GIS IN HEALTH AND SOCIAL CARE PLANNING

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ABSTRACT

The application of GIS and GI science approaches within health and social care has been an established area for research for over twenty years. The chapter identifies core theoretical concerns with topics such as: supply, demand, need and choice in health care, and examines some of the ways in which these notions have been modeled quantitatively in applied settings. In addition, summaries are provided of previous research in the sub-themes of accessibility & utilization, health inequalities, location-allocation modeling, epidemiology, service planning and health informatics. The second part of the chapter examines three research case studies carried out by the authors in the UK and Ireland around the areas of: a) cross-border hospital accessibility, b) geographically-weighted regression modeling of illness data and, c) the planning of social care services. The final section identifies some future directions for work under the wider headings of spatial data, analysis and visualization.

KEYWORDS

Health care, Social care, modeling, spatial data, visualisation

1. INTRODUCTION

Given the inherent spatiality of health and the organisation of structures within society to manage health, it is no surprise that geographers have developed an interest in the subject in a variety of ways. Driven primarily by relationships between health, place and space, geographers and other subject specialists from computing, medicine, mathematics and statistics have researched spatial modelling aspects of the management of health care (Gatrell and Löytönen, 1998; McClafferty, 2003). Prior to the 1980s much of this exploration was carried out using quantitative models but with improvements in computing power, new forms of geocomputational modelling and analysis have been developed (Joseph and Phillips, 1984; Gatrell and Senior, 1999). As an analytical tool, GIS have been at the core of those explorations, while the increasingly common term, GI Science also frames that analysis as a process and a paradigm (Wilson and Fotheringham, 2008). One focus of this chapter will be on exploring the quantitative and theoretical aspects of how health care is modelled and theorised in spatial analytical terms. This is also linked to an improved reputation within health for the potential of spatial approaches as GIS becomes increasingly embedded in health care systems (Croner and Sperling, 1996; Gatrell and Senior, 1999; Melnick, 2002; McLafferty, 2003; Smith, Higgs and Gould, 2005). At the same time social scientists have also become interested in other aspects of the organisation of health in society and the more qualitative elements that shape that structure. These more theoretical and applied aspects have in part led analysts to consider some of the more formative aspects of health care, including social care. They also suggest the need to link people more fully into the systems to provide more effective modelling (Couclelis, 2003; Elwood, 2006).

The core concerns for these particular branches of theoretical and quantitative geographies have strong foundations within economic, biomedical and to a lesser extent, social geographies. As state systems in all these areas developed after the First World War and in to the 1960s, the quantitative revolution in the subject became a strong driving force for early research on these topics (Hubbard et al., 2002). Well-known examples of the kinds of quantitative models developed would include Christaller's Central Place Theory and Hägerstrand's early models of diffusion (Dicken and Lloyd, 1990). The former theoretically modelled the hierarchical nature of urban networks and their spatial organisation while the latter was interested in how spatial phenomena varied and developed over time and across space. Both were applied to an extent within medical geography and indeed acted as markers for the main initial divisions of interest in the subject, namely epidemiology and health care planning (Joseph and Phillips, 1984; Cliff and Haggett, 1988). Much of the early modelling, while theoretically very sound, was also partially hamstrung by two core barriers: access to detailed spatial data and the lack of processing power. Despite this, there was some effective cartographic research in the area of mapping disease, using examples such as measles, influenza and later, HIV/AIDS (Cliff, Haggett and Ord, 1986; Cliff and Haggett, 1988). With the advent of desktop computing power and improved access to electronic data records, these problems were partially tackled in the 1970s and early 1980s. A third issue related to how these data could be effectively visualised so as to bring out the inherently spatial aspects of the modelling. Traditional cartographic approaches were applied in the medical/health arena and as a result there was a reasonably strong tradition of medical mapping include some good historical, if contested examples from the work of John Snow and William Booth around cholera and poverty and Mourant on blood group distributions (Mourant, 1954; Cliff and Haggett, 1988; Koch and Dennike, 2006). How these three main elements, spatial data, spatial analysis and spatial visualisation, remain at the heart of all subsequent work in this field will be explored throughout the chapter and will form its primary aim (Fotheringham, Brunsdon and Charlton, 2000).

As a subject, medical geography emerged primarily from Germany (as *GeoMedizin*) and Russia in the 1940s and 1950s. In turn taken up in the English-speaking world, especially in the US, UK and Canada, the subject developed along two broad lines from the 1970s onwards. Focused firmly on health care planning, a concern with modelling effective spatial structures for service planning was to lead into much of the early quantitative work around modelling optimal locations of health services as well as looking into the equitable distribution of those services (Jones and Moon, 1987). The other main strand within medical geography related to epidemiology, the distribution and management of disease, driven by ecological theory and using diffusion modelling as one effective way of mapping and predicting the spread of disease (Gatrell, 2002). While this latter strand will be discussed briefly in this chapter, the focus is very much on the planning and service aspects of the subject. The two are clearly linked in that services are put in place to combat disease and the location and supply of services are in some ways determined by the demand created by the location and spread of disease. In addition, social care, in the form of support services for the poor, the elderly and people with disabilities, also has a strong service dimension which requires planning for both the delivery of those services and their integration with health care. Nonetheless, current understandings of health and social care planning spread well beyond the curative aspect of the subject. Indeed it could be argued that a strong focus on the planning aspects, in terms of improvements in access, social supports, preventative health and health promotion initiatives, are key steps in reducing disease in the first place and require more attention (Curtis, 2004).

The rest of this chapter will consist of two main sections. The first one will provide a critical literature review which looks at how theoretical and quantitative geography perspectives have been developed and used within health and social care planning. It will look at the range of theories, problems, methodologies and models developed around the broad themes of data, analysis and visualisation and seek to critically examine where the subject situates itself in late 2008. The second half of the chapter will summarise some examples of work that the authors have been engaged in for the past decade and will be drawn from the UK and Ireland to demonstrate how those themes have been addressed. A final section will look at where the future may lie and suggest some ways in which the attention of quantitative and theoretical geographers and computer scientists can be effectively directed into the future of health and social care planning. At all times, the work will have a very strong emphasis on services and their associated planning.

2. RECENT ADVANCES IN HEALTH AND SOCIAL CARE PLANNING.

2.1 INTRODUCTION

Before embarking on a survey of work in the areas of health and social care planning, it is helpful to briefly list some of the core theoretical issues for researchers working in this area and identify the kinds of problems researchers have been grappling with over the past three decades. This is helpful in framing how subsequent quantitative approaches have sought to tackle these problems. The discussion will focus on empirical issues and not on the underlying political and ontological ideas which shape health care systems in the first place, though any meaningful study of how health and social care planning functions is shaped by how those services are organised within any single country. Nevertheless the same core issues commonly emerge no matter what type of health care system operates. In a summary document on the then current themes in the US, McLafferty (2003) identified four headings around which GIS and Health Care more generally might be studied, namely: need, access, utilisation and the evaluation and planning of health services. This provides a useful starting point for this work as well.

At the core of any health and social care planning discussions are the simple theoretical constructs of supply and demand. In a perfect system, supply would match demand. For geographers, this would be represented spatially by the correct placing of services in urban and rural settings to exactly match demand in those areas. It is probably fair to say that such a system does not exist anywhere in the world. Indeed in many countries, especially in the global South, systems barely exist and huge demands swamp limited supplies (Meade and Earickson, 2000; Curtis, 2004). Even in the more developed global North, similar inequalities exist, albeit on nothing like the same scale. Where those mismatches occur and at what scale remains a primary interest for geographers and identifies a role for spatial approaches in health and social care planning. In addition, the ways in which supply and demand operate in the real world are multiple and complex. One might consider a number of additional factors which add to the theoretical difficulties spatial planners face, namely equity or effectiveness, need and time (Rushton, 1998; Goddard and Smith, 2001; Guagliardo, 2004; Yuan, 2008). Equity within health care systems relates to notions of fairness and equal supply to meet equal demand. But this is skewed so that supply is often structured unfairly whereby unequal supplies operate in some areas when measured against need. Some examples of this might be the over-supply of general practitioners in urban areas as opposed to rural areas, a phenomenon observed in the US, China, France and the UK (Vigneron, 1997; Gatrell, 2002). Another example which is particularly relevant to geography is the notion of the Inverse Care Law, where proximity to a supply seems to be a more marked explanatory factor than need-based demand (Curtis, 2004). A further complicating factor is the linked concept of effectiveness (often mentioned in conjunction with efficiency), whereby health and social care planners need to make some judgements on how best to provide supply to meet what they perceive as realistic demand while at the same time spending limited funding in as efficient a way as possible (Oliver and Mossialos, 2004). Clearly there are conflicts between planning and the operation of equity or effectiveness based systems. Many of these are outside the control of theoretical and quantitative modelling but it does suggest that such models should be flexible and complex enough to take these structural elements into account.

Linked very strongly to the term demand is the notion of need. Demand is an all-encompassing term so that within any planning system, provision must be made for different forms of need. In most societies, the supply of services may have to be weighted in favour of those groups within society, namely, the very young, the elderly, the poor or the excluded, who are most likely to be in need. These considerations add considerably to the simple supply versus demand model but must be considered in any theoretical and quantitative model of service planning (Weiner and Harris, 2008). A final complicating factor is time. Clearly it is one thing matching supply to demand in a fixed time period but planning is very strongly associated with predictive capabilities. Any meaningful planning system should have the capacity and indeed aim, to try and model future supply and demand as well. This is often difficult and subject to many additional factors which are again, often outside the control of the planners or modellers (Curtis, 2004; Charlton, 2008). All three of these areas provide challenges, but also opportunities for health and social care planners and some of the ways in which these challenges have been met will be outlined in the rest of the literature review below.

Clearly for theoretical and quantitative geographers, the kinds of problems listed above provide a rich framework for their fertile imaginations. When need, demand, supply and additional elements such as choice and volume need to be expressed spatially, the use of geo-computational approaches seems simultaneously ideal and under-exploited. Plotting the relationships between these different concepts has been led by a number of statistical approaches which in turn have helped develop the medium of spatial statistics (Fotheringham, Brunsdon and Charlton, 2000). Regression and correlation have been used to look at and understand underlying relationships between expected and observed health patterns and has derived some useful explanations from these. Some of the more planning-specific aspects are also driven by spatial theory especially around identifying optimal locations for services when weighted by existing patterns of supply and demand. In addition, the increasing technical power of computing has led to much more rapid and sophisticated modelling of different scenarios so that multiple choices can be modelled and best results identified. Within the geo-computational models, much of the research has been around improving the quality and precision of how that modelling is carried out. For example the development of improved estimations of kernels and associated aspects of spatial statistics has continued to drive work in this area (Fotheringham, Charlton and Brunsdon, 2000; Jacquez, 2008; Wilson and Fotheringham, 2008)

Mindful of the ontological and epistemological backgrounds and the technical concerns discussed above, the remainder of this section will explore recent work in a number of sub-themes of health and social care planning. Within each sub-theme there will be an implicit link to the core themes of data, analysis and visualisation. Accessibility and utilisation has been a common theme in health and social care planning which in turn has links with ways of studying and measuring health inequalities. Theoretical work around the areas of location-allocation and optimal location modelling is then examined followed by a more epidemiologically focused section. The following section discusses a summative theme, namely that of service planning and how policy is theorised, modelled and achieved. A final section focuses on what is an increasingly public and open interface between health geographers, medics, statisticians and the general public. With the increasing embeddedness of GIS in public life and the role of the internet in broadening both knowledge and expectations around health information, the potential for GI Science to take its potential into the public arena is considerable but must be approached with caution.

2.2 ACCESSIBILITY AND UTILISATION

While the subject of modelling accessibility to health care is more comprehensively and fully explored in a separate chapter in this book (Morrissey, 2009), it still has important links to other aspects of health and social care planning and will be briefly discussed here. One of the original core texts in the subject by Joseph & Phillips (1984), explicitly studied the twin terms accessibility and utilisation. In addition, any study of access to and utilisation of health care needs to be aware also of the core concepts referred to previously such as need, equity, supply and demand. A large number of authors have incorporated some of these elements into their spatial data requirements which in many ways are fundamental to the modelling of accessibility and utilisation. For example, geographies of supply are expressed through counts of the number of hospitals, their physical location and configuration and the relative size of those hospitals and numbers of services provided (Luo and Wang, 2003). Demand is often measured through utilisation but there are issues here in terms of how fully demand identifies need in a setting where waiting lists and staffing shortages are not unknown and where the structure of the system itself shapes utilisation rates. Need is also a complex term with a number of different definitions relating to expressed need in the form of presenting patients and unexpressed need within the wider population (Joseph and Phillips, 1984). Finally equity can be expressed in a number of ways, depending on whether one uses a vertical or horizontal definition (Goddard and Smith, 2001) or even whether one takes a measure based on a population or catchment based approach (Christie and Fone, 2003). The work of Khan and Bhardwaj (1994) is particularly useful in developing a fuller understanding of what they refer to as spatial and aspatial aspects of accessibility. The aspatial aspects include a wide and complex set of variables including income, education, social class, insurance and other social and economic factors, which affect how people access and utilise health care. They identify these as being separate but linked elements to the more purely spatial aspects of location, distance, time and supply which provide the other part of the equation. Together these provide a fuller integrated model. In addition, utilisation can often act as a confounding factor when combined with accessibility measures in that it sometimes merges measures of 'supply' with proxy measures of 'demand', especially for use in a health policy setting (Oliver and Mossialos, 2004).

The core traditional approach used by medical/health geographers has been to focus on a number of core spatial datasets and use these in the modelling of accessibility. Some of these approaches have been used before the widespread use of GIS and digital spatial data (Horner and Taylor, 1979; Joseph and Phillips, 1984). The arrival of the latter has, however, allowed for more efficient and effective modelling using a number of new spatial analytical techniques. In general terms, modelling spatial accessibility has involved the following key spatial data. Firstly, the location and distribution of health care facilities often forms a first layer of information. While much of the research has focused on secondary and tertiary care, other services associated with primary care, community care and even voluntary services have also been modelled in this way (Bullen and Moon, 1994; Foley, 2002). A second core element is a layer that incorporates demographic data and the distributions of different populations. These function as proxies for demand/need and can be broken down into sub-populations depending on the services being modelled (Love and Lindqvist, 1995; Teljeur, Barry and Kelly, 2006). A final layer of information needed is information on the transportation network used to model the spatial linkages between patients or potential patients and services. This was traditionally modelled as Euclidian or straight-line distance which often enabled planners to quickly see buffers or catchments zones around hospitals and to visualise quickly those areas or groups who fell outside those areas (Kumar, 2004). Other visualisation approaches which have been enhanced by GIS include spider-graph approaches showing linkages between patient and service as a series of straight lines (Bullen and Moon, 1994; Campbell and Parker, 1998).

With the advent of GIS the ability to overlay and merge these three different layers within a single automated information system has been recognised as providing an important new evidence base for health care planning (Gatrell and Löytönen, 1998). Brabyn and Skelly (2002) took these core elements and combined them in a vector (linear) GIS to model access to public hospitals by travel time across New Zealand. They identified an effective accessibility score by area, weighted by population which also incorporated a locally relevant remoteness factor. Such a concern for local topography was also reflected by Lin et al. (2002) who studied access to hospitals in British Columbia in an area also characterised by mountains and a limited road network. They produced a tabular output by district which also incorporated existing utilisation data to weight the model. A final example of this straightforward spatial modelling was provided by Christie & Fone (2003) who used the same methodologies to look at access to tertiary hospital services in Wales. In their example, they used GIS to help tabulate travel time by social groups (weighted by deprivation score) to look at equity of access to very specialist services, which unsurprisingly was biased towards the more affluent urban dweller, a finding consistent with much accessibility modelling work.

Some of the studies above GIS to produce more robust forms of spatial modelling, by moving beyond Euclidian distance to include consideration of travel distance along road networks and even more usefully, travel time. Additional sophistication was provided by studies which looked at incorporating public as well as private transport into the models (Martin et al., 2002; Lovett et al., 2002; Jordan et al., 2004). These studies looked respectively at Cornwall and Norfolk and added public bus and train networks to the previously modelled road network to try and get a fuller picture of levels of access. Martin et al. (2002) also developed their model as a raster (surface) approach which is the other method feasible within a GIS and this was replicated by Luo and Wang (2003) who developed a model of access to primary care in the Chicago area based on a raster travel friction approach. They also used the power of the GIS to develop a gravity model approach which incorporated floating catchments weighted by location and population. This approach was also developed by Guagliardo (2003) in a similar study of access to primary care in Washington DC with the additional spatial modelling element of kernel density which effectively modelled the effect of service clustering and the subsequent impact on access. Other GIS approaches have focused on specific services within hospital provisions with interests in maternity and other specialist services (Beere and Brabyn, 2006; Schuurman et al., 2006).

Another valuable example is the work of Damiani et al. (2005) who used a surface model approach to measure access to acute hospitals which in turn was weighted by a measure of choice, as expressed through levels of available beds. In this way, a normal mapped result, which identified rural and remote areas as poorly served, was considerably modified when the impact of waiting times and available beds was fed in. In the modified version, areas around the South East and South West of England showed up as under-served, an interesting example of how demand and supply affect the original models. In all cases, the ability of GIS to effectively visualise accessibility in the form of vector time maps and raster accessibility surfaces have allowed for ready analysis and interpretation as both a pointer to and a time-saving short-cut for subsequent explanatory analysis. Finally the work of Robitaille et al. (2008) points to ways in which accessibility can be measured not just to services, but rather to its opposite, sites of health risk. In this case, the location of gambling machines in Montréal is used to model risk and vulnerability to health-endangering behaviours, within a GIS. Each small (dissemination) area was mapped with a gambling vulnerability score which in turn was spatially weighted using gravity model and LISA spatial autocorrelation methodologies, to identify locations for targeted health promotion interventions (Anselin, 1995).

2.3 EQUITY AND HEALTH INEQUALITIES

Apart from the more service-specific areas, much of the work of medical geographers and cartographers has also focused on the related issue of health inequalities. Some of the early cartographic work in the UK by the likes of Howe (1972) focused on mapping spatial variations in morbidity and mortality to draw attention to inequalities across regions and even within cities. This work was taken up by a number of early applied users in the late 1980s and early 1990s though it took till the late 1990s for it to become mainstream in the National Health Service (NHS) in the UK (Gordon and Womersley, 1997). In the US the use of GIS in visualising and analysing health inequalities was developed at an earlier stage principally through the work of Gerard Rushton, Chuck Croner and Robert Earickson (Gatrell and Senior, 1999; Rushton, 2000; McLafferty, 2003). In the same period European research, often with an epidemiological flavour was also developing strongly in areas such as water quality (Kistemann, Dangendorf and Exner 2001; Crabbe, Hamilton and Machin, 2004), and motor neurone disease (Sabel, 2000).

Quantitative measurements of health inequalities have taken a number of forms. There is a clear relationship between wealth and poverty and the different measures of health inequalities. Put simply, the rich traditionally have good indicators for health while the poor bear the burden of ill-health. A simple starting point for many geographers is to look at how these relationships are expressed spatially by mapping income against health indicators (Wilkinson et al., 1998; Driedger et al., 2007). For many countries, spatial data on income is hard to access. This is less of a problem in some Western European and Scandinavian countries but elsewhere the mapping of poverty and deprivation is more problematic. To get around the absence of direct measures of poverty and wealth, the development and creation of mathematically derived deprivation indices has been a common response. This was initiated in the UK with an explicit health focus to measure the extra income needed by general practitioners (GPs) working in deprived areas but has since developed a much wider suite of applications in both health and social care planning (Jarman, 1984; Noble et. al, 2004). Typically a series of relevant census indicators are chosen, standardised, weighted and then combined, often based on simple statistics but sometimes using principal components analysis to come up with a final score (Townsend and Davidson, 1982; Haase and Pratchske, 2005). Other innovative approaches include the use of associated multi-criteria analysis to develop the creation of deprivation scores (Bell, Schuurman and Hayes, 2007). These scores can then be applied as either an absolute or relative measure, with the latter being used more widely in policy interventions (Kelly and Teljeur, 2004; Philibert et. al, 2007). There are a number of technical issues with the ways in which deprivation indices are created, especially as new versions have begun to combine global scores with domain specific subsets such as employment, access and health (Noble et. al, 2004). Principal amongst those are the choice, type and relative weighting of indicators, technical issues with standardisation and the shrinkages applied in creating final scores and the geographic scale of their application within administrative units (Pringle et al., 2000). All of these are and have been contested, but despite the fact that there are on-going issues with their construction, deprivation indices remain popular proxies of poverty. In turn they also provide a valuable denominator for the spatial modelling of health inequalities and geographical areas with high relative and absolute deprivation scores have been shown to have a persistent and strong association with indicators of poor health (Curtis, 2004). This is a common finding whether it is a study of the suburbs of Glasgow, the *banlieu* of Lyon or downtown Montreal. Other ways in which the associations between place and inequalities in health outcomes have been measured include the afore-mentioned standardised approaches, in this case through the production of single indicator measures. The relationships between ‘poor places’ and poor health is a strong one and GI Science provides an ability to measure morbidity and mortality in more sophisticated ways. Clearly to enable effective scientific comparison between places, there is a need to provide age and gender standardisation with the raw morbidity or mortality data (Bailey and Gatrell, 1995; Longley et al., 2005).

From an exploratory spatial data analysis perspective, other theoretical problems relate to the scale and size of the units for which comparisons are made. Detailed spatial units, whether wards in the UK, *Départements* in France, *Gemeinde* in Germany or mesh blocks in New Zealand, are rarely homogenous in either size or population. In addition rural units are typically larger, but with smaller populations, than their urban equivalents. A number of statistical techniques have been applied to try and account for this spatial heterogeneity. Bayesian shrinkage approaches have been used to try and bring extreme values and outliers closer to the mean values (Langford, 1994; Johnson, 2004). A persistent issue in mapping health data to areal units is the modifiable areal unit problem (MAUP) whereby the distribution of observations may be aggregated to different areal units and thereby exhibit completely different patterns of density. A number of researchers have studied, and continue to study, this problem. One approach is to increase the levels of homogeneity in the basic building blocks and work in this area is being carried out by the National Centre for GeoComputation (NCG) in Ireland whereby a new geography of 'atomic small areas' has been designed to improve the homogeneity and level of detail of census units for the forthcoming 2011 Census. Other approaches return to the raw data and use a number of interpolation-based surface models to essentially bypass the MAUP problem through the creation of health and population surfaces (Openshaw and Taylor, 1981; Marceau, 1999; Shuttleworth and Lloyd, 2005). A final issue relates to comparative work between jurisdictions which may use different types of spatial units. In these cases a variety of approaches to unit modification in forms such as weighted aggregation and splitting are necessary to enable meaningful comparisons to be made (Gleeson et al., 2008)

The use of multi-level modelling has also developed apace in the last decade or so with an increased interest in the spatial variation of health-place relationships when examined at a number of different scales. This is not unlike concerns about using global relationships to model at a local level expressed in other statistical settings, but essentially the use of multi-level modelling allows analysts to look at regional or local variation against a national standard. One example was the work carried out in the north of the UK by Jones et al. (1997) which explored national patterns in the area of dental health and the see how these varied by local authority area. A further twist was to pick three areas where different models of flouridisation (none, artificial and natural) were practiced to see which provided the best outcomes. In the end, the best outcomes were achieved in the region where natural flouridisation was practiced. However in all cases, a strong positive linear relationship between levels of deprivation and poor dental health were observed. A final linked area, and one with a long tradition within medical & health geographies is the use of location quotients, whereby each local/regional measure is weighted by the national average to identify its relative performance against that global measure (Joseph and Phillips, 1984).

2.4 LOCATION-ALLOCATION & OPTIMAL LOCATION MODELLING

One theoretical problem which was particularly difficult to tackle in the pre-digital period, was that of location-allocation modelling and the associated area of optimal location modelling. Most health and social care planning systems need to plan the location of services in as efficient a way as possible. There is a spatial dimension to this problem in that decisions need to be made as to the locations of services. This decision is usually based on one of a number of different scenarios which can include: the location of a brand new service, the addition of a new service to existing services, the removal of a service or the multiple alteration of existing services. While it was possible to manually examine this problem, the constant drawing of different scenarios coupled with the mathematical calculations of summed distances and catchments meant it was slow work which often limited the number of different scenarios that could be modelled. With the arrival of GIS and geo-computational methods working in tandem with improved spatial data, the calculation of multiple scenarios became much quicker and the arrival at optimal locations for services based on available data was easier to achieve.

In addition some of the complexity of real-world choices could be built in to the system. Typically location-allocation models can factor in different location criteria, aimed at minimizing the aggregated distance travelled from home to health centre. The relative sizes of centres are important as well, as they are taken, in a very broad sense, as measures of attractiveness and the catchments and drawing power of larger centres can be factored in to the models as well (Fotheringham and Rogerson, 1994). Some examples of the kinds of work done is this area include the work of Hodgson in Goa, whereby the existing locations of clinics were remodelled and overlaid with the optimal locations given the distribution of the demand population (Bailey and Gatrell, 1995). What emerged was clear evidence of a need to shift the existing services from the over-supplied south to the under-supplied north. Oppong and Hodgson (1994) also carried out some local level planning in Ghana to observe the differing distributions between an existing and a modelled solution for rural health clinics in Northern Ghana. Indeed the application of location-allocation modelling may be particularly effective in mobile settings in the global South, as opposed to the more fixed health facility locations in the global North.

A third area where the modelling of optimal locations has been demonstrated to have power is in the area of system re-organisation, a common issue in most jurisdictions dependant on often fluid patterns of demand and supply. Clarke's work on the options and possible outcomes of the closure of a cardio-thoracic service in one hospital in Yorkshire and its spatial implications is a good example of such work (Martin, 1996). In this example, the knock-on effect of the re-distribution of service supply was modelled to examine where revised catchments would emerge and effectively modelled the new geographies of demand against three different hospitals, thereby enabling the health authorities in their choice of where to relocate services. Another example was the work of Charlton, Fotheringham and Brunsdon (2001) who looked at the spatial implications of hospital service closure in the UK Midlands. More recently this type of work has been extended specifically into the planning of community and health promotion areas through the work of Tomintz, Clarke and Rigby (2008) around smoking cessation services in Leeds, England. In the paper, the technique of micro-simulation is used to take existing survey and area data on 'at-risk' groups and use this to provide an intelligent estimate of smoking rates within the smallest available data units (output areas). This new knowledge is then used to look at the location of existing smoking-cessation services to see if they are effectively located given the modelled demand. In turn, location-allocation approaches were used to model potentially more effective locations for those services.

2.5 EPIDEMIOLOGICAL PLANNING

Much of the early work of quantitative and theoretical geographers on health and social care planning had been focused on the modelling of disease (Meade and Earickson, 2000). One of the earliest examples of disease modelling from a spatial dimension was Cliff, Haggett and Ord's work on the spread of influenza in Iceland (Cliff, Haggett and Ord, 1986). Prior to 1900 Iceland had no history of the disease but its outbreak and spread in three separate decades provided a very useful test-bed for the mapping of its arrival and diffusion. It was found in the last epidemic in 1957-8, that the infection arrived by air and was then spread, not in a gradual surface spread form but rather in a hierarchical way, moving from the capital Rekyavik to the smaller provincial towns and then out to smaller towns and then the countryside. Once visualised in cartographic form, the hierarchical and spatial aspects of these flows were clearer to planners and as a result more effective disease prevention measures were put into place.

This hierarchical process was also observed by Gould and Wallace (1994) with the spread of HIV/Aids in the US in the early 1980s. At a key time for the management of the spread of the virus, the advantage of being able to map existing and model potential future outbreaks of the disease was both providential for the containment and understanding of the disease and as a by-product, established the potential of GI science for epidemiological purposes. The Centre for Disease Control (CDC) in the US, continues to use GIS in disease mapping. Clearly for epidemiologists, the specific statistical and spatial statistical techniques used for mapping and monitoring disease are important. As there is no single definitive or perfect statistical approach, this has led to a variety of quantitative approaches across a range of health settings. A useful first collection on GIS and Health, Gatrell and Löytönen (1999) focused primarily on the epidemiological strand. Within that text a number of important issues were identified in terms of the effect of using different methodologies to map the same datasets. Braga et. al's work in the mapping of lung cancer clusters in the vicinity of the Italian cities of Lucca and Viterbo showed the benefits of using kernel and Bayesian methods for classifying rates of stomach cancer over more traditional standardised methods (Braga et. al, 1998). However while the results were more effective in visualising clusters they continue to raise some issues around whether the method drove the patterns rather than vice versa. In addition, critical concerns with the nature and meaning of disease clusters also inform ongoing epidemiological work in this area (Jacquez, 2008).

Again the place of statistical modelling of spatial data is central to studies like that of Johnson (2004) on the modelling of prostate cancer rates in New York State. In this work, standardised incidence rates (SIR) for prostate cancer by zip code were subjected to full Bayesian hierarchical modelling to identify the relative performance of spatially smoothed data. The result showed that the spatial scan statistic was effective in mirroring observed SIRs and that relative density of population was behaving consistently within the model with smaller rural zip codes being associated with greater levels of uncertainty. Innovative data approaches were used to try and link personal spatial data with measured air quality data was the subject of work by Crabbe, Hamilton and Machin (2000) whereby the health status of individuals and their daily time-space patterns of exposure was compared with observed air quality data to see if relationships could be established. It was also a comparative piece of work between the cities of London and Barcelona.

2.6 POLICY AND SERVICE PLANNING

The location and distribution of health services, both primary and secondary, has long been a core concern of medical and health geographers. In particular the location of services in relation to the distribution of populations has focused attention on issue of equity, location quotients and notions of inverse care (Joseph and Phillips, 1984; Boyle et al. 2002). Additionally the relocation, reallocation and in some cases, closure of services has also been a highly contested area of health care planning debate. While such debates are often related to political and cultural factors, they are also debates which are regularly couched in spatial terms (Meade and Earickson, 2000; Jordan et. al, 2006). Similarly the geography of service administration and the tensions between administrative health region boundaries and the more natural and even non-spatial aspects of patient choice and mobility remain significant issues (Curtis, 2004; Gatrell and Rigby, 2004). All of these debates have a spatial dimension and clearly implicit in all, the notion of access to services is paramount. Indeed accessibility is often used as a proxy measure of service equity and it is with this in mind that the ways in which geographers have measured and modelled accessibility are explored below.

An area of study which in a sense links accessibility and utilisation with the location of services in a very specific spatial sense is the planning of emergency services. Such services include a range of ambulance services as well as fire, air-sea rescue and other paramedic services. A key aspect of such services is their mobility and spatial spread. Unlike most user-service interactions, which involve the former travelling to the latter, the reverse is often the case in emergency situations, though the patient is ultimately brought back to the service. Time and space modelling within GIS had been carried out in a number of emergency scenarios (Jones and Bentham, 1995). Examples include the work of Jones and Jørgenson (2003) who used multilevel modelling to explore risk factors associated with road traffic accidents in Norway and Zerger and Smith (2003) who looked at how GIS could effectively support disaster-scenario planning in the event of cyclones in Queensland, Australia.

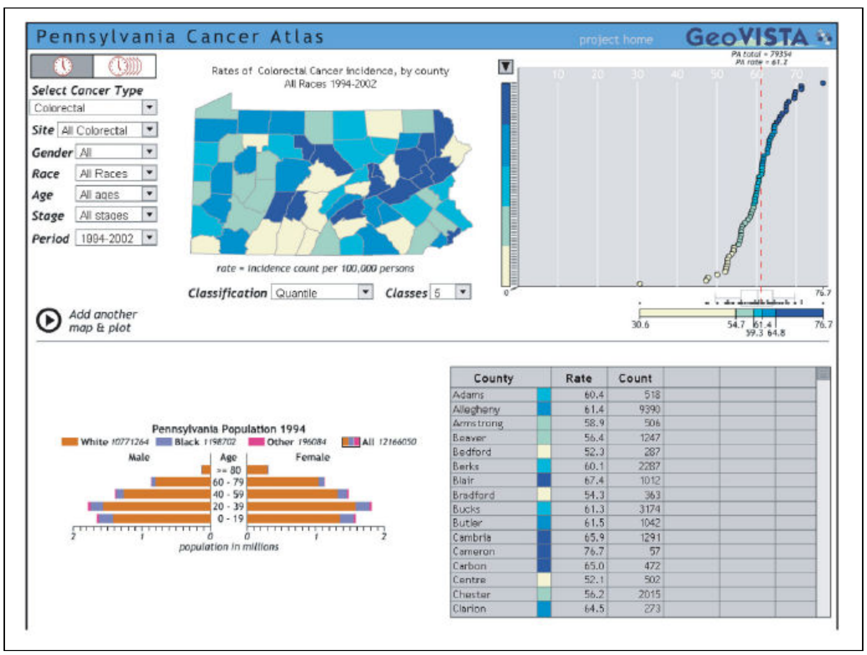
GIS has also been applied to the financial modelling aspects of health and social care planning. The funding and resourcing of health care systems is a complex mix of econometrics, demography, case-mix data and forecasting. In the 1980s in the UK, there was a realisation that health care resourcing was likely to vary over space and a number of approaches, broadly named, resource allocation models, were applied. These methods set in place the process whereby funding was moved from over-resourced areas to under-resourced areas and similar patterns were observed under the period of communist rule in the USSR as more equitable resourcing in the different republics led to an evening out (and improvement) in a range of health indicators. More recently, the spatial dimension of resource allocation modelling has been more fully incorporated in countries such as Wales and New Zealand (Gordon, et al., 2001; Senior and Rigby, 2001; Rigby et al., 2005).

The use of GIS in the planning of social care services, is, as stated previously, much less developed than health care. Depending on the jurisdiction, social care was traditionally managed separately from health care (as in the UK and Scandinavia) or embedded within health care structures (as in Ireland). With a growing realisation that a more integrated approach to social and health care planning may be more effective, some of the GI Science approaches used in the health sector are being slowly moved across to the social services. Many of these are still quite close to health services such as in the areas of community health, exemplified by the work of Driedger et al. (2007) whereby GIS-based spatial decision support systems were introduced into a public/community health arena related to early years services. The work was engaged with seeing how easy or difficult it was to engage non-experts using web-based spatial tools and a number of difficulties arose, specifically around spatial literacy and the lack of spatial skills amongst key staff. Other work has been linked again into more specifically social settings such as the work of Zhang et al. (2006) on monitoring obesity and physical activity levels in public schools in Chicago. Here, the data was used to link spatial data across two different sorts of boundaries, namely census tracts and school catchments to better target educational initiatives to improve the future health of the children. Again some of these studies, while having a social/community dimension, are still within the health arena. More social-specific studies include the work of Foley (2002) on using GIS to plan services for informal carers (described in more detail below) and Milligan and Fyfe (2005) on planning for volunteering services as well as developing work in the fields of disability (Moss, Shell and Goins, 2006).

2.7 PUBLIC HEALTH AND INFORMATION MANAGEMENT

As noted previously, the gradual ‘democratisation’ of GI science and spatial data sets within society has led to a developing concern with the ways in which GIS experts can translate their theoretical and quantitative concerns and knowledge more effectively into the public realm. Quite apart from the promotion of the subject, it does behove GI experts to think through more fully about ways in which to inform and engage the public (Goodchild, 2006; Elwood, 2006). The development of the Internet as both a process and platform is also timely in terms of the presentation of health information. A number of public agencies including government health departments, specialist agencies such as the CDC in the US and even international bodies such as the World Health Organisation, have all been engaged in the promotion and dissemination of spatial health information in the last decade or so. In addition, this is an area where the potential of the visualisation features of GIS are particularly suitable. Bell et al. (2006) noted the increasing production and consumption of traditional flat maps but suggest that there is a need for more interactive and on-line health information which allows the public to carry out their own queries and analysis. Given concerns around cancer and other data sets, especially in relation to public (mis)interpretation, the clarity and communicative potential of such maps must be carefully thought through. They identify some examples, both from the work of the CDC but also within individual US states, which identify interactive formats, incorporating spatial statistical summaries and displays (see **Figure 1** below) to better inform the public. Another area where digital health information has developed is evidenced by the gradual normalisation of electronic patient records (EPR), especially in countries such as France, where full patient data is held on a small credit card allowing for a much greater mobility and sharing of digital patient information. In terms of disseminating the tools and base data to set up a Health GIS capacity, the work of the WHO and its Health Mapper system, though flawed, is also an example of work in the developing world to tackle critical and on-going issues around the management of infectious and increasingly, degenerative diseases. A good regional example of data sharing and disease monitoring is the work of Singhasivanon et al. (1999) on the management and spatial modelling of drug-resistant malaria in the Mekong Delta. Other ongoing examples are the work of the Health Observatories in the UK and the creation in Ireland of a new online product, jointly development by government, academia and private agencies called Health Atlas Ireland (Pringle et. al, 2007). While ongoing problems remain with such initiatives, especially in the release of detailed spatial data sets for public consumption and getting the balance right between technical knowledge and public understanding, these are hopeful developments, especially in relation to the democratisation of public health information and the greater partnership involved between GIS experts, health professionals and lay users of health services.

Figure 1. Example of Interactive Health Statistics Website.



Source: Bell et. al., 2006

2.8 SUMMARY

The above summaries are precisely that, a brief survey of ongoing GI science research in a number of sub-themes within the broader heading of health and social care planning. While the theoretical and quantitative aspects may be more fully appreciated by reading the cited references, it is hoped that a flavour of the kinds of problems and ways in which those problems have been tackled to date is incorporated in sections 2.2 to 2.7. While the division amongst the different application areas has created an applied structure, it is useful to summarise them in relation to the wider themes of data, analysis and visualisation. Clearly as the value of spatial data has become better understood, the collection and tagging of health data has become more and more effective and detailed. While the quality and level of this spatial ‘tagging’ does vary from country to country and from region to region, there is a much clearer understanding that good analysis requires good data. From an analytical perspective, the ongoing development of spatial statistics and spatial data analysis whether through

Bayesian models, improved scan statistics along with increasingly sophisticated methods of data mining have all improved both the precision and quality of data analysis. Notwithstanding this, there are some persistent spatial problems, primarily around sampling, the spatial configurations of the data sets and comparability issues which continued to be problematic for analysis. Finally, the improvements in data and analysis are gradually feeding through into the public arena. While traditional maps and other cartographic output continues to be widely used, there is a development, driven by the ubiquity of the Internet, in other more interactive and innovative ways of displaying spatial data which are leading to better health and social care planning. Issues remain however in the areas of access, interpretation and public spatial literacy.

3. APPLICATIONS IN HEALTH AND SOCIAL CARE PLANNING

This section will deal with the work of the authors and their own histories coming out of the UK and Irish systems. A number of surveys and studies carried out by the study team, do, we feel, exist as a useful body of work around spatial analysis and GI Science applications in the health and social care arena and we have been selective in choosing three examples. The chosen studies are driven by concerns with data, analysis and visualisation but also focus in on a core applied problem, with the intention of identifying an outcome or solution as well as identifying future directions for that particular line of enquiry. The first, and longest, example is based on work presented at the 15th European Colloquium on Theoretical and Quantitative Geography, held in September 2007 at Montreux in Switzerland. This work explored the modelling of cross-border hospital access on the island of Ireland. The other two examples are more briefly discussed and relate to: a) a UK based research project on the application of GWR techniques to the modelling of limiting long-term illness in Northern England and, b) a social care application in Southern England. From these empirical works, we have developed a range of evidence that also informs the wider literature. Many of the issues we have found in our research reflect wider concerns and we will end the chapter with some suggestions around how these issues might be tackled.

3.1 Cross-Border Access to Hospital Services on the island of Ireland

With recent changes in the security situation in Northern Ireland, the two governments of the Republic of Ireland and Northern Ireland became interested in modelling economic and social structures across the whole island and health has been one of the key areas explored (Gleeson et al., 2008). Informally, there has been cross-border movement in the utilisation of health care and a recently published study by Jamieson & Butler (2007) identified considerable potential for cross-border collaboration in hospital services, particularly in the vicinity of the border. The pilot study presented here took a geographical or spatial approach to measuring accessibility to acute hospitals and examined how the current configurations both north and south could be expressed in terms of an accessibility score. It also quantitatively investigated another of Jamieson and Butler's themes, namely the relative equity of hospital catchments both North and South as expressed by beds per patient. In the latter half of the 20th century, the introduction in the North of the NHS model created one structure while a theoretical national public hospital system also existed in the South, though characterised by a more complex public-private mix with a stronger role for private health insurance. Northern Ireland had a population of 1.69 million according to the 2001 Census and this was estimated to have increased to approximately 1.74 million by 2006. In the Republic of Ireland Census data put the population at 3.92 million in 2002 and 4.23 million in 2006. Within both jurisdictions there was a range of hospital sizes, expressed in both the number of specialisms and the total bed count, with the latter being the sole measure which was meaningfully used in the model. In all 9 hospitals (Trusts) in the North and 40 hospitals in the South were included in the modelling.

From a spatial modelling perspective, there are a number of important considerations contained in policy discussions, which need to be considered. The re-organisation and improved planning of hospital services is by definition, the core concern of policy in both jurisdictions. Clearly, geographical tensions always exist in any decisions on where to locate services. These will reflect tensions between urban and rural areas, between densely and lightly populated areas and between local, regional and national imperatives. Few decisions made around either additions to, or cuts in, services provision escape the contentious question of exactly *where* these adjustments take place. On-going discussions noted in Jamieson and Butler (2007) and Murphy and Killen (2007) around the location of new hospitals (both regional and service-specific), exemplify all of these issues and further emphasise the importance of geography and the need to have spatially-informed decision making.

One area where policy was arguably lacking was in some of the evidence bases that were used for health care planning, particularly those with spatial dimensions (Charlton, Fotheringham and Brunsdon, 2001). It was possible to access annual data on the nature and level of hospital service provision in terms of bed counts, occupancy rates, specialisms and day patient activity. These were associated with individual hospitals but were aggregated up to regional or national level as well. It was also possible to get information on utilisation of services though the spatially-tagged data on this was better in the North than the South with postcodes found only in the former. Both of these sets of data have been studied and analysed but rarely had the locational/spatial aspects of both been put together in a holistic way. Additionally, geographical aspects such as density of population and the impact of distance had rarely been factored in to strategic planning (Murphy and Killen, 2007). Perhaps the primary value of a GIS based approach is its ability to collate large volumes of information and to produce not one answer but a number of different answers to inform a number of different planning scenarios.

The aim of the project was to test the use of a spatial approach to examine specific aspects of accessibility associated with existing hospital provision. The specific objectives of the study are a) to use GIS to model spatial accessibility to acute hospitals in both Northern Ireland and the Republic of Ireland; b) to model for two different time periods to identify how changes in bed provision and local populations had impacted on accessibility; c) to provide a spatial measure of supply equity in the form of beds per patient and finally d) to explore how changes, even over a very short time period, impacted spatially on improvements or reductions in modelled supply.

The modelling was driven by the three core geographical considerations mentioned previously around: a) the distribution of potential patients (potential need/demand), the configuration of hospitals north and south (potential supply) and the transport network (accessibility based on travel time). Based on the literature on spatial accessibility noted above, three core datasets were identified as being essential. These included a) demographic data at electoral divisions (ED) and output area (OA) levels (drawn from the census), b) point datasets for individual hospitals with associated data on size, status and levels of provision and c) data related to the road networks in both countries A number of issues arose in relation to spatial scale, compatibilities of classifications and the timing of data collection but a robust initial model was still produced (Pringle et al., 2000; Kitchin, Bartley and Gleeson, 2007). Once all the component parts were in place the data was fed in as a set of spatial data layers into Arc-Info, a proprietary GIS package, using a primarily raster approach. For the travel time each road segment had a unique ID and classification code for the road type which in turn allowed for the modelling of average speeds and hence travel time. The demographic data for population (and sub-populations) for each ED/OA was initially stored within a set of vector polygons but these data were transformed to be attached to an ED/OA centroid for development within the raster model. Finally the locations of all the hospitals were digitised into the system, initially in vector format.

Given that the aims were to produce a working accessibility ‘score’ as well as to define nominal catchments, the model started by assuming the creation of nominal non-overlapping catchments for each hospital. Once these catchments were defined and mapped, it was possible to use the background demographic data to compute the number of residents in each catchment. Given that we also knew how many beds were available at all the hospitals, we could then compute the national ratio of beds per head of population. To develop this, it was possible to then compute the expected number of beds if local supply followed the national rate and then calculate the ratio of the actual number of beds to the expected number of beds gives us the local bed rate as a location quotient. The second piece of modelling was more complex and primarily carried out within the GIS to combine the road network, travel speeds and the specific locations of the hospitals with small area local population counts to produce an effective ‘cost-distance’ surface which provided us with an accessibility score. The final technical stage was to remodel the accessibility scores with the Border included and excluded to examine its spatial effect on hospital activity.

The initial modelling focused on the period 2001/02. There was an estimated combined island population of 5.59 million in this period. The total number of beds modelled into the system at this time was 14,129 and using the two statistics together and all-island rate of 0.00257 beds per person was identified. Multiplying each modelled catchment’s population by this rate would yield the expected number of beds, which could be compared with the actual number. The initial map (**Figure 2**) identified a strong clustering of high accessibility values around the urban centres. This was driven very strongly by the location of the hospitals and by extension the higher densities of population close to those hospitals. The areas with the lowest accessibilities consist of two types, firstly the lakes which had been given artificially high values in the modelling and secondly, mountainous areas which were typically areas of low population density and amounts. However, the general low levels of inaccessibility associated with the western seaboard and the upland parts of the north should also be noted as identifying areas with genuinely low accessibility.

The second phase of the modelling looked at the period 2005/06 using updated hospital, road and demographic data. There were strong caveats with the demographic data due to the lack of up to date small area data for Northern Ireland and as a result this data was modelled from district level estimates. The accessibility modelling identified for 2005-06 provided very similar results for the earlier period with the same urban clusters being identified as areas with good accessibility and the more remote and rural areas being identified as poorly served. It was difficult to get a very strong sense of change from the spatial accessibility maps as the periods were particularly close and the increases in bed provision were matched by an increase in population across both jurisdictions. From a policy evidence point of view this is a useful finding in that the input of additional beds in this period (15,008 in 05-06 as opposed to 14,129 in 01-02) was countered by an almost identical 6.2% increase in population.

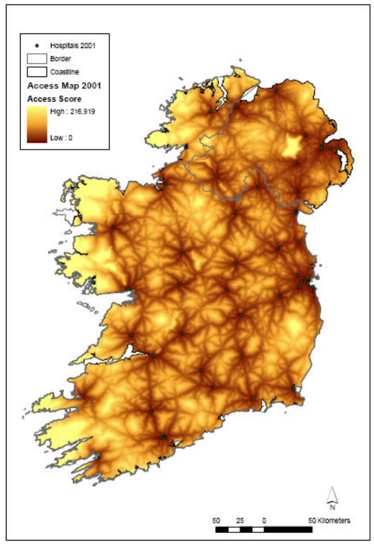


Figure 2. Modelled Accessibility to Hospitals on the Island of Ireland.

What was more valuable from a comparative point of view in this period was to look at change in a more disaggregated way by looking at provision at a regional scale. This was achieved by looking at the local hospital regions and their modelled bed rates. As noted in the methodology section, for each hospital catchment a form of location quotient for that hospital was calculated which compared actual local provision to the expected provision if national averages were applied. This allowed for the calculation of location quotients for both periods. When the two time periods were compared (**Figure 3**), it was possible to tease out more fully changes at a local level. A number of areas showed a reduction or a loss in their location quotients, most definitively in Galway but will small losses recorded across the Midlands and South Coast and in Donegal and South Down as well. While a global pattern of change was hard to establish, this local level change was explained by areas where bed numbers had been reduced or had stayed static against an increasing population. In turn much of the North saw slight increases in the their location quotients as did parts of central and mid-Leinster and even some more remote parts of Mayo and West Cork. Policy makers could find this data, caveats notwithstanding, useful in a number of ways. Spatial approaches such as this identify more exactly where change is taking place. In addition, it should be noted that a reduction in the location quotient for an area like Galway, while in absolute terms suggests a diminution of service provision, could also be seen in relative terms as a reduction in over-supply which in turn brought the area more into line with the national average.

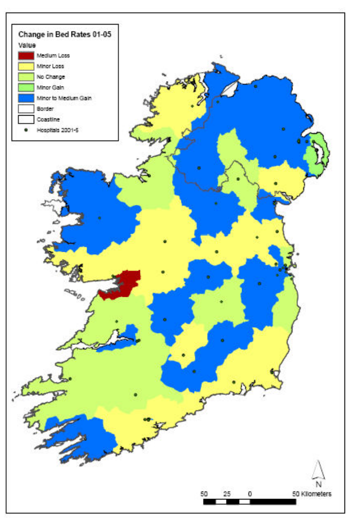


Figure 3. Variation in Service Provision: Change in Regional Bed Supply, 2002-2006, Ireland.

As a final part of the modelling the impact of the border was identified and spatially modelled as two scenarios, one with and one without the border. This allowed the impact of a non-border scenario to be modelled and compared with a separate model. This identified the location of areas disadvantaged in terms of accessibility by the presence of the border, as well as the extent, expressed in excess travel time zones, of that disadvantage (**Figure 4**). Within the GIS it was possible to model in the border as a fixed feature and by subtracting the 'no-border' and border accessibility surfaces, it was possible to calculate a time disadvantage grid. This grid was then classified into time bands, vectorised and intersected with the population data to obtain the proportions in each band. While 52% of the populations in these areas were disadvantaged by the presence of the border by less than five minutes, a full 26% of the residents were disadvantaged by fifteen minutes or more. As Figure 4 demonstrated, the GIS was able to not only calculate these inequities but identify exactly where the zones were. This also identified another very useful policy function for a spatial modelling approach

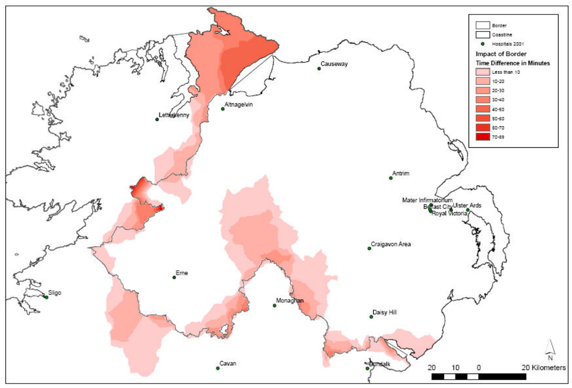


Figure 4. Time Variation in Access related to the presence of the Border.

A developed version of the model would be improved by analysis of population data at small area level along with specialist health service data by specialty (utilisation rates, staffing numbers, hospital throughput). However the primary aim of the research was to identify the potential of GIS in terms of 'scenario modelling' and allowed for both a spatial and a numerical analysis of the impacts of the existence of the border. A predictive version of the model for say 2011 or even 2015 which included an adjustment to the bed sizes based on planned capacity changes would also be relatively easy to do. A third quantitative approach would be to model individual services which would incorporate the production of service specific accessibility surfaces, which might also be weighted by utilisation data.

3.2 Using GWR to model Limiting Long-term Illness in Northern England

One of the most common technical issues is modelling health care applications in such a way that local, rather than global associations are incorporated into those models. Fotheringham, Charlton and Brunsdon (1998) looked at this problem in relation to the development of what they term geographically-weighted regression (GWR). Though GWR has been further developed in the intervening decade, this application is a health-specific one. Taking as a starting point earlier work around estimation methods (EM) which try to tackle the problem, the basic premise is to see how regression techniques can be improved by shifting from global to local relationships (Jones III and Casetti, 1992). Typically, when a regression approach is used to establish a relationship between two variables for a number of spatial units, that relationship, usually expressed as a parameter estimate in the regression equation, is assumed to be the same (*stationary*) across all units. Yet clearly if one was applying this method across a region or country, one would assume that there would be some spatial variation (*spatial nonstationarity*) in that relationship in different parts of the country or region. Such spatial nonstationarity is not accounted for in the model. The methods used in EM tackle this problem by looking at trends in parameter estimates over space. However GWR develops this more fully by assuming that within the regression equation there is a continuous surface of parameter values, and we can obtain estimates of the values of the parameter at various locations of this surface. A number of statistical problems affect such an approach, particularly in the model specification, and are related to the choice of the spatial weighting function (to find the optimal bandwidth for the kernel type approaches used in the model) and also to finding a balance between sample bias and variance.

These issues were applied to a health-related data set, namely levels of limiting-long-term illness (LLTI), in Northern England, to test and map the spatial variation in the local parameter estimates created by GWR. In essence the paper analysed: a) how the GWR parameter estimates (showing spatial non-stationarity) compared with the earlier EM method and, b) how they performed when tested against a number of independent variables used to predict LLTI. The variation between the two different methods is shown in **Figure 5** below with a focus on the parameters used in modelling the relationship between LLTI and unemployment. The spatial distributions of the EM (Quadratic) showed an artificial tendency to the north-west of the map, whereas the GWR version much more closely matched empirical patterns of unemployment on the ground. Another particularly interesting result was that for population density, another of the independent variables. One would assume that given that LLTI rates are higher in urban areas; these would in turn be associated with greater population densities. Yet the mapped GWR parameters for this variable showed up as very high in more rural part of Durham, one of the counties in the study. However, given the fact that high levels of LLTI in the UK have traditionally been associated with former coal-mining districts, it was found that those parts of rural Durham were actually where most of the former miners lived. This proved the effectiveness of GWR in exposing previously disguised local variations in explanatory statistical relationships. This and other forms of spatial statistics have to date been proved effective, yet have been under-used in other health related studies and continue to provide potential value in the planning of public and chronic health interventions.

Figure 5. Spatial Variations between EM and GWR Methods.

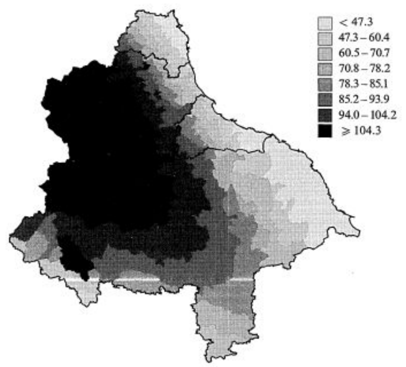


Figure 9. Quadratic expansion of the unemployment parameter.

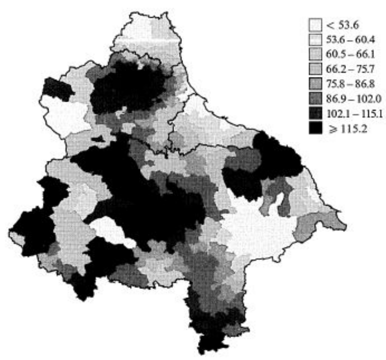


Figure 14. Geographically weighted regression distribution of unemployment parameter.

Source: Fotheringham, Charlton and Brunsdon, 1998

3.3 Modelling Social Care Planning for Informal Carers in Southern England

One of the few examples where GIS was applied in a social care setting, Foley (2002) looked at the potential of GIS to assist in the planning of services to and for informal carers in Sussex, England. While a considerable lack of knowledge of the potential of GIS in this area was identified in discussion with key informants in the services involved, three useful case studies were developed to show its potential. The first case study used GIS to help model the financial implications of different levels of service provision within a spatially-costed model of potential demand. In essence, a cost per spatial unit (ward) for three different levels of service, daily, weekly and monthly, was calculated for respite and short-term care services across the county of East Sussex. This was weighted by existing and potential future demand and helped the local social services department identify exactly where costs might accrue in respect of the different models of services provision proposed.

The second related to identifying the optimal location for a new special school as access to an existing school had been closed off. This involved the mapping of existing utilisation of services and the demographic modelling of a specific sub-population of children (under-fives) who might use the school in future. Two potential sites were chosen and while the final choice was outside of the scope of the project, the narrowing down to two sites was a big step forward for the commissioning agency.

Finally, the work also modelled the impact of changes to service boundaries and the impact on potential catchments for a new voluntary service located on the border of two different authorities and crucially helped the service identify that it had sufficient capacity within the new authority to justify its location. The final section of the work also looked at some of the barriers and opportunities for the use of GIS in social care planning more generally, some of which are persistent and will be discussed below.

4. Conclusion: Setting a research agenda.

Having examined the wider literature and the specific recent projects carried out by the authors, it appears that the application of theoretical and quantitative aspects of GI science has reached a certain level of maturation, but is also ready for a new injection of energy. As an application area, health and social care planning are emblematic of this stage. Within the broad areas of data, analysis and visualisation, we have identified a range of ideas, many of which have been around for twenty years or more, such as MAUP, modelling local relationships and the meaningful measurement of health inequalities, which still exercise the minds of theoretical quantitative geographers. The focus on the spatial is in part what separates GI scientists from mathematicians and statisticians, which is also a source of complexity. Many algorithms and models, which work well in the abstract, become more problematic when projected onto Cartesian or three-dimensional space. Spatial behaviours, especially when modelled within the arenas of health and social care planning, have an additional applied aspect which is also a source of complexity. While theoretical aspects of supply, demand, need and access can all be modelled spatially, the planning aspect, essential in any applied use of these ideas, is subject to the input of humans, who have an innate ability to contradict any known theoretical construct. From a social care perspective, professional knowledge of these factors may be better fed into any future GI modelling.

This remains a core challenge to any work in the health and social care planning arena; to make the theoretical and quantitative work make sense in a real world environment. It should also be noted that GI scientists do not work in a vacuum and collaborate in both theoretical and applied ways, with a range of social and health professionals and biomedical experts. In such interdisciplinary settings, this potential is not always met as established practices and approaches often sustain barriers. This is not to say that such models cannot have value on their own. Indeed they often help planners to rethink the ways in which they model their own data. For example, the MAUP notion, familiar to most GI scientists, still comes as a surprise to some social and health care planners. Yet there is rich evidence that the demonstration of spatial analysis and the outputs of that analysis have helped focus planners and administrators attention much more thoroughly on the spatial potential of their own data sets (Foley, 2002; Smith, Higgs and Gould, 2005). Indeed the simple ability to map a health data set has often been sufficient to stimulate the interest of health service managers (Gordon and Womersley, 1997). As a balancing effect, the established work of health and medical professionals, especially in clinical and applied epidemiological settings, has sometimes been underused by GI scientists, and stronger collaboration and better communication must be considered. Finally, it should be noted that many of the algorithms and quantitative tools used by GI scientists in other arenas such as economics, engineering and the biological sciences may also have a wider applicability within health care, especially in the epidemiological and service-planning aspects of the subject (Longley et al. 2005; Wilson and Fotheringham, 2008). These have been barely looked at to date and represent a useful future direction.

With the gradual development of web-based products and the increasing ease with which locational data can be created, there are a number of pointers towards opportunities for the GI science community to embed their ideas into health and social care planning. As was noted in Section 2.7 above, the increasing publication and dissemination of health data on the Internet has created on the one hand, an expectation and on the other a requirement, to engage the public in this way. The success of Google Earth and the increasingly common applications being developed which link this to public mapping, mash-ups, wiki-environments and location-based services points to ways in which spatial data and visualisation are developing almost beyond theory. Information on health and social care facilities for example, is becoming one of a range of service information which is provided on such services. This is led by developments in the US, with many sites set up to provide answers to spatial queries such as ‘where is my nearest hospital?’ and ‘what residential care homes exist within 30 miles of my home?’. These types of sites are less well developed, though likely to be no less popular, in the more publicly-funded systems in Europe and other parts of the global North. The development of government sponsored web sites, both from within the health arena, but also from wider statistical sources such as the Office for National Statistics in the UK and EUROSTAT at an EU level, have also begun to create expectations for quality health data. In addition, the development of easy to adapt technologies such as Google Maps and open source software provides a real opportunity to promote the use of GIS in health and social care planning in the poorer countries of the world.

So what are the possible barriers to accessing this potential wider and deeper supply of spatial data? As noted above with the realisation of the potential of spatial information, data holders, public and private, are experiencing a demand for that information which has made them sit up and take notice. In an information society, where knowledge is power, ownership of spatial data, especially data at a detailed or even individual scale, had become more contested in the last decade. At the same time as the usability of data had improved due to better spatial tagging (often at address or even detailed co-ordinate level) and the development of EPRs, access to that data can remain problematic. This is less of an issue in countries such as Sweden, Finland and Norway, where traditions of public access to private information are well-developed, but in other parts of the EU, data holders often retreat behind issues of privacy and data protection. Indeed recent ‘scares’ around the loss of CDs containing personal information are likely to harden rather than soften that position (Fresco, 2008). While INSPIRE, the recent EU Directive on spatial data should theoretically embed frameworks to make a range of spatial data sets more publicly available, health and social care data do not appear prominently in the initial data appendices (European Union, 2007). A number of successful examples of accessing health data seem to have features in common. Working with and on behalf of health and social care agencies is important as are signed agreements around access. Proofs of concept, whereby sample data provided can be shown to be: a) safe and b) useful (in terms of its output being usable for planning purposes) may also help to build up a culture of trust and openness.

While technical advances in spatial modelling are and will continue to develop, there are a number of ways in which some of that technical work could perhaps be better integrated. While research on accessibility and utilisation often go hand in hand, they are often treated as separate issues in theoretical and modelling terms. This is partly to do with the fact that conflating the two can sometimes lead to counter-intuitive results. In addition, work on the measurement of accessibility is dominated by the supply end, so that much of the modelling looks at population-weighted travel times to generate accessibility surfaces. At the same time, location–allocation approaches are interested in the ways in which the volumes of supply impact on the location of services. Yet it seems as if the logical and strong theoretical connections between these two are not as well developed as they could be. The development of supply-weighted (as opposed to demand-weighted) accessibility and travel time maps seems a logical next step. Damiani et al.’s (2003) attempt to model choice into such an equation is a useful first step but it feels like more could be done. It is unlikely that the problems associated with MAUP will ever be overcome, especially in the area like health and social care planning. Given the fact the organisation of service planning in most jurisdictions is still wedded to fixed boundaries, catchments and administratively-oriented real units, this will remain a problem. Perhaps one approach might be to see if advances in spatial data at an individual level can be used as ‘input’, thereby providing a greater flexibility for developing different forms of areal units of ‘output’. By aggregating better quality raw data into models and using them to develop more applied, practical but still ‘data secure’ outputs, a lessening of the grip of MAUP and traditional reporting units might be possible. One interesting example of this from Ireland was the work of McCafferty and Canny (2005) in mapping benefit claimants into previously unused areal units such as housing estates and Traveller (Gypsy) halting sites.

While the development in secondary health care is stronger, there is the feeling that much promise remains in primary and social care settings. There is a suggestion that a gap still remains between the methods/technologies and their use in applied settings and part of the aim of the literature review is to see whether this gap is expressed through issues of spatial literacy, resourcing, data constraints or even human factors such as participation (Elwood, 2006). The increasing use of primary care data in interesting forms of analysis and visualisation coming out of research centres like CASA in London points to ways forward for this type of work (Batty and Longley, 2003). Examples include using geo-demographic data to model potential demand and the use of new survey sources to model interventions in a variety of public health and health promotion application such as teenage pregnancy and social deprivation (Longley and Singleton, 2008; Petersen et al., 2009). The championing by the WHO of the use of GIS in planning health care services in countries as diverse as Ethiopia, Cambodia and Niger points to its global potential. Indeed in many poor countries with poorly developed health surveillance infrastructures the arrival of location-based technologies has been a huge boon to spatially-tagged health data (Kloos et. al, 2007). Finally, the challenges of climate change, and particularly its environmental health dimensions, point to ways in which GIS can be applied to more effective planning at a global level.

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