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THE ACHIEVEMENTS AND FUTURE POTENTIAL OF APPLIED QUANTITATIVE GEOGRAPHY: A CASE STUDY

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Abstract

There has been much debate about the usefulness of human geography for public and private sector planning. In this paper we make the case in terms of quantitative analysis in geography. We provide a wealth of applications of applied research from the perspective of one team of quantitative geographers – based in the School of Geography at the University of Leeds. This research is rooted in spatial interaction modelling, microsimulation, spatial optimisation and geodemographics. A number of applications are explored and their benefits articulated – for end-users. i.e. planners in the broadest sense of the word, the University and the School, for students and, more broadly, for the research environment within applied spatial analysis.

Key words

applied quantitative geography • spatial interaction • microsimulation • optimization • geodemographics
• GIS • benefits of applied geography

Introduction

Fashions in academic disciplines change. It could be argued that critical human or cultural geography is now the dominant sub-discipline in human geography, notwithstanding

the fact that it was quantitative geography which was seen as the key to the future in the 1960s and early 1970s. In this paper, a first aim is to present the case for continuing investment in one particular branch of quantitative geography: geographical modelling, in both

research and teaching. We will show that there are substantial benefits to be gained by building on what has already been achieved, and that there is tremendous potential for the future. There should be no need to see this as a battle between sub-disciplines, as different sides of the methodological divide each have insights to offer. However, we are concerned to ensure that there is a continuing development of the skills base needed to sustain modelling expertise, particularly in mathematics and computer science. This is necessary to sustain and develop modelling capabilities, though it is not a condition for a wider audience to gain a broad understanding of what modelling has to offer.

A second aim is to argue more broadly for the benefits of applied geography, particularly from the perspective of quantitative geography. The debate over this is reviewed briefly in section "Applied geography, consultancy and public policy". The four authors have been involved with applied spatial analysis, GIS and modelling for the last thirty years and more – both through the School of Geography at the University of Leeds and a university consultancy spin-off company, GMAP Ltd (Geographical Modelling and Planning). This work has involved contracts with private and public sector organisations in areas such as retailing (in the broadest sense), health, education, social policy and environmental geography (e.g. involving water demand and planning). Our experience has been that geography can be brought into the policy arena, whether through the boardroom of a major blue-chip client, a government department, a local authority, or a health authority. A brief history of this background is given in section "History and methods".

In section "Applied geographical modelling" we provide examples of this type of applied geography: first in relation to commercial organisations (section "The private sector: automotive retailing") and second with respect to the public sector (section "The public sector"). In section "Quantifying the benefits of applied spatial analysis", we examine the benefits to the University of Leeds, the

School of Geography and the discipline more broadly. One immediate and obvious benefit has been an increase in funding to the university and the department. Much of this funding has been reinvested in new facilities or research projects. However, other benefits include a set of teaching modules which show geography students that their discipline can be important to agencies, and that good jobs await them on graduation. We also look at the benefits of applied work on 'pure' research. Many academics equate consultancy or applied work to routine applications of tried and tested methods. We argue that it is more appropriate to see sustained investment in the refinement of methods through the solving of real applied problems as a generator of new ideas.

This paper has therefore sought to show the benefits of model-based applied spatial analysis. However, it is not a review of advances in quantitative geography *per se*; since that task has been accomplished effectively elsewhere (e.g. Fotheringham et al. 2000; Batty et al. 2003; Longley et al. 2005; de Smith et al. 2007; Fotheringham & Rogerston 2009); but nor is this a critique of alternative methodologies. What is stressed here, however, is that analytical skills are in great demand outside academia, and that geographers with skills as regards data analysis, GIS and modelling are eminently employable. Applied spatial analysis should be encouraged as a fundamental component of modern geography degrees. Demonstrated here are the kinds of work that can be undertaken under the banner of 'applied spatial analysis and policy', to show that geographical research is and can be relevant, in a policy context; and that there are many potential benefits within and beyond academia.

However, as we write this review there are signs that the political climate of research funding in the UK is changing. The concern about skill shortages in the social sciences has been picked up on recently by bodies in the UK funding research. In the mid 2000s, the Economic and Social Research Council (ESRC), for example, announced new

funding opportunities for the development of a more quantitative curriculum within the social sciences as a whole and for more support for the funding of masters courses which contain quantitative methods. The ESRC's 'National Centre for Research methods' has put in place funding for training, including a major grant, TALISMAN at both our institutions. TALISMAN has been funded to develop methods for geospatial data analysis and simulation, specifically models of spatial systems that emphasise interactions in applied geography and urban and regional economics. The ESRC has also funded recent large-scale projects in relation to the linking of academia and the retail sector (RIBEN – at the Universities of Leeds, Southampton and Oxford) as well as the £15 million project on 'big data networks' (with two hubs at our institutions). In addition, the ESRC has joined the Nuffield Foundation and the Higher Education Funding Council for England (HEFCE) to fund a series of investments in quantitative social sciences (the Q-step programme). These are all promising signs for the future of quantitative geography in the UK.

Applied geography, consultancy and public policy

There has been considerable debate on the policy relevance of geography. Many believe that more effective means should be found for working with policymakers. All contributors to this debate note that the concern over academic usefulness is nothing new – there has always been a plea for more applied work: see the review chapter in Johnston and Sidaway 2004 – but most agree that the link to policy seems to be more tenuous now than at many other times. A recent debate on policy relevance established two distinct camps. First, Martin (2001), Hamnett (2003), Dorling and Shaw (2002) and Stimson and Haynes (2012) argue that, as we noted above, geographers simply do not pay enough attention to the key contemporary problems in modern society. In turn, the second camp has argued that geographers have been making a significant

contribution in the literature, but that their messages have been ignored by policymakers (Massey 2000, 2001), although Massey does agree that academics should engage in wider debates outside academia, rather than simply "talking to each other". This second approach has been echoed by a number of US geographers who argue that it is not so much a question of content as of poor communication. De Blij (2005) for example, argues for an eight-point attack to improve communication with the media as a whole, and the general public in particular, whilst Staeheli and Mitchell (2005: 369) simply note that "If we can change the way that actors in Government and policy think, and act, the relevance of geography to society would be obvious".

Other contributors to the debate have questioned whether it is quite so easy for geographers to engage in policy research. Is the nature of much critical human geography actually too critical for politicians? Peck (1999) for example, divides research into 'shallow' and 'deep'. The latter, whilst most interesting, may involve research that politicians do not want to hear, though clearly this should not prevent more media coverage! There is also an interesting argument about when knowledge actually becomes useful. Ward (2005) for example argues that research can often be used in ways not intended originally: "A new theoretical insight might end up discredited and used in the most unlikely of circumstances" (see also Bell 2006.) This leads to interesting theoretical debates on issues of 'ethics' and 'values' in applied research (see Stimson and Haynes 2012 for a good discussion of this).

Another key debate focuses on the nature of the material we teach in geography, and what constitutes an academic discipline. Cas-tree (2003: 284) for example, argues: "University education is not exclusively or even primarily about producing employment-ready students or teaching core transferable skills. Universities remain precious spaces where the achievements and maladies of the wider world can be openly examined". Similarly, Staeheli and Mitchell (2005: 362) report their

findings that many scholars they interviewed: "Expressed a desire to use research on contemporary social issues as a way of helping people think about their world – a fairly different sensibility than using such research to directly solve problems". Such sentiments will be widely held by many geographers. Haynes and Stimson (2012: 2) argue: "The discipline, we suggest, has an obligation both to educate and train graduates who are useful to and employable in government and business and who can be innovators in enhancing the effectiveness and efficiency of the diverse domains of contemporary society".

Finally, we note the issue of applied research and 'mundanity'. Bell (2006) gives an excellent insight into the world of academic consultancy from the cultural geography perspective. He argues that, since much research is reactive rather than proactive, academic integrity is compromised and 'mundanity' is the consequence, especially when related to local or regional policy agendas wherein the norm is often to follow national expectations or guidelines. He also considers the academic's dislike for the 'material props' of consultancy: the slick powerpoint presentation, the business cards and the smart suit! Johnston and Plummer (2005) debate the reactive/proactive issue further by usefully distinguishing between policy-relevant research (normally academic led) and policy-directed research (normally policymaker-led) and the implications of this for the relevance debate.

Despite these critiques and issues surrounding consultancy work, the literature does contain many examples of applied research in human geography, not least in journals such as *Applied Geography*. There is also plenty of evidence of applied work in journals such as *Environment and Planning A, B and C, Urban Studies, Regional Studies, Health and Place* and many others. Also, many of the more national geographical journals publish a great deal of applied geography work. This journal, *Geographia Polonica*, has a number of useful and important applications in human geography, especially on the subject of transport access, tourism and regional policy

(Więckowski 2010; Więckowski et al. 2014). There have also been some recent books on the subject (Pacione 1999; Clarke & Madden 2001; Stillwell & Clarke 2004; Bailly & Gibson 2004; Longley et al. 2005; Stimson & Haynes 2012; Wilson 2012). Unwin (2005), in response to the issue of relevance in contemporary spatial analysis, notes the wealth of applications in what he refers to as 'planet GIS'. Recent GIS studies providing applications in crime analysis (Chainey & Ratcliffe 2005; Davies et al. 2013), health care (Gatrell & Loytonen 1998; Maheswaran & Craglia 2004; Higgs 2009), retailing (Birkin et al. 2002), geodemographics and neighbourhood targeting (Harris et al. 2005; Longley 2005) are testimony to that (Birkin et al. 1996). The wider argument is put by Wilson (2010).

However, some of the reasons for applied studies not being more widely available within the literature are discussed by Birkin (2005). These reasons include confidentiality of the data and methods, the difficulty in monitoring change within markets over time, and – importantly – the absence of benchmarks for comparison.

History and methods

In this section, the scene is set for the discussion of examples which follows. There are three objectives – to present an overview of the development of four key strands in quantitative geography; to highlight the capabilities which flow from these developments; and to outline the way in which one group of geographers at Leeds has sought to leverage these capabilities in an applied context.

The first strand we draw upon is **spatial interaction modelling**. The term 'spatial interaction model' was increasingly applied to a family of models derived on the basis of statistical mechanics and information theory (Wilson 1970, 1974), rather than by analogy with the gravity model. It is important to recognise that spatial interaction models have been used widely around the world in applied settings (Haynes & Fotheringham

1984; Birkin et al. 1996, 2010; Roy & Thill 2004). The first strand in the applications narrative of section "Applied geographical modelling" therefore concerns the introduction and deployment of spatial interaction models to network location problems for individual retail and service businesses. This capability can be traced back directly to important traditions in quantitative geography – a set of traditions which is by no means unique to Leeds, but to which Leeds geography has made a significant contribution.

A second important research strand at Leeds has been **spatial microsimulation**. The technique of microsimulation was introduced into the economics literature by Guy Orcutt (1957) and adopted as a powerful means by which to understand the distributional consequences of policy decisions and micro-economic behaviour (Orcutt et al. 1961). The application of microsimulation in a geographical context was initiated by Wilson and Pownall (1976). The ability to estimate geographical variations in the 'demand' for products and services has become a fundamental problem in applied spatial analysis, data which are often missing or hard to obtain. This remains no less true today than it was 20 years ago – when the problem was to estimate unknown distributions of income and expenditure (Birkin & Clarke 1989). Now retailers can capture huge quantities of information in the form of loyalty-card data or lifestyle databases, but still need to generalise this intelligence across the complete universe of (potential) customers (Birkin 1995). Questions involving the demand or need for services are even more important in relation to public services (Longley 2005; Birkin et al. 2005), where the requirement to demonstrate a balanced allocation of resources in the face of increasing spatial inequalities (e.g. Dorling et al. 2007) is a problem of enormous political currency. For a fuller review of microsimulation, see Ballas and Clarke (2009), Birkin and Clarke (2010), O'Donoghue et al. (2013), and Tanton and Edwards (2012).

The third important element of capability relates to **spatial optimisation**. Finding the

ideal location of activities is another key theme within quantitative geography, with links back to the classic theoretical works of Christaller (1933), Loesch (1954) and others. The initial practical applications of spatial optimisation methods generally focused on a limited set of location-allocation problems and the associated algorithms (Teitz & Bart 1968; Rushton et al. 1972; Ghosh & Harche 1993). Although it was in the late 1970s and early 1980s that the theoretical foundations were laid for the linkage between spatial interaction models and both location-allocation models (Hodgson 1978) and location theory more widely (Birkin & Wilson 1986a,b; Wilson & Birkin 1987), only in the 1990s did it become possible to optimise entire retail and service networks through the integration of location algorithms and spatial interaction models of customer behaviour with access to the resources of super-computing (Birkin et al. 1995), which in turn spawned much more powerful artificial intelligence techniques utilising both simulated annealing and genetic algorithms (Openshaw & Openshaw 1997; Birkin & Culf 2001).

The fourth strand of important modelling work has been the construction of **geodemographic systems**. Arising from social area analysis of North American cities in the post-war period (Shekvy & Bell 1955), classification systems were initially developed in the UK in the 1970s (see Birkin & Clarke 2009 for a detailed review). Geodemographic segmentation systems are widely used in both commercial and public-sector applications, such as crime (Ashby & Longley 2005), education and health care: see Longley (2005) for further examples and discussion. While the technology of geodemographic classifications based on multivariate clustering has been fairly stable over a long period of time, recent research at Leeds has emphasised new techniques such as fuzzy clustering (Openshaw 2001) and neurocomputation (Openshaw et al. 1995), the incorporation of supply-side variables and dynamics (Debenham et al. 2003), the development of the UK's first open source geodemographic classification (Vickers et al. 2005) and the linking of geodemographic systems

with other types of spatial analysis techniques (Birkin & Clarke 2012)

The development of a strong tradition in applications at Leeds is linked to the growth of GMAP (Geographical Modelling and Planning) Ltd, initially as a business division of University of Leeds Industrial Services (ULIS) and subsequently, from 1990, as a fully-fledged business in its own right. GMAP was remarkable for its commercial success, growing quickly from an operation which appointed its first dedicated employee in 1987 to a business with more than 120 employees in the mid 1990s. Two of the authors of this paper dedicated their time intensively to GMAP, the other two more fully to the University. The University of Leeds relinquished control of GMAP's successful automotive business activities to RL Polk of Detroit in a multi-million pound deal in 1997, and four years later the retail, financial service, petrol and other interests were merged with EuroDirect Ltd, then a subsidiary of the Skipton Building Society and a marketing services business which continues to operate from Leeds with more than 300 employees.

However the ongoing interrelationship between the 'applied' research of GMAP, and the 'academic' research within the School of Geography is manifest in at least three important ways. First, an exchange of personnel has been maintained across the applications-academia boundary. In 1994, GMAP employed more than 50 graduates from the School of Geography, and no less than 10 University of Leeds PhD students. Four research council studentships were completed as collaborations between GMAP and the University of Leeds, while GMAP also collaborated with the University of Edinburgh on two EPSRC/DTI-funded projects in the mid-1990s. GMAP case study material has also been exploited intensively in both undergraduate and Master's-degree teaching.

Secondly, the School of Geography and GMAP each operated to an extent independently in the pursuit of applied business. For example, while GMAP's clients include the Northern Regional Health Authority and the

Department of Health, the School of Geography has itself worked with the Leeds and Birmingham Health Authorities. The continued importance attached to applied research at Leeds is recognised in the formation of a Centre for Spatial Analysis and Policy (CSAP) as one of its major research groupings in human geography. In the case of study material of section "Applied geographical modelling", we draw freely from the applied research of both GMAP and CSAP.

In the late 1980s and early 1990s, public-sector interest in spatial modelling increased – perhaps because a new set of planners with new sets of data became interested in new methods of analysis. In addition, it can be argued that although models went out of fashion in the 1980s and 1990s, the issues of 'optimal' locations and structures never went away: how well served are local populations in terms of access to hospitals, good schools, GPs, libraries, fire stations and retail centres? These remain crucial areas relating to social justice, equity and quality of life. Indeed there is increasing evidence that community-service provision is very much back on the agenda: "Policymakers are falling over themselves to proclaim a 'new localism' as the best way to make public services both more legitimate and more responsive to the needs of local communities" (Bound et al. 2005: 11). Table 1 summarises the types of client of the School and GMAP since the 1980s.

Table 1. GMAP: Applied spatial modelling and planning clients; and School of Geography, University of Leeds clients

GMAP	School of Geography
Ford of Europe	The Home Office
Daimler Chrysler	West Yorkshire Police
Walmart	Derbyshire Police
ExxonMobil	West Yorkshire Fire Service
Shell	Birmingham Health Authority
IKEA	Secta
BP	Leeds Health Authority

GMAP	School of Geography
BHS	Surestart (Pendle)
Barclays	Yorkshire Water
Arcadia	Channel 4/Fulcrum TV
Dixons	Yorkshire TV
GSK	Yorkshire Forward
HBOS	ODPM
Safeway	ONS
Jaguar/Land Rover/Volvo	Joseph Rowntree Foundation
Sainsbury's	Skills Council
HSBC	
NatWest	
Aventis	
MG Rover	
Energis	
Total	

Applied geographical modelling

In this section we detail examples of applied research in both the private sector and the public sector. A case-study framework is adopted in section “The private sector: automotive retailing”, in which we consider the Ford Motor Company as a representative and high-profile multinational commercial organisation which has derived value from spatial analysis in many parts of its business. In section “The public sector”, the second set of examples cover a range of modelling exercises for many different public-service organisations.

The private sector: Automotive retailing

The Ford Motor Company is one of the world’s biggest businesses, with an annual turnover of \$118 bn in 2008, and some 176,000 people employed. Ford manufactures and distributes automobiles in 200 countries (Data-monitor 2010). Historically within the major developed economies of North America and Europe, motor vehicle retailers have adopted a distinctive business model. Distribution

is typically franchised from manufacturers to a network of dealers, with each dealer taking responsibility for a defined geographical territory. Within Ford, these territories have been known as Dealer Areas of Responsibility (DARs). In the late 1980s, Ford began work with GMAP on the development of a planning and analysis capability known as RADAR – Retail Analysis of Dealer Areas of Responsibility. A combination of features characterised RADAR as a sophisticated and powerful Spatial Decision Support System. Each DAR could be disaggregated into constituent postal sectors, in each of which sales of motor vehicles (known thanks to data available from Government sources) and hence market penetrations, were capable of being assessed with full GIS functionality – for example, to appraise variations in market penetration overlaid with the locations of competing dealers, in the context of local accessibility patterns and neighbourhood social geography. Most importantly, RADAR offered a capability allowing expected sales of a dealer to be modelled, by vehicle type or ‘segment’, in relation to competitor brands, locations, dealer characteristics, and customer demographics. These models provided the means for powerful ‘what if?’ analysis of network opportunities. If a dealer relinquishes the Ford franchise, is there a better location for a new dealership? Are there implications for territory assignment? What happens if a new competitor moves in?

The ability to estimate performance levels accurately is the most important application of geographical analysis for commercial organisations. Impressive empirical results for the interaction modelling approach have been reported by Birkin et al. (1996, 2002, 2014). For example, in a case study of 14 retail outlets for which data on turnover were withheld and had to be modelled, the authors in question report average estimation errors of just under 10% (Tab. 2). The outlets in question are retailers of home furnishings and garden equipment¹.

¹ The Case Study reports work undertaken for Homebase Ltd in South-East England.

Table 2. Model results for 14 stores in South-East England

Centre name	Sales ratio	Model prediction	Errors (%)
Ashgate	200	220	10.0
Bayfield	160	150	6.3
Chetburn	120	118	1.7
Darkridge	105	125	19.0
Eastport	100	102	2.0
Fernley	90	83	7.8
Greenthorpe	80	75	6.3
Holford	60	50	16.7
Icklington	185	180	2.7
Jaywich	147	150	2.0
Kentside	105	120	14.3
Ladyhill	105	100	4.8
Millwood	84	85	1.2
Northwood	72	70	2.8

Once built, these types of models can be powerful predictors of short-term change *via* the so-called impact analysis that has been a classic strategy in spatial modelling technology from the early UK shopping centre planning applications such as Haydock in the mid 1960s (Foot 1981). Negative impacts on established retail centres were viewed as unacceptable in the 1960s and early 1970s, and were an important consideration behind the shelving of many of the early out-of-town retail schemes. In commercial organisations, the negative impact on existing outlets is also a key consideration. These kinds of impacts are impossible to assess using traditional techniques such as regression modelling. Good examples are provided by Birkin et al. (1996). Table 3 illustrates how spatial interaction models can be used to model the impact of new store openings on competitors and the clients' existing stores. The example comes from a real case study in Cornwall, South West England. Our client (all names have been anonymised in the table) was proposing to open a new supermarket in the

town of Penzance. We were asked to forecast the impact of this proposed development. The table shows how our model forecasts implied a very high level of success for the new store, a deflection of trade from other stores in the town, but a minimal impact on the next nearest store run by the same company. The store was built and opened in late 2013 and trading figures to date do indeed suggest that our forecasts were broadly in line with the actual outcomes.

The dealer sales models deployed on Ford's behalf were oriented around established techniques outlined conceptually in the 1960s and 1970s (Huff 1963; Wilson 1970, 1974; see Foot 1981 for a review). However, it was quickly established that in a sector characterised by competitive clusters of retail businesses, an approach recognising the hierarchical nature of spatial decision-making by customers was a necessity, hence the adoption of a competing-destinations structure within the models (Fotheringham 1983, 1986). A second distinctive feature of these models was the incorporation of a brand-loyalty effect. Conventional models assumed an environment of retail competitors chasing retail expenditure in accordance with a portfolio of customer and outlet characteristics, but none considered the impact of previous buying preferences on customer behaviour. In automotive applications, we discovered that, in the event of a new retail franchise, for example, customers would not migrate freely from established suppliers with existing purchaser-provider relationships. The brand-loyalty effect was parameterised within GMAP's dealer interaction models, and was not surprisingly strongest for the higher-value marques and prestige brands (Birkin et al. 2010). Although this effect may be related in part to high-value products, strong branding, and ongoing vehicle support relationships between dealers and their customers, the same effects were also found to be important, for example in analyses of the financial services sector, where the 'churn' of customers from one provider to another was found to depend, not just on customer demographics, but also

Table 3. Trading characteristics of existing and proposed stores post investment

Brand	Location	Total Sales (£ per week) (52-week average)	% change in sales	Trading Intensity (£) (sales/sq ft/wk)	Market share (of food and drink spend) within a drive time of 15 min (%)
Cooland	Penzance	73,242	-34.8	14.31	6.2
Little	Penzance	117,579	-29.1	13.83	5.9
Moreasons	Penzance	350,271	-31.8	12.25	19.8
Clubcard	Penzance	333,068	-29.9	13.88	16.7
Client	Penzance	604,903	N/A	13.44	31.5
Client	Helston	343,926	-4.7	10.59	1.5

on the strength of local geographical networks. So as banks and building societies began to shed branches in the 1990s, they found it easier to retain customers in towns and villages in which overall network intensity remained high. Such considerations had an important place in the modelling of branch evolution scenarios.

Another feature of the GMAP retail/car models is a high level of disaggregation in relation to dealer and outlet attractiveness (reported more fully in Birkin et al. 2010). Classical models tended to assume a simple relationship between size (floorspace) and outlet attractiveness. We have noted already that this view is complicated by the notion of competing destinations. Many other features, ranging from availability of parking, store layout (e.g. number of floors), opening hours, store frontage, pitch, and neighbouring fascias were included in a more wide-ranging assessment of retail attractiveness. The ultimate expression of these ideas came in the specification of scorecard models of location attractiveness, in which a wide range of characteristics are weighted and scored in combination to provide a fine-level calibration of variations in store performance.

In the early 1990s, local dealerships became increasingly unprofitable in the context of dilapidated infrastructure and excess market capacity. In major markets like Germany, France, Spain and Italy, Ford was

still frequently represented by small family-owned businesses providing irregular standards of product advice and post-sales support. At this time, GMAP worked with Ford to devise an approach to market planning using the concept of an Idealised Representation Plan (IRP). Model-based assessments of dealer potentials and profitability were embedded within the IRP, allowing the preparation of plans to provide effective and profitable coverage within local market areas. In early applications, heuristic procedures were adapted from the classic approach of Teitz and Bart (1968), though the implementation of these approaches in an applied planning context needed some clever computational developments explored in joint work with the University of Edinburgh Parallel Computing Centre (Birkin et al. 1995; George et al. 1997). This again demonstrates the close relationship between applied research feeding back into basic academic research. Later developments of the method included the deployment of genetic algorithms to find the ideal configuration of a retail network amongst potential distribution nodes (Birkin & Culf 2001). Figure 1 shows the existing distribution of Ford dealers in Denmark (left picture) and the optimal distribution (to sell the same number of cars). Table 4 shows that the same number of cars could be sold from 35 fewer dealers for Ford.

Spatial analysis capability has also been used by Ford and other retailers as a means

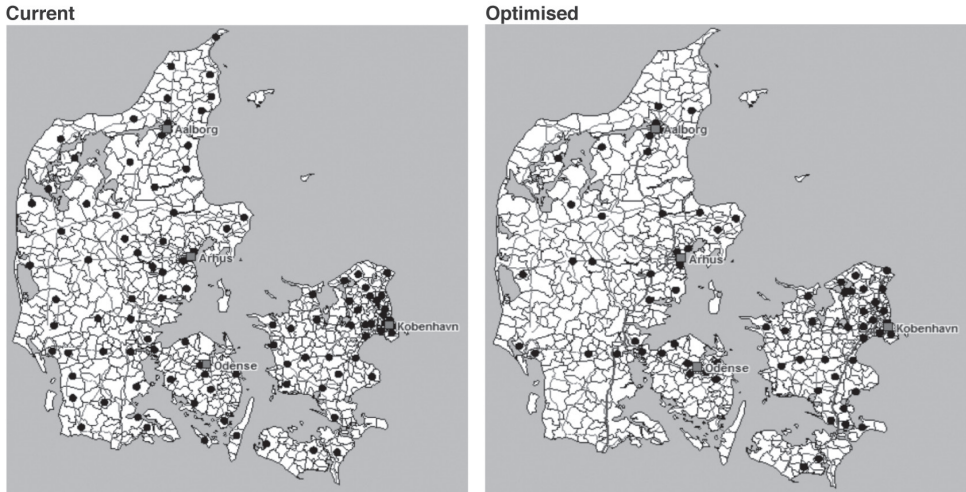


Figure 1. An idealised representation plan for Denmark

Table 4. Ideal network size for various manufacturers, Denmark

Manufacturer	Rationalised network IRP run											
	existing dealers			rationalised network			change			% change		
	sales	dealers	average	sales	dealers	average	sales	dealers	average	sales	dealers	average
Ford (01)	16,615	105	158	16,893	70	241	277	-35	83	1.7	-33.3	52.5
Audi-VW (03)	19,745	101	195	19,478	59	330	-267	-42	135	-1.4	-41.6	68.9
GM/Opel (09)	17,590	100	176	17,676	60	295	86	-40	119	0.5	-40.0	67.5
Mercedes (17)	697	45	15	916	19	48	218	-26	33	31.3	-57.8	211.0
Nissan (19)	6,152	84	73	6,943	50	139	792	-34	66	12.9	-40.5	89.6
Rover (23)	1,275	23	55	2,078	9	231	803	-14	175	63.0	-60.9	316.5

of tailoring a product offer to individual competitive marketplaces and customer environments. For example, in UK urban markets like Brighton or Bournemouth with a relatively elderly customer demographic, small vehicles with automatic transmission may be favoured in relation to larger vehicles with manual gearboxes. Traditional distribution models have tended to adopt a quota system, with individual dealers receiving a standard mix of vehicles for sale. In the case of Ford, nuances can be detected through a database or GIS query of sales patterns within the local catchment area. A more sophisticated application to determine the ideal allocation

of retail space between products for the UK book retailer WH Smith was based on repeated deployment of a spatial interaction model in which the distribution of space is updated successively to increase sales. This process of ‘format optimisation’ can also be applied on a brute-force basis if a retailer has a discrete choice between alternative formats².

The idea of the Customer Marketing Area (CMA) was developed for Ford as a self-contained region with minimal workforce or retail

² For example, typical formats for a retail forecourt might be either convenience, supermarket or fast food. The task would be simply to run three different models to find the option with the best return.

interactions into other areas. CMAs therefore provided an ideal building block, in which to optimise not just the sales of new motor vehicles, but also post-sales support. The CMA framework was used by car manufacturers to reduce the impact of intra-brand competition in which dealers competing on the same local markets tended to erode the loyalty of customers to the underlying brand. This idea is illustrated in Figure 2 for France. The proposal, that was adopted by Ford and

other retailers, was that all the retail outlets in a CMA would be owned by the same retailer. This would offer consistent levels of pricing and service, and thus eliminate intra-brand competition. Based on this advice, Ford rolled out a CMA plan for every European country, as exemplified by Figure 2. Our analysis changed the way in which a large multinational business managed its retail network fundamentally. Automated zoning procedures of this type (Alvanides et al. 2002) have

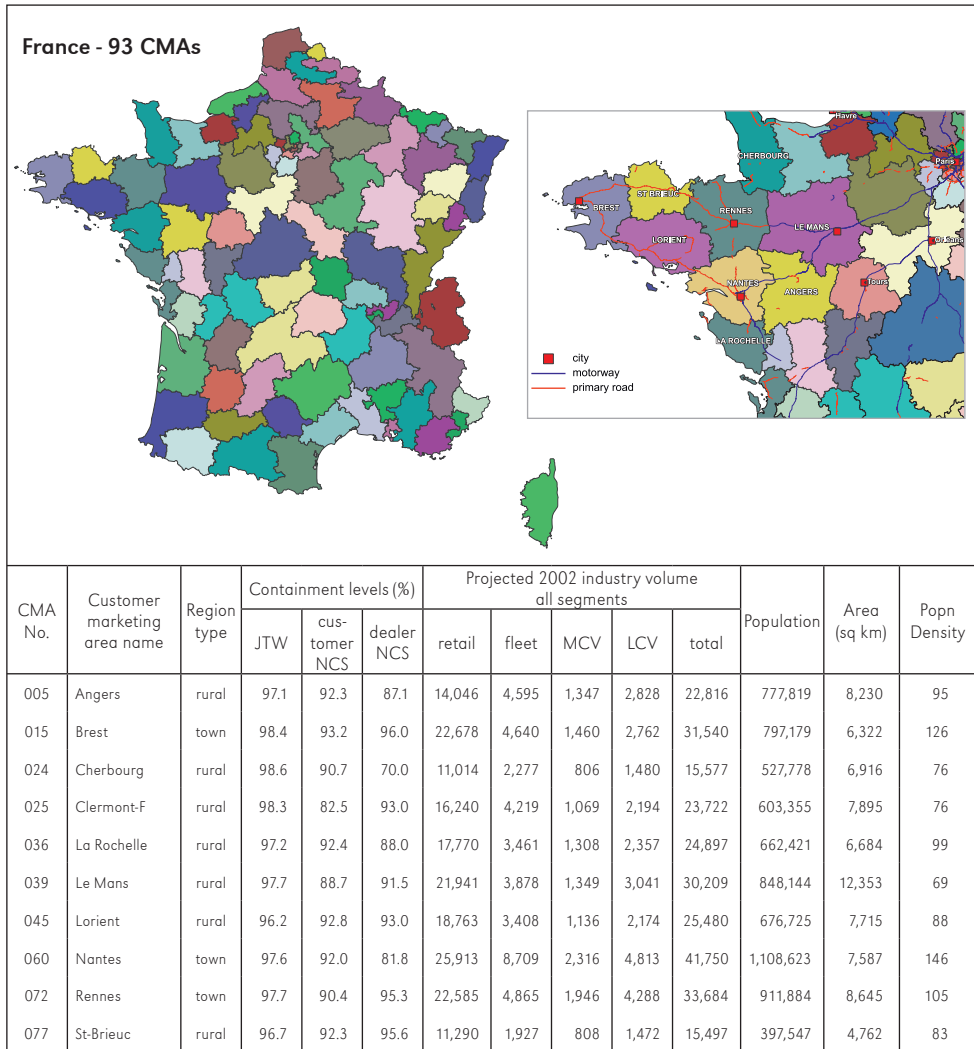


Figure 2. CMAs for Ford in France

been deployed in a number of administrative reporting contexts (e.g. Coombes et al. 1986) but few examples have been seen in a business planning context. The CMA concept was also adopted eagerly by Financial Services organisations as an organising framework for service rationalisation, while the same methods were translated in work for various pharmaceutical organisations and franchise businesses (with a view to sales representatives being provided with a balanced workload), as well as in various retail businesses to provide balanced sales opportunities for neighbouring franchises.

Finally, it can be noted that many but not all of the major approaches adopted in relation to commercial planning challenges are illustrated by the work undertaken for Ford, but some other methods and challenges have been uniquely adopted elsewhere. For example, the use of spatial analysis techniques including the identification of CMAs and deployment of idealised representation planning in the context of network mergers was investigated by Birkin, Clarke and Douglas (2002), in relation to numerous financial service scenarios. The question of price as a determinant in the spatial behaviour of both customers and retailers has been explored in later work incorporating insights from agent-based modelling (Heppenstall et al. 2005, 2006).

The public sector

National policy issues

In this section we give a range of illustrations of applied spatial analysis that have either helped to formulate policy or have tested the impacts of changing national policies. Both remain important tasks. An increasingly important application of spatial modelling for the public sector relates to the need to benchmark services, and to the possibility of using such analysis to help better allocate existing resources. This type of work stems from recent Government enthusiasm for performance indicators in public services, and the increasing interest in geodemographics for public-sector applications (Clarke & Wilson 1994;

Longley 2005). Often individual schools, hospitals, police authorities and other organisations or institutions are listed in a league table based on such key performance indicators. Academics have argued that many of these league tables are unfair, in that certain areas of our cities are always going to have schools with lower educational attainment, higher crime rates, older hospitals and so on. Measuring value-added is one way to provide alternative indicator lists. A second way is to measure performance in terms of 'distance from expected value'. Higgs et al. (1997) provide a good example of such principles in education. They examined schools in South Wales and, using regression analysis, built a model of expected exam scores based on the socio-economic characteristics of the local community. A number of schools at the bottom of the raw indicator list moved up the revised list as their performance actually seemed very good compared with other schools in similar areas of high socio-economic deprivation.

A significant example of a contribution to national policy lies in the field of crime analysis. Working with the Home Office (and subsequently a documentary for the UK Channel 4 TV Company), we built a geodemographic system for crime analysis, which in effect constructed 'families' of locations around the UK with similar geodemographic compositions. This in turn allowed us to construct a statistical model of 'crime expectation' based on variations in socio-economic deprivation. Police authorities working in similar types of community environment could then be compared more directly (see Harper et al. 2002 for more details on the construction of these families for the Home Office). Figure 3 shows variations in burglary rates within family 4, large city areas with many socio-economic problems. These new rankings and families proved useful policy alternatives to the traditional crime lists, which always had 'leafy' England at the top (lowest crime rates) and the Forces working in the most deprived estates at the bottom. Using the 'distance from expected value' approach, Knowsley, for example, emerged as an area

in which crime rates were lower than might be expected (if still of course high), despite some of the highest poverty rates in the UK. Subsequent media attention focused on the new tactics that the police force had introduced in order to reduce drug-related crime in particular. The Home Office now makes routine use of these families for Police Force comparisons (subsequently revised over time).

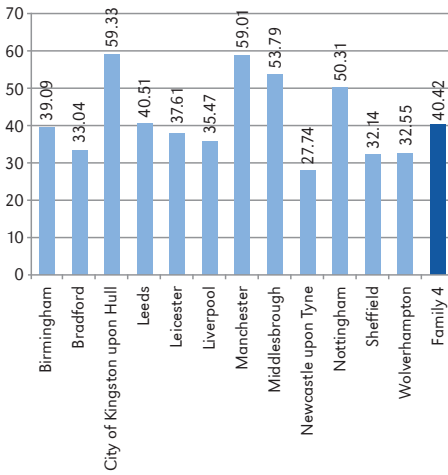


Figure 3. Family 4 from the Home Office classification: a comparison of domestic burglary rates 2000 (per 1000 persons)

Alongside the formulation of policy, an important area of critical analysis lies in the testing of policies and potential alternatives. In Ballas et al. (2005), we attempt to model future levels of income and wealth in the UK through a major research programme called SimBritain. First, a number of key indicators of income and well-being are forecasted on the basis of trend analysis from 1971. Table 5 shows the results for the city of York, UK from 1991-2021. These baseline predictions can be altered by changing Government policy. The SimBritain model was used to estimate the impacts of the introduction of the "Working Families' Tax Credit Legislation" (an allowance provided to low-paid workers with children), the introduction of the "Minimum Wage & Income Guarantee" and

"Winter Fuel Payment and Free TV License for the elderly". Table 6 shows the results of these policy changes on the income of York residents.

As can be seen from Table 6, the policy changes were assessed as contributing to a marked increase in the average income of very poor households. In particular, simulation outputs showed that the income of these households would increase by 17.8% on average in 2001. Further, the income of poor and below-average households would also increase by 6.41% and 4.92% respectively. On the other hand, there would be very small proportional increases to the incomes of above-average and affluent households. The above changes would thus result in a convergence of the incomes of the different household classes in absolute terms (for more details see Ballas et al. 2005, 2007).

Table 5. York population statistics, 1991-2021

York population statistics	1991	2001	2011	2021
Households	41,855	47,202	51,074	54,796
Unemployed (as a % of economically active)	4.6%	2.7%	1.8%	1.5%
LLTI (%)	9.5%	8.3%	5.8%	3.9%
Elderly (over 64 years as a % of all individuals)	34.5%	41.9%	41.3%	45.9%
Economically active (%)	46.2%	49.3%	55.1%	58.4%
Health problems: Anxiety, depression (%)	5.7%	4.8%	3.7%	3.8%
'Loneliness' (% with no one to talk to in times of need)	6.6%	7.2%	8.8%	11.5%
Single-person households	34.4%	42.3%	4.4%	41.8%
Cars/Households ratio	0.73	0.88	1.02	1.03

Table 6. Changes in York statistics following policy changes

	Extra income (in 1991 terms) £k	Extra income (in 2003 terms) £k	Income increase	Income increase as % of all income in York
2001				
Very poor	6,481	8,379	17.8%	0.996%
Poor	4,478	5,789	6.41%	0.707%
Below-average	3,098	4,005	4.92%	0.476%
Above-average	3,756	4,857	4.11%	0.577%
Affluent	527	681	0.14%	0.081%
2021				
Very poor	13,130	16,977	21.73%	1.591%
Poor	3,574	4,622	6.87%	0.433%
Below-average	9,981	12,906	4.40%	1.210%
Above-average	4,305	5,567	2.45%	0.522%
Affluent	7	10	0.00%	0.001%

Related work on retail saturation has obvious relevance to planners, as well as to commercial businesses. For example, Langston et al. (1997, 1998) developed local market measures to suggest the reinterpretation of saturation as a spatial phenomenon with huge geographical variations. This work was echoed in later representations undertaken by GMAP on behalf of retailers, in response to the 2001 Competition Commission Inquiry into supermarkets – in which simplistic assumptions by the Competition Commission (CC) gave rise to a hugely skewed view of local market competitiveness. In particular, because the CC adopted a view of market areas with a fixed physical size, local monopolies were often identified in urban markets in which customers actually had rather extensive choice, but then ignored in small market towns where many customers are hugely constrained. In this research, the cycle and interplay of academic and commercial interpretations continued in research which explored saturation in a pan-European context (Poole

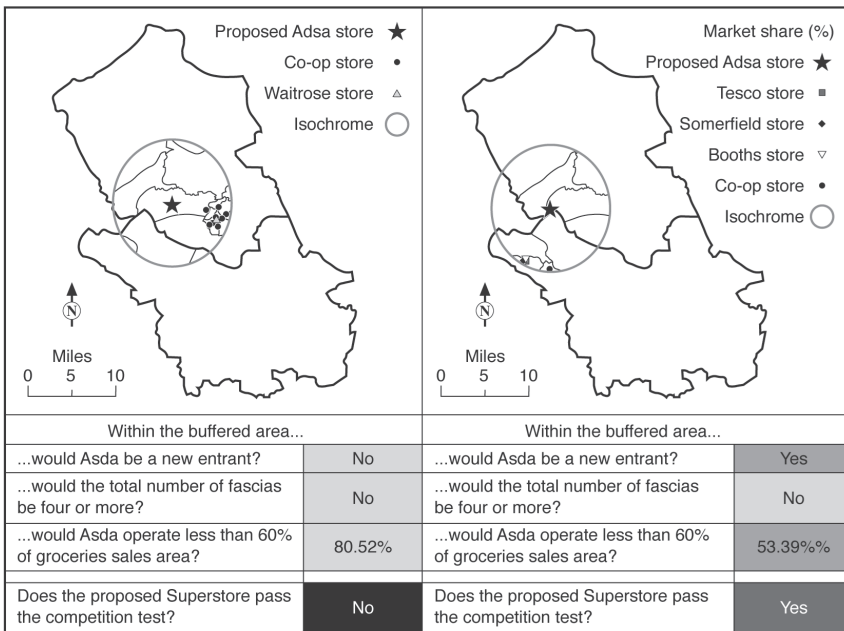


Figure 4. Spatial analysis to examine the new UK Competition Commission ‘competition test’

Source: Hughes et al. (2009).

et al. 2006). More recently analysis has been undertaken to test the implications of new planning legislation which may come into force in the UK following the more recent CC investigations into local spatial monopolies. In early 2008 the CC published its final report and offered a package of measures intended to try and control the power of the major retailers (Competition Commission 2008). One of these measures was a recommendation for the inclusion of a 'competition test' in respect of planning decisions on so-called larger grocery stores. So, for the first time, the Competition Authorities were suggesting to a Government Department (Communities and Local Government) that its policies should be changed to incorporate their concerns. Hughes et al. (2009) explore the benefit of analysis which can test the implications of such policy change. Figure 4 shows one pattern of results for investigating the effectiveness (or as it turns out the lack of effectiveness) of the new legislation for preventing more corporate growth. On the left is a potential new site for Asda-Walmart in Harrogate, North Yorkshire and how it would address the 3 key questions the new CC test would ask. It only takes one 'yes' to pass the test but this site would fail. The site on the right (very close spatially) would pass the test largely because it would be a new entrant in the 10-mile-drive time buffer around the store, and because it would also not exceed a 60% market share within the buffer.

Local policy issues

As noted in section "History and methods", microsimulation has been a core approach in the social sciences for many years, since the first application to spatial problems by Wilson and Pownall (1976). To some degree, spatial microsimulation may be seen as a sophisticated approach to the problems of 'demand estimation' associated with service delivery planning (see above, section "The private sector: automotive retailing"). The essence of the problem is that many health and lifestyle conditions exhibit demographic profiles which are

strongly skewed and richly characterised within surveys like the Health Survey for England and British Household Panel Survey, but none of these provides the spatial detail required for the planning of local services. Through the combination of synthetic individual demographic profiles for small areas, which may be generated from an abundance of Census Area Statistics (Birkin & Clarke 1988; Ballas et al. 2005), with health profiles of real but anonymised individuals from survey sources, researchers have been able to estimate local distributions of conditions as diverse as diabetes (Smith 2007), obesity (Procter et al. 2008) and smoking (Tomintz et al. 2008). In addition to their use as a backdrop for service evaluation (see below), simulated distributions can provide valuable estimates of 'missing data' in their own right. For example, in recent work supported by Leeds City Council Social Services, microsimulation has been used to identify individuals with a specific combination of health needs (Fig. 5). The School of Geography's Moses project has identified a number of crucially interesting questions relating to the changing demand and provision of health care services (Birkin et al. 2009). A major demographic driver in all of this is clearly ageing of the population, which is likely not just to accelerate the demand for social care, but also to reduce the supply quite dramatically, given that most care is actually provided informally, rather than through the institutional sector. One of the key problems in planning social services is that the best available forecasts from the ONS show no spatial detail below the Metropolitan District, and therefore yield no insights into either future local healthcare requirements, or the interaction between ageing and other important indicators of need, such as household composition, affluence and mobility. Other local demographic trends, such as the growth in ethnic minority populations – whose health care requirements may be distinctive in relation to both cultural and genetic factors – also necessitate a decomposition from aggregate demographic forecasts. Through detailed simulation of local demographic processes, the

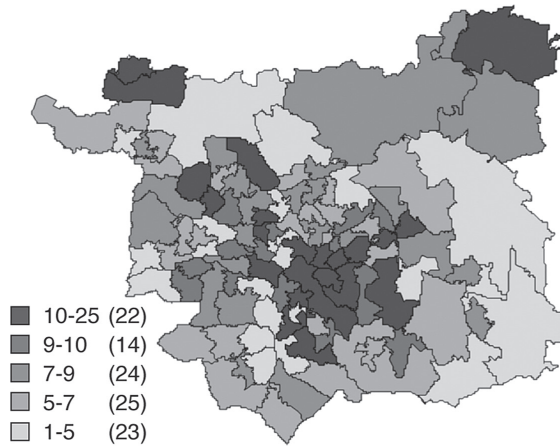


Figure 5. Elderly individuals, living alone, in poor health, in low-quality housing in Leeds, UK

Moses project aims to provide intelligence that is both more spatially refined and more comprehensive than the data which is currently available in these policy areas (Birkin et al. 2009).

Targeting services towards such high risk groups is seen by local health organisations as a key component in any strategy to combat accelerating inequalities within Britain's cities (for example, the recent WHO Report which identifies a 28-year divergence in life expectancies across a 10-mile divide in the city of Glasgow, see Daily Record 2008). Similar approaches have been used to estimate missing data on household water consumption, providing invaluable knowledge for water companies keen to reduce domestic consumption rates and identify loss through leakage in local networks (Williamson et al. 1996).

The assessment of health needs and inequalities can also be richly informed through the incorporation of spatial interaction modelling approaches. In addition to their use in revenue estimations by commercial organisations, the models can be used to look at 'tactical' planning issues such as access to services. This has a long history within applied research (Knox 1978). Clarke and Wilson (1994) used these models to define new

measures of accessibility which could be used for looking at how well served residents are by various types of service provision. The use of model-based indicators allows planners to move away from simple measures of accessibility based, for example, on straight-line distance. Thus recent work has explored measures of accessibility to food retailers in Leeds and Cardiff, to help identify so-called food deserts (Wrigley 2002): areas of poor access to good-quality grocery products, especially fruit and vegetables. Figure 6 shows the contemporary (2003) pattern of access across Cardiff, as well as the obvious peaks and troughs of good/poor accessibility. These surfaces are much more informative than the standard 500 m straight-line distance commonly used in the policy environment for measuring food deserts. By overlaying the characteristics of each area that has poor access (i.e. basic census data for the areas), priorities can be identified for retail planners to encourage some kind of retail investment (i.e. private sector stores or local community shops). There is also increasing interest in identifying potential health problems in areas that currently lack good access to the fresh fruit and vegetable stock held in most larger supermarkets (especially obesity and type II diabetes: see Smith et al. 2006).

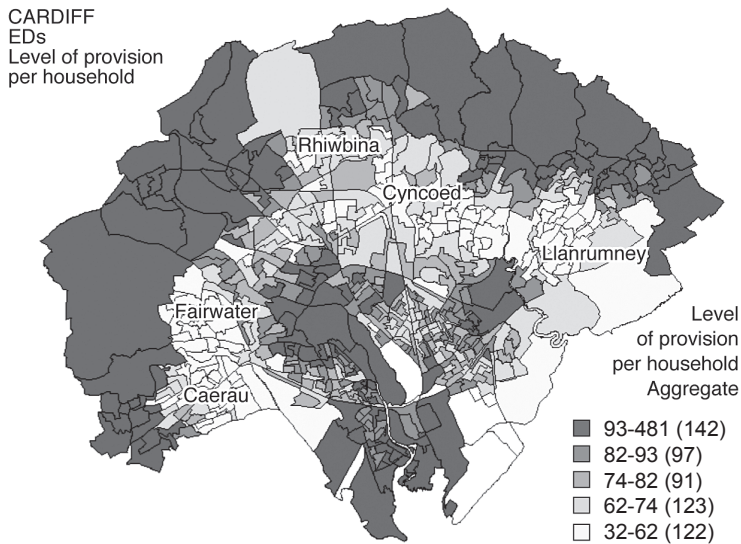


Figure 6. Mapping 'food deserts' in Cardiff 2002

Source: Clarke et al. (2002).

Quantifying the benefits of applied spatial analysis

Benefits to partner organisations

All of the models and examples considered here aid decision-making in the face of uncertain real-world environments. It is inevitable that any attempt to quantify benefits will reflect this uncertainty. For example, in evaluating the impact of any given decision, how does one gauge the *status quo*, had such a decision not been made? Nevertheless, enough is known to be able to demonstrate clearly that the pecuniary benefits for the applications described in this section are considerable. For example, in relation to tactical business operations, Birkin (2005) has demonstrated that the introduction of reasonably accurate performance estimates for cash machines can result in reductions of up to 30% in new investment requirements. For our part, we showed above (Fig. 2, Tab. 3) that for a typical network of automotive dealerships, the work of 105 franchises can be achieved

by a network of 70, simply by finding the right locations. If this strategy was implemented and the associated savings passed on to customers, this would result in an average saving of £525 on every car purchased. More examples of quantifying the business benefits of improved spatial analysis appear in Birkin et al. (1996, 2002). Such examples include results from another exercise in modelling the car market. The task was to find two new dealer sites for Toyota in Seattle, USA, which would minimise the impact on existing Toyota dealers. The optimisation model found two sites which generated around 1000 incremental sales. If this scenario could be operationalised, the benefit to Toyota would be an additional \$1.5 million in profits. If this model was rolled out across similar geographical markets to Seattle then the long-term profits would be well over \$100 million.

A second example is that of a major DIY retailer in the UK. Prior to investing in modelling, their in-house prediction system often produced forecasts for new store revenues

with error margins as high as 30% or more. By introducing spatial models that could operate closer to 10% error margins, the organisation felt more confident about embarking on a new programme of investment which entailed 25 new stores over a 5-year period. That investment was forecast to result in profits of over £40 million.

The direct financial benefits of public-sector applications are much more difficult to define, since they are linked inextricably with political objectives, while the intransigence of practitioners is a major factor. Furthermore, whilst objectives in private-sector applications are relatively easy to define (for example, revenue, profit, return on capital employed – ROCE, internal rate of return (IRR) and so on), in the public sector it is not always clear what the ultimate goal is, beyond greater equity and a fairer allocation of resources. In this case, the best evidence may simply be the increased confidence of decision-makers. For example, in response to the Home Office benchmarks described in section “The public sector” above, the Commander of Knowsley Police, Superintendent Stuart Kernohan, was quoted as saying: “This is a thought-provoking analysis of crime statistics, and highlights the importance of the Force’s move to neighbourhood policing across Merseyside” (*Liverpool Daily Post* 11th January 2001), and even those Police authorities at the bottom end of the list appreciated the merit in the analysis: “It is known and documented that Hastings has its particular policing problems (...) it is expected there will be a significant increase in funding in 2000-2001” (Superintendent Paul Curtis, Hastings police chief, *Hastings Observer* 19th January 2001).

A similarity between commercial and public applications are that each plays to a very wide range of beneficiaries: in retailing, the financial services, automotive, petrol or pharmaceuticals businesses, schools, transport agencies, utilities, health care providers or emergency services. There will also be diverse users of geographical analysis within particular organisations. Birkin and Foulger (1992) note the implementation of 22 independent versions

of GMAP’s NIMS (National Information and Modelling System) within the UK retail WH Smith Group, with users ranging from sales, property and finance through to corporate planning, logistics and marketing.

Benefits to academia

There are also considerable benefits to academia – in our case to the University of Leeds, to the School of Geography and, more widely, to the discipline of geography itself. The most obvious benefit comes in the form of increased revenue. We estimate that between 1985 and 2005 the combined income of the GMAP organisation was £55-60 million, with profits in the order of £10 million. As a major shareholder, the University has taken a good percentage of this profit in the form of a dividend. The School of Geography has benefited from a substantial slice of this income (some £4-5 million). Over these years, the School was able to invest heavily in its laboratories and new infrastructure (the physical buildings), as well as in new studentships and the appointment of new teaching fellows, plus many one-off research funding opportunities.

The School and the University benefited from a set of applied courses in spatial modelling. Such courses do not simply focus on techniques for the sake of techniques (as does the traditional first-year statistics courses that puts everyone off quantitative methods), also offering exciting spatial analysis courses based on real-world case studies. A further implication of applied work is the ability to tap into the market in continuing education, namely persons in work requiring further qualifications. With partners at Southampton and Penn State, the University of Leeds can now offer a suite of applied GIS courses by distance learning. Launched in 2004, the current recruitment levels stand at over 100 per annum, providing new income streams in the era of far more competitive postgraduate markets. All of this increases and enhances employability, and offers some contribution to the shortage of skilled spatial analysts. Interestingly, Openshaw (1997: 22) pondered

the 'missing skills' debate nearly twenty years ago. "There is a risk of ideological intolerance that has not been so visible previously because the gulf is no longer just philosophical or paradigmatic but is reinforced by serious deficiencies in research training".

Eurodirect (one company recruiting strongly from the University of Leeds) have published the benefits to them of a well-trained, local graduate pool in applied spatial analysis. Martin Bradbury of Eurodirect wrote in the UK *Guardian* newspaper: "First of all it is clear that, apart from a high academic rating, the School of Geography at Leeds is special in other ways, particularly in terms of its willingness to accept responsibility for a role in graduate employment. This is maintained through specific taught modules and a willingness to deal with the business world (...) the School can rebut any accusation of living in an ivory tower by pointing to its relevance to the hard-nosed commercial world" (*Guardian* Saturday 21 April 2001).

In the UK retail market, for example, many of the site location teams at Tesco, Sainsbury's, Morrisons, Waitrose and ASDA are now Leeds graduates; and in the summer of 2007, 30 jobs in the retail sector alone were offered to the 3rd-year Leeds students (Sainsbury's, Tesco, ASDA, Planet Retail, CACI, Experian, Mapinfo(Geobusiness), GMAP/Eurodirect). All these organisations continue to be major sources of employment for students trained in GIS and applied spatial analysis.

A major advantage to the discipline of geography as a whole is more awareness of what geography can offer in the senior managements of public- and private-sector organisations. Many of these are now represented in organisations such as the Association of Geographic Information (AGI). There is also increasing recognition of the value of a spatial perspective from other disciplines, especially health, business studies and computing. Unwin (2005: 682) confesses that through his lifetime working in GIS "I feel privileged to have seen the rest of the world – including many of the cognitive sciences – discover the power of geography".

Finally, it is worth noting that it is also our experience that engaging in solving 'real world' spatial problems can throw up more 'hard' modelling challenges than academic research alone. Indeed, Martin (2001: 199) suggests "policy analysis can and should feedback into theory". As we noted in section "Applied geographical modelling", end users demand high accuracy, and model specification and calibration need constant attention. For example, it is difficult to start with 'let us assume...' (*Ceteris Paribus* cannot be invoked!). Second, academic research is not necessarily governed by any success factor other than model fit or development of the field. For applied work, models must demonstrably work and address the key problems faced by the partner organisation.

Conclusions

As an academic discipline, geography has always been a broad church embracing a wide variety of approaches and a huge range of subject matter. It has always been strongly connected to other disciplines. It retains its distinctiveness by focussing on processes that have an explicit spatial dimension. In this paper we have sought to demonstrate that applied spatial analysis can contribute to both the understanding and the planning of a wide variety of important issues in both the private and the public sector that have an explicit spatial component. In areas such as health, education and crime, better methods of allocating resources across space can help reduce inequalities between areas and between social groups. We find it difficult to believe that anyone would question the benefit of doing this, though geography, seemingly, has a unique problem of being uncomfortable with applied problem solving. Economics trains consultants and accountants to contribute to business and public sector planning, Law trains solicitors to resolve legal disputes, Engineering by its very nature is concerned with practical problem solving. Human Geography in the last decade or so has been more comfortable either providing commentary or critique

on important subject matters, rather than contributing to analysis that might help in problem solving. Over the coming years, as higher education is opened up to a 'market forces' environment, geography is going to have to fight hard to win over the hearts and minds (as well as the cheque books) of a new generation of students who may question more deeply the relevance of their degree schemes to the wider

world. We strongly believe that applied spatial analysis can contribute to making geography an accessible and relevant discipline of broad appeal in the 21st century.

Editors' note:

Unless otherwise stated, the sources of tables and figures are the author(s), on the basis of their own research.

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