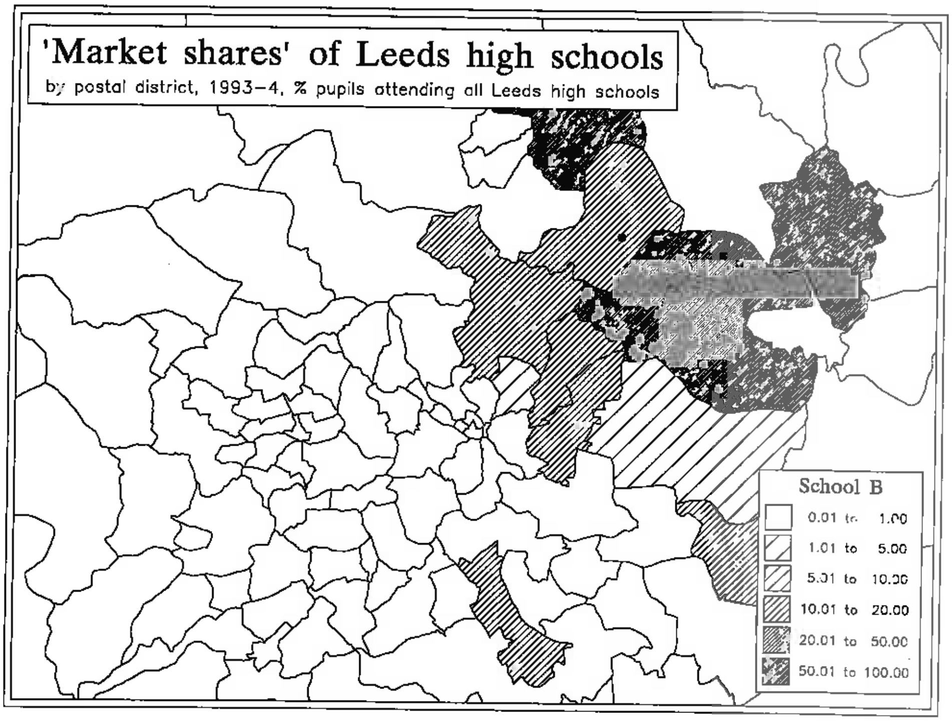


Figure 4.10c: Market penetration, school with low examination results

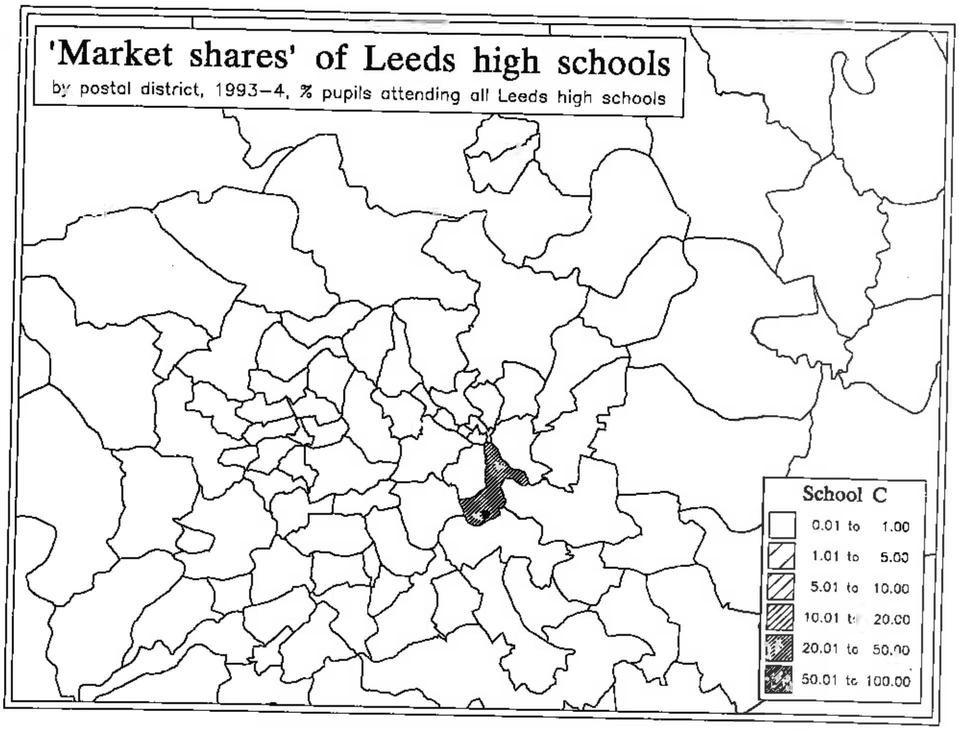
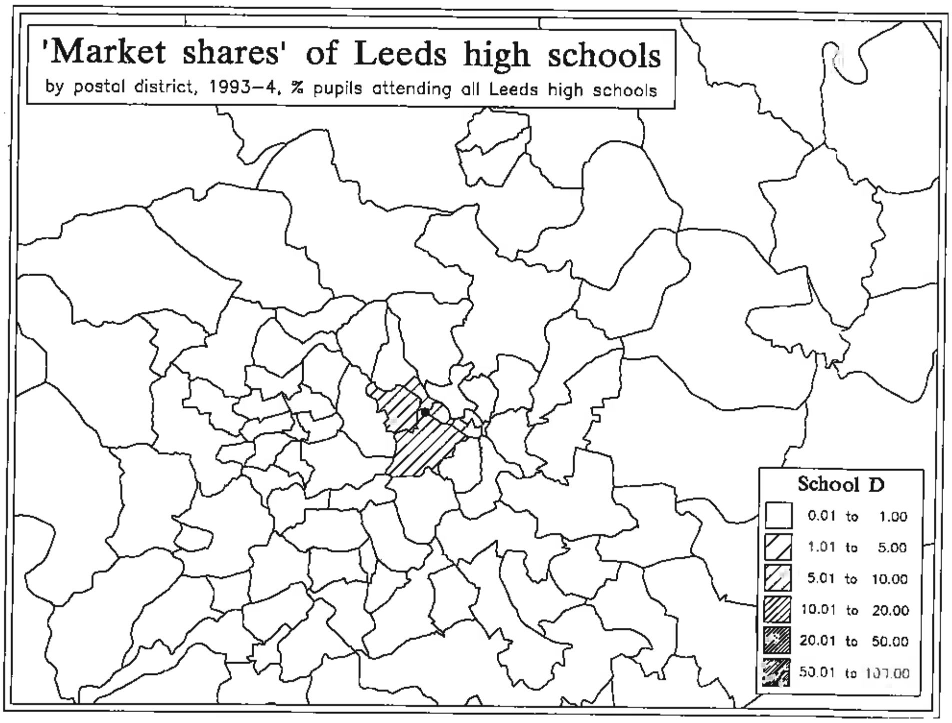


Figure 4.10d: Market penetration, school with low examination results



The overlay procedure in GIS is often undertaken in conjunction with spatial buffering to assist impact assessment. That is, an estimation of the impact of opening a new school or a school closure could be made by demarcating the average distance travelled to the school in question (*i.e.* a buffer could be outlined) and overlaying the number of pupils within that buffer who were likely to be affected. This is the typical approach used in GIS applications for retail and service planning (see Grimshaw 1994, Castle 1993). There are difficulties with this procedure, however, and we shall return to these in section 4.

However, the buffer facility may be an effective way of solving the traditional problem of how and where to draw suitable boundaries around schools in order to provide free transportation. Measuring travel times within a GIS is less arduous than walking the streets and hence could be used to define a standard dataset of distances from houses to schools for the rapid resolution of such disputes in the future. However, there are problems with such an approach. Legislation dictates that LEAs must use the shortest walking route to a school, which requires the presence of a much more detailed digital road network underpinning the GIS. The most common GIS-based method for dealing with this problem is the use of network analysis tools discussed in section 4.5 below.

4.5 Network analysis

Despite the usefulness of buffering, the transportation problem outlined above could be more effectively solved using network routines which now exist in many GIS packages. In Arc/Info for example, the ALLOCATE routine is designed to assign features of a network to point locations according to some minimum/maximum travel time constraint. The Arc/Info manual, for instance, actually cites the example of school roll planning: the idea would be to assign pupils living along arcs of the network to various schools according to this time constraint (ESRI 1992, p4.2). Although this is difficult to accomplish with free parental choice the allocation routines could still offer a useful solution to the problem of providing free transport through the definition of time bands radiating from schools along key routes. The analytical routines in GIS network analysis also offer facilities for calculating the optimal route between any start and end point specified by the user. Hence, it would be possible for a LEA to look at school bus timetables and experiment with changing routes and pick-up points.

4.6 Conclusions

Different authorities are necessarily at considerably different stages in their implementation of GIS-based analysis and display of data. Some use it simply for mapping of catchment areas and the display of pupil origins. For many, it is not actually used but is a 'holy grail' which could in the future provide the kind of functionality they require. We hope the argument in the above section gives some guidance on what may be possible in the most straightforward GIS framework. However we believe that traditional GIS provides only part of the solution to the sorts of policy questions outlined in section 3. In the next section we illustrate how the marriage of GIS with spatial modelling techniques could result in a much more powerful analysis system for planners within a LEA.

5. Linking GIS and spatial models

5.1 Introduction

Academics have long advocated the use of spatial models in education planning and there is a wide literature on various modelling procedures. We shall review some of this below. However, it is clear that very little of this has been taken on board by education planners and that such models have a very poor history of real-world applications. The reasons for this are undoubtedly numerous but there have been a few key stumbling blocks. The first is the high degree of complexity to be seen in much of the academic literature. It is only now apparent that modellers are beginning to think hard about the outputs from their research and the need for greater simplicity and ease of interpretation (see Bertuglia *et al*, 1994). The second is the genuine difficulty of transferring much of this research from a suite of often hand-built computer programmes to a robust, easy to use, desk-top planning tool. It is here that the marriage of GIS and spatial models seems particularly appropriate: if we can provide the greater analytical power of some of these modelling environments within a IT framework which is user-friendly then we have at least a fighting chance of their successful application. The third reason may well be the scepticism of planners over the efficacy of models and the concern as to whether they are 'ethically' sound. What follows in this section may sound very much like old-fashioned social engineering which is perhaps becoming less relevant in a market environment. However, we do not believe that LEA planners are uninterested in issues of social justice and equity (see for example Brighouse 1994, Judd 1994b, Hofkins 1995). As we hope will become clear, the methods discussed may afford LEAs the opportunity to reappraise their rôle with respect to schools, and as they lose direct power over schools planning, they may still be able to maintain some form of influence over the development of 'segregation'. This new influence is most likely to take the form of predicting trends in advance and attempting to alleviate the 'worst-case' scenario, perhaps through the production of marketing strategies and management assistance for struggling state schools. What we hope to show is a framework for providing decision support material which simply offers an avenue into a second, much more investigative, analysis of the way in which the education service satisfies its 'consumers' and the consequences of its major reform.

A major research question at the outset is how to link GIS with models in the most effective manner. A number of proprietary GIS packages have begun to add greater modelling capabilities as standard options. Maguire (1995) provides a good illustration in relation to the world's best-selling package, Arc/Info. Such 'direct coupling' is to be broadly welcomed but it can still require a considerable investment of time to learn such programming skills and the models themselves are forced to be fairly simple given the needs for generic solutions which will provide solutions for any common system of interest (retail, health, education and others).

An alternative route is to offer pathways through current GIS menu systems to models which have been developed and calibrated outside the package being used. That is, the models have been run and tested by specialists and the GIS acts as an interface between the model outputs and the planner. This inevitably suggests an element of customisation since the argument involves the use of models designed exclusively for the education system. Model outputs can be transferred into the main GIS environment for storage, mapping, aggregation, overlay and so forth. Such 'indirect coupling' is a key feature of the difference between standard GIS and 'intelligent GIS' or 'spatial decision support systems' (see the detailed arguments of Densham 1991, Birkin *et al* 1995). We shall now look at what models can offer in addition to the capabilities of proprietary GIS.

5.2 Population forecasting methods

GIS have traditionally offered little in the way of forecasting techniques, beyond simple trend extrapolation routines. On the other hand, there is a long history of modelling methods to attack forecasting problems. The forecasting of population numbers is clearly a function central to schools planning. As we argued in section 3, LEAs need to have a good idea of likely pupil rolls for some years ahead if they are to address questions concerning the removal of surplus places and consequent closure/ opening of schools. Various methods of prediction are currently in use. These range from a simple use of birth and infant mortality statistics to very much more advanced, specialist modelling software. At present population forecasting in many LEAs is most commonly based on the projections made by OPCS and Area Health Authorities for births coupled with various forms of annual school return. It is essentially calculated by hand, using the most basic spreadsheet computer functions, and can only really be said to be accurate on an authority-wide scale. Trends at a local scale can be fairly accurately predicted (whether the school-age population will increase or decrease) but beyond this there is considerable difficulty, although for secondary schools in authorities reasonable predictions can be made through the application of known data and experience in spreadsheets. In some LEAs there is use of more complex modelling (see Simpson and Lancaster 1987, Jenkins and Walker 1985), although this is usually as part of a wider council-based project and, as with much GIS, such models are operated centrally. These models are clearly ideal for embedding into a GIS framework, since the rapid visualisation of accurate cohort predictions at various points in the future, say five or ten years ahead, could help planners immensely and potentially save money in closures and/or openings of schools.

To further develop this argument, the plotting of census variables such as young families might offer a useful signpost to future demand on the education service. A more sophisticated procedure is, as mentioned above, to use population forecasting models. Standard 'cohort survival methods' are the most common tool. These can be stated as:

$$P_i(t+1) = P_i(t) + B_i - D_i + \sum_j M_{ji} - \sum_j M_{ij}$$

where

$P_i(t+1)$ Population in i at time t plus one time period

$P_i(t)$ Population in i at time t

B_i Birth rate in i

D_i Death rate in i

M_{ij} Out migration from i to j

M_{ji} In migration from j to i

One such attempt to incorporate population forecasting models within a GIS environment is provided by Rees and Rees (1991) for Swansea and GMAP (1993) for West Yorkshire authorities. The cohort-survival models need good predictions on future births and hence on population movements within the city. OPCS estimates can be linked with estimates of intra- and inter-urban migration (themselves estimated through spatial interaction models – see section 4.4) and local authority house-building and demolition statistics to provide more detailed predictions at say census ward level. The key emphasis here is that relatively good forecasts can be made through the non-trivial combination or overlay of a variety of data sources. This notion of 'non-triviality' puts such forecasts beyond the reach of conventional GIS.

There is clearly a great deal of potential for accurate cohort forecasting methods in the context of education planning, and also, as will become clear in later sections, within most modelling procedures. In this situation there would be a need for the inclusion of robust population prediction routines within any integrated decision-support system, as they can be argued to provide the basis on which much of the other predictive analysis can be built.

5.3 Goal programming models

There is a fairly small body of literature which discusses the potential for the application of what is known as 'goal programming' in an educational context. This method is basically catchment area-based, and attempts to define catchment areas based on certain user-specified criteria. In education the impetus was provided by demographic changes in the late 'seventies and early 'eighties;

> "falling rolls have necessitated the closure or merger of … schools and the generation of a new set of catchment areas" (Sutcliffe and Board 1986, p661)

and these changes were coming at a time of increased criticism of the *ad hoc* planning procedures of local authorities. In at least one case, as Sutcliffe and Board report, there was an investigation into school catchment design by the Commission for Racial Equality. Clearly there was a need for an efficient design mechanism for catchment areas based on the lower pupil numbers and thus ways of defining 'ideal' or 'optimal' catchments through the analysis of pupil flow data.

Goal programming techniques allow such an approach. These techniques produce a series of optimum flows from residential areas to destination zones. In the case of education the model described by Brown (1987; see also Irwin and Wilson, 1985a) builds from a basic interaction model (see section 5.4 below) to ensure the school's capacity is not exceeded and to minimise the distance between homes and schools, thus ensuring that pupils have the shortest possible journey-to-school time. Brown's model then progresses in a similar way to those proposed by Sutcliffe and Board and also by Thomas (1987). In this development the model is further constrained by introducing greater degrees of disaggregation into various pupil 'types' and then ensuring that other factors are minimised or equalised. For instance, the most common example is to produce catchment areas which not only produce minimum travel times/costs to schools but which also produce a 'balanced' school population in racial or social terms, a model which clearly begins to move from one with a purely safety remit (travel time/distance) to one which requires much more of an ethical justification.

The main drawback of this type of modelling approach is the implicit assumption that there is a pliant 'consumer base' which will go to whichever school the authority designates, and that therefore all schools must be equally attractive to pupils who are effectively assignees rather than choosers. Clearly this is not a situation which exists under recent legislative changes in Britain. An LEA no longer has the power to fix catchment areas in this way and force pupils into certain schools selected by 'optimum' catchments (which are themselves defined based on subjective criteria). Clearly this limits the usefulness of a goal programming approach. The only obviously possible application of goal programming would therefore be for the monitoring of an area's population and the production of 'ideal' catchment areas for LEA officers' policy interest only. This would allow authorities to define areas of a city where the introduction of parental preference had had a particularly segregatory effect on sections of the population and perhaps allow them to target additional resources to ameliorate the situation, a far less proactive rôle for goal programming than the original authors intended. Although such routines are not available within existing GIS packages, it seems that there is unlikely to be room for them within an integrated SDSS aimed at authorities in the current legislative climate. Their purpose, for the time being, would seem to be confined to providing additional information of interest outside the main arena of planning, if such additional information is required.

5.4 Multilevel modelling

Multilevel modelling (MLM) is an approach based on the statistical technique of regression, and aims to take into account a range of factors which might influence a child's exam results. Thus, it is a particularly useful approach, in theory, for addressing the question of how to 'soften' the hard indicators of exam success in order to take account of social factors. MLMs are designed to take account of not only child-level data (for instance) but also the effects that schools, homes or some other level or set of levels might have on those children. In their simplest form MLMs take just two levels of data, which usually 'nest' with each other hierarchically, but it is possible to expand the approach to take into account more levels or more complex interplay between them (see Goldstein, 1987).

There is a wide literature on the subject of the multilevel analysis of data, including much on education, and this is not the place to cover it all. This brief, simple description is based mainly on Paterson's (1991) account, which provides an excellent introduction to the methodology of MLM. The multilevel approach recognises the fact that there are differences between schools in terms of the 'effective' delivery of education as well as differences between pupils from different residential backgrounds. To this end, it is clear, that if we follow the example of socio-economic status' effect on examination attainment, children of equal socio-economic status (SES) may not necessarily achieve the same results if they are at different schools. Thus success is driven by both pupil and school factors;

> "regardless of whether they come from different schools, the observed difference in attainment between [two pupils of different SES] will arise from two sources: general association between attainment and SES, but also

the chance factors that would cause any two pupils to differ even if they had the same SES" (Paterson 1991, p17).

These will be factors which are perhaps associated with the school, perhaps with some other psychological or physiological influence on the child. Hence, ordinary regression "could attribute to SES some attainment differences that were actually the result of school practice"(Paterson, p21). In an attempt to iron out this problem, MLM rewrites the standard regression equation so that each school has its individual regression line;

$$\text{attainment}_{ij} = a_j + b_j\,(\text{SES})_{ij} + e_{ij}$$

where the subscript *i* refers to pupils and *j* refers to schools. Attainment is therefore in pupil terms (the attainment of pupil *i* at school *j*); *a* refers to the point at which the line crosses the vertical axis on a graph of SES against attainment, *b* the slope of the line. The subscripts *j* allow the line to vary between schools. SES refers to the socio-economic status of pupil *i* at school *j* and *e* is used to account for the discrepancy between actual and predicted attainment when defining attainment purely in terms of SES. This is used at an individual pupil level, hence the addition of the *i* and *j* subscripts.

The standard MLM software then provides additional statistical tests to establish whether estimated differences in the effects of schools have occurred by chance because of the sample or whether they are likely to be a feature of the population as a whole. It can also test factors used to try and explain the variation between schools. In Paterson's example school size is used and produces the hypothesis that "a pupil of average SES would have higher attainment in a larger ... school" (p24), although he qualifies this by acknowledging that school size is likely to be a proxy measure for other factors, such as a wider range of teacher skills or more facilities in classes.

Clearly MLM has a great deal to offer those concerned with educational performance. It can take account of a range of data (although there is a need to define 'socio-economic status' in quantitative terms) and judge the likely effect of that data on outcome data such as examination results. However, it is also clear that there is very little explicit consideration of the effects of space on school outcomes. The use of socio-economic data implies that children will be from different areas from each other, but there is no real concern in the model as to where that is. From a number of points of view this could be seen as a failing. It is apparent that a child's address makes a difference to his or her socio-economic status, but it also affects that child's choice of schools, and thus the possible range of in-school influences on attainment (see Boudon 1974, Mortimore and Blackstone 1983). However, there is no reason why a MLM approach could not provide the basis for a series of performance indicators based on quantitative data which could then be used as inputs into a spatial interaction model (see below). They do not, however, provide a complete solution to the problems facing educational planners.

5.5 Spatial interaction models

We argued at the end of section 3 that LEAs need robust methods for impact assessment and briefly in section 4 that GIS overlay and buffer facilities were insufficient for this task. In simple terms, the overlay/buffering analysis is too simplistic: catchment areas are never circular around a school (see figure 4.4) and pupils within that buffer may attend a large number of schools over a wide residential area. Hence the analyst has the difficult exercise of deciding how many pupils in a given buffer would go to the new school (see Beaumont 1991 for examples of how this is handled in retailing). What is required is a method which can explicitly handle flows or interactions, and spatial interaction models have a long history of successful application to catchment area analysis (both for existing and for new developments) (Birkin *et al*, 1995). A typical model for the journey to school could be given by:

$$T_{ij}^{aw} = A_i . O_i^{aw} . W_j^{aw} . e^{-\beta^{aw} d_{ij}} \qquad [1]$$

$$A_i = \frac{1}{\sum_j W_j^{aw} . e^{-\beta^{aw} d_{ij}}} \qquad [2]$$

where;

T_{ij}^{aw} is the flow of pupils of type a (age) and w (social class) from residential zone i to school j

O_i^{aw} is the distribution of pupils types a and w in residential zone i

W_j^{aw} is school size or attractiveness for pupils (or parents) of types a and w

β^{aw} is a parameter governing the average distance travelled to school by pupil groups a and w

d_{ij} is the distance travelled from home i to school j

Once the models have been calibrated to reproduce the actual flow matrix within a city they can be used to test the impacts of school closures, openings, reductions in size and so forth. Hence, it would be possible to test what the most likely redistribution of flows would be if a school were to be closed and what impacts this would have on pressure for places at remaining schools in the area. Although reorganisations are not commonplace, the issue of surplus places is very much still with us (see section 3) and these models could still play a useful rôle in impact assessment. The Leeds LEA spent much of the 1980s trying to produce the 'optimal' reorganisation of school places given considerable changes in the population geography of the city. This involved a complex consideration of school closures, mergers and openings. If one considers that this involves over 1500 school buildings throughout the city it is easy to see the benefits that a GIS-based set of interaction models would have brought over and above the more manual methods actually used.

In addition, spatial interaction models can be useful for designing new forms of performance indicator for educational facilities. Irwin and Wilson (1985a,b) designed a suite of indicators for education planning based on the variables contained within, and calculated from, spatial interaction models. As mentioned in section 3 we need such indicators, not related to single zones, but which take account of the spatial interactions between zones. They designed indicators to represent 'efficiency' (mainly associated with costs), 'effectiveness' and 'equity'. It is interesting to revisit these indicators in the light of concern over such issues caused by the new market environment. The debate concerning measurement of school performance is helped by the definition of two sorts of performance indicator (*cf.* Clarke and Wilson, 1994); residential (relating to pupils and residential areas) and facility (relating to schools). A major research task is to define a suite of residential performance indicators that may be able to offer alternative indicators to the hard indicators of exam success/truancy rates *etc.* As Simkins (1994) emphasises, these are clearly the 'effectiveness' indicators which the government sees as important. Alternative indicators need to concentrate on social background, the residential environment of the pupil and previous levels of attainment (*cf.* Moulden and Bradford, 1984). The importance or influence of some of these variables has been investigated through multi-level modelling (MLM) procedures on individual pupils – see section 5.5.

To make progress we can build in the arguments of Irwin and Wilson (1985) and Clarke and Wilson (1994) in order to define:

$$c_j^{aw} = \sum_i \frac{T_{ij}^{aw}}{T_{i*}^{aw}}$$

where c_j = catchment population of school j

Then indicators such as;

$$\frac{E_j^{saw}}{c_j^{aw}}$$

where;

E_j^{saw} = passes at school j in exam subject s by pupil types a, w

c_j^{aw} = catchment population type a, w in area j (where c_j is calculated as above)

become interesting to measure. A fuller list of the range of efficiency and effectiveness indicators which it is possible to build using the arrays $\{T_{ij}\}$ and $\{c_j\}$ are shown in figure 5.1. It would be useful to explore variations across schools for such indicators.

In addition, research on the social mix of school catchment areas might offer greater insights into the equity of current funding procedures at the local level. Although funding is now based on a *per capita* basis there are discretionary amounts available for the LEA to top-up budgets for those schools it perceives as 'underprivileged' in some way. These additional funds are often distributed in line with historical patterns of resource allocation. Simkins (1994) suggests this reaffirmation of traditional funding has been reinforced by the pressures to minimise the number of additional 'losers' and 'winners'. Some LEAs base their discretionary payments in relation to the number of pupils granted free school meals, now the commonest indicators of deprivation used in LEA planning. Whilst there has been some research to find alternative measures these have tended to concentrate on variations within in-school activity rather than on residential environment or pupil background (see Kelly, 1992).

The LEA is able to produce accurate measures of market penetration for each school without the need for modelling research because of its access to full flow data for the schools in its area. However, individual schools may only have access to their own pupil address data. In this case, the only methods for estimating market penetration are model-based. In this sense the spatial interaction models would operate in a traditional private sector style; to help target areas where 'market share/penetration' was low.

It is our contention that the use of accurately devised and calibrated spatial interaction models could be made to sit at the heart of the policy and planning units of LEAs and the Funding Agency. Their widespread application in the private sector, and retail planning in particular, provides an excellent example of the efficacy of such models in assisting the process of facility location and flow prediction. As planning in education becomes an increasingly market- and finance-oriented process, and the retail analogy becomes more relevant, so the application of private-sector methods seems more appropriate. In addition to this, modelling methods and the increases in predictive power and efficiency in planning which they bring, can provide an avenue for future planning regardless of the direction taken by legislation. Capital projects in our schools will always be expensive, and if costly mistakes can be avoided by the adoption of long-term model-based development strategies then surely that is to the benefit of all concerned about the future ability of Britain's education system to support children in the most efficient manner.

5.6 Dynamic models

Once again, the argument proceeds by noting that GIS does not have a good record of applications based around time-series data and hence dynamic processes. However, the development of dynamic models based on spatial interaction principles does have a long tradition (see Clarke and Wilson, 1985).

The main aim of dynamic models in an educational framework would be to monitor and to predict the likely consequences of parental choice and competition if the market environment has a free hand. As we saw in section 4.3 the traditional catchment area modelling based on goal programming or optimisation becomes less relevant as a planning tool since, with greater powers of parental choice, LEAs have lost their power to set catchment area boundaries according to some overall welfare criterion. For this reason it seems appropriate to examine methods used in the private sector and investigate their potential in the public sector. The ideas are based on predicting the possible growth/decline of different schools over time as their attractiveness to parents waxes and wanes. If a school has very good exam successes then it will become more attractive to parents (and the evidence of figure 4.10 would seem to suggest that this is currently happening). As its school roll increases so pupils will transfer from other schools. These are most likely to be those who are best informed and those which can afford additional transportation costs associated with school transfer. As we saw at the end of section 3, there is great concern that this is most likely to be pupils from middle/upper class backgrounds. In turn, this leaves poorer performing schools with a reduced roll and a pupil intake much more likely to be from parents who do not have the means to support school transfer. In sum, schools with the best performance scores might be in a strong position (especially if intakes reach their upper limits) to cream off more able pupils from better backgrounds leaving a residual pupil base in inner city schools or lower income parents who have little choice in where their children are educated (*cf.* Bradford, 1991).

Figure 5.1: Indicators from a model-based framework

Use of facilities

T_{ij}^{aw} number of (a,w) type pupils from i at j

a_j^{as} number of hours of subject s demanded by type s pupils at school j

b_j^{as} average class size

$$\frac{\sum_w T_{ij}^{aw} a_j^{as}}{b_j^{as}}$$

cost of subject s for year a at school j

$$\frac{\sum_w T_{ij}^{as} a_j^{as} \gamma_j^s}{b_j^{as}}$$

number of s staff hours needed for a pupils at school j

$$\frac{\sum_{isw} T_{ij}^{aw} a_j^{as} \gamma_j^s}{b_j^{as}}$$

cost of year a at school j

Efficiency

$$\frac{\sum_{iaw} T_{ij}^{aw}}{\sum_{vs} U_j^{vs}}$$

Pupil-teacher ratio

$$\frac{\left(\sum_w T_{ij}^{aw} a_j^{as} \gamma_j^s \big/ b_j^{as}\right)}{\sum_v U_j^{vs}}$$

Cost per staff hour for subject s in year a at school j
(There are many indicators similar to this)

Effectiveness

E_j^s Number of passes in subject s in final year at school j

$$\frac{\left(\sum_w T_{ij}^{fw} a_j^{fs} \gamma_j^s \big/ b_j^{fs}\right)}{E_j^s}$$

cost per pass; f indicates final year
(this will also be a product of investment in earlier years, of course)

$$\frac{E_j^s}{\sum_w C_j^w}$$

exam pass per head of catchment population

$$\frac{\left(\left(\sum_j T_{ij}^{**} / T_{\bullet j}^{**}\right) E_j^s\right)}{T_{i\bullet}^{**}}$$

could therefore be taken to be the pass rate per head of residential population, and similar indicators could be calculated for all cash and staff resources.

based on Irwin and Wilson (1985)

The aim of the modelling process is thus to monitor these events, highlight such concerns when and where they are likely to arise and help prevent worst-case segregation scenarios actually developing. This may mean producing marketing strategies for individual schools so that they are best able to counter market forces. If we define D_j as the number of pupils attracted to a school j, and K_j as the costs of supplying W_j places then the model dynamics work as follows (*cf.* Harris and Wilson 1978);

If $D_j > K_j W_j$ then W_j will expand
If $D_j < K_j W_j$ then W_j will contract

At equilibrium $D_j = K_j W_j$ for all j

The modelling exercise is to build suitable interaction models to calculate likely patterns of D_j (see section 5.5). These can then be used to inform the process of definition of 'problem areas' in an authority and thus the production of strategies to counter any undesirable trends.

The 'policy' exercise is to determine the factors which make up the attractiveness of individual schools. This is clearly a very difficult and contentious issue. The Government rhetoric is that attractiveness will be defined by performance indicator scores and the publication of league tables. This is one form of attractiveness which could be inputted into the models. However, it is far from certain that parents will react consistently in this way; they may well also look at transportation, sports facilities, after-school clubs *etc.* The important factor for the modelling exercise is that a variety of attractiveness terms can be included and the impacts forecast on an experimental basis. More research on parental reaction to the reforms and league tables will eventually guide the modelling exercise in a more purposeful manner.

6. Conclusions

It can be seen that a number of LEAs around the country are beginning to realise the potential benefits of GIS to their operations. The various sections of the education departments which do use GIS use it for very similar purposes, namely for the display of data held or at most for overlaying pupils onto other data. However, the development is somewhat piecemeal, and there is very little usage of integrated spatial modelling procedures. We believe that this ability to predict accurately is a function which sits at the heart of the efficient planning of schools at all levels and is one which can be made to sit within an integrated GIS, as shown in sections three and four. We recognise however that there are other difficulties with the current use of GIS in LEAs. The fact that many of the systems in use are not native to the education departments can be a hindrance, and so although they make extensive use of geographic data, any mapping or analysis must be carried out on demand by another department, in most cases the planning department. This means that such analyses are not necessarily integrated into the normal procedure of the education department, and are found useful but at present are not a *de rigeur* part of the planning process. It is possible that a greater use of GIS containing more customised and complex geographical techniques might in time enable decisions to be taken more swiftly and provide a more efficient employment of the large datasets available to the education departments of local authorities.

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