PART 4

APPLICATIONS

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Introduction

THE EDITORS

The previous Parts of this Book have considered the principles, technical issues, and management issues of GIS. This Part deals with the applications of GIS. In many respects applications are the most important aspect of GIS since the only real point of working with geographical information systems is to solve substantive real-world problems. This might include performing an existing task better, cheaper, or faster (e.g. automating the process of producing maps, or tracking building permits), or allowing new problems to be tackled (e.g. directing cruise missiles using onboard digital terrain analysis, or looking for clusters of infrequently occurring diseases such as childhood leukaemia). GIS is perhaps best considered a methodology or collection of tools which when *applied* can bring great benefit.

The applications of GIS are legion, and indeed several pages of this Book could be filled by a list of the constellation of areas to which GIS has been applied. From archaeology to zoology GIS can contribute a great deal to our study of patterns and processes on the surface of the Earth. There are many books which are themselves devoted to the description of GIS applications and those who care to peruse the bibliography of this Book will discover an extended list of application areas.

Even though the innovation of GIS is itself quite recent, it is possible to classify GIS applications as traditional, developing, and new. Traditional GIS application fields include military, government, education, and utilities. The developing GIS application fields of the mid 1990s include a whole raft of general business uses (e.g. banking and financial services, transportation logistics, real estate, and market analysis). New application areas, which are probably due for takeoff in the next decade, include small office/home office (SOHO) and personal or consumer applications. This simple classification, although useful in itself, hides a complexity of approaches to applying GIS. To choose but one example, utilities frequently undertake applications which fall into traditional, contemporary, and forward looking application classes identified above. Traditional utility applications include creating asset inventories (e.g. databases of pipes, valves, manholes, customers, pumping stations) and mapping networks. Contemporary developing applications include outage analysis (tracing the cause of faults and predicting shortages during planned maintenance) and work order processing. New, forward looking applications include integrated SCADA (Supervisory Control and Data Access – field-based dataloggers) systems and automated network load balancing. Further details of utility applications are provided by Jeffrey Meyers (Chapter 57) and Carolyn Fry (Chapter 58).

Diverse though the range of GIS applications is, many nevertheless share common themes. A convenient way to group them, and the one used in this Section, is on the one hand those dealing with operational issues and on the other those dealing with more general social and environmental issues. At the risk of overgeneralisation it is possible to say that the former typically focus on very practical issues, such as cost effectiveness, service provision, system performance, competitive advantage, and database creation/access/use; in contrast, the latter are often more concerned with model sophistication, the social and environmental consequences of results, and the precision and accuracy of findings.

In part by design, but also because of the background and interests of the authors, the chapters in this first Section, 'Operational applications', deal with the 'nitty-gritty', often day-to-day, practical issues of applying GIS. Most of the authors are GIS practitioners and would classify themselves first and foremost as direct users or managers of GIS. The chapters in the second Section, 'Social and environmental applications', take a wider look at the issues with which they are concerned. Whilst all of these authors are also GIS users, their backgrounds as academics and researchers have allowed them to write more general chapters from a wider perspective.

The information about GIS applications in this book is not solely contained in this Section. Other important contributions on GIS applications include those by Birkin et al (Chapter 51) which considers distribution and other business planning applications, Elshaw Thrall and Thrall (Chapter 23) which covers desktop and business applications, and Forer and Unwin (Chapter 54) which deals with educational application issues.

COMPARISON WITH THE FIRST EDITION

To see how GIS applications have changed over the past decade it is interesting to compare the current situation with that described in the first version of this Book (Maguire et al 1991). One of the most noticeable differences is in the structure of the applications Part. In 1991 the editors felt it necessary to provide general reviews of the state of GIS applications at the national level. This was mainly because the field was comparatively immature at the time. A further significant factor was that there was comparatively little written about who was using GIS. Close examination of the applications Sections of the first edition also reveals that in the early 1990s there were relatively few areas with sufficiently well-established operational GIS to allow authors to write on the general characteristics and lessons learnt from several years of activity. How things have changed!

In 1991 Maguire, Goodchild, and Rhind called for more to be written on failed GIS and cost–benefit analysis (Maguire et al 1991). More than half a decade later there are still very few descriptions of failed GIS. This is probably for the same reason identified in 1991, namely, that few people are prepared to admit that they 'failed', let alone write about it and then publish it for all to see. It is more pleasing to report that there has been considerable work in the intervening period on cost–benefit analysis and cost justifying GIS. Much of this work has confirmed what we all suspected: GIS *do* add value beyond their cost. The most important work on cost–benefit analysis is summarised in Obermeyer (Chapter 42).

GIS APPLICATION TRENDS

The earlier part of this discussion classified GIS applications as traditional, developing, and new. A different way of examining trends in GIS applications is to look at the diffusion of GIS use. Figure 1 shows the classic model of GIS diffusion originally developed by Everett Rogers (see Brown 1993). Rogers' model divides the adopters of an innovation into five categories:

- Venturesome Innovators – willing to accept risks and sometimes regarded as oddballs.
- Respectable Early Adopters – regarded as opinion formers or 'role models'.
- Deliberate Early Majority – willing to consider adoption only after peers have adopted.
- Sceptical Late Majority – overwhelming pressure from peers is needed before adoption occurs.
- Traditional Laggards – people oriented to the past.

Applying this to a generalisation of the adoption of GIS applications (Figure 2), it can be seen that GIS conforms fairly well. In the late 1990s GIS seems to be in the transition between the Early Majority and the Late Majority stages. The Innovators who dominated the field in the 1970s were typically based in universities and research organisations. The Early Adopters were the users of the 1980s, many of whom were in government and military establishments. The Early Majority,

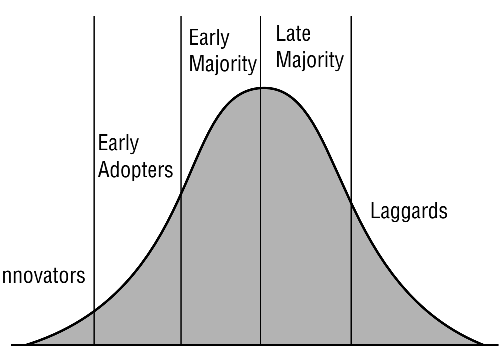

Fig 1. The classic model of GIS diffusion.

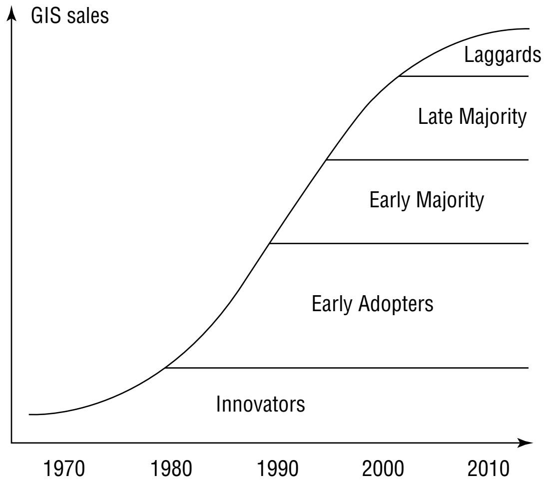

Fig 2. Classic diffusion of innovation applied to GIS.

typically in government and private businesses, came to the fore in the mid 1990s. Whether history will see this analysis as correct only time will tell, but it seems to parallel the introduction of similar technologies such as database management systems and statistical analysis software. The current question for potential users appears to be: do you want to gain competitive advantage by being part of the Majority user base or wait until the technology is completely accepted and join the GIS community as a Laggard?

CURRENT STATUS AND TRENDS

It is interesting to look at the current status of GIS applications and examine some of the current and envisaged trends. The predictions will probably hold at best for the two–three years following publication of this Second Edition, and the only certainty is that because the field is moving so quickly, no one can have any clear idea about what will happen beyond that (but see the Epilogue, Chapter 72, for some general predictions).

1997 was probably the year in which the number of GIS software systems installed passed one million. At a conservative estimate of an average of two users for every system installed, this means a user base of around two million. These crude estimates are only for core GIS and do not include associated systems which also have some GIS capabilities (usually mapping or data management), or the massive number of users who now experience GIS over the Internet using a conventional Web browser (Longley et al, Chapter 1). Examples of such associated systems include AutoCAD (claimed user base of three million), Datamap in Excel (claimed user base exceeding one million), and the many electronic atlases (Elshaw Thrall and Thrall, Chapter 23). The very rapid rise in the deployment of Internet Map Servers and mapping products has also very significantly increased the number of GIS users. A conservative estimate is that at the end of 1997 over two million maps were being made and viewed over the Internet each day. This would mean that the number of Internet GIS users is several million. If the definition of a GIS were extended to include associated systems and Internet users then the estimate of the size of the GIS community would probably be as large as between eight and ten million. It is interesting to note that in the First Edition of this book, the editors did not forecast a GIS population beyond 580 000 even in the year 2000 (Maguire et al 1991).

As well as there being more GIS users today, there are also more large mature user sites. It is not uncommon for a large government agency, university, or utility to have more than 100 GIS seats. There is also a significant number of the largest sites with site licences for software products and more than 1000 seats.

The reasons for this explosive growth of GIS applications are legion, and for each individual person or organisation they are unique. In general the key factors include:

- *Greater awareness of the potential GIS has to offer*. It is estimated that over 1000 universities now teach degree level courses in GIS and there are many others which touch it in passing. At the school level a number of curricula require GIS to be taught and, in the USA at least, GIS is now working its way into elementary and middle schools. GIS is now diffusing quite rapidly into many organisations as education increases and awareness spreads.
- *Better technology to support applications*. The substantial research and development investment by many GIS software vendors in the 1980s and early 1990s is now beginning to pay dividends in many areas, particularly visualisation, data management, and analysis. Most GIS software packages now have customisation capabilities suitable for use by third-party application developers and technical users within organisations (see Maguire, Chapter 25, for further details). This has led to a proliferation of many domain-specific, highly focused applications which has swelled the size of the user community. A further reason for the success of GIS is their ability to link to other software systems (Goodchild et al

1992), such as corporate databases, statistical and spatial analysis systems (Maguire 1995; Gatrell and Senior, Chapter 66; Yeh, Chapter 62) and dataloggers (Larsen, Chapter 71).

- *More, cheaper data*. Clearly GIS are almost worthless without data. In the past few years a number of projects have implemented well-designed data collection programmes and have delivered databases which are persistent and application independent. There is a significant number of substantial local, national, and global databases. Some of these are in the public domain, others are under the control of national mapping agencies, and some are privately held. With the increasing commodification of spatial information, there is already a substantial and growing market for data. Since it is almost always cheaper to buy data than capture it first hand, this has led to significant cost reductions for several projects (Smith and Rhind, Chapter 47; Rhind, Chapter 56).
- *Improved ease of use*. Most general-purpose GIS software systems have now adopted standard windowing environments: X Windows on UNIX or Microsoft Windows on PCs. The latter is becoming particularly important as the norm for client or desktop GIS user interface. Because of many users' familiarity with Windows, some of the previous barriers to user acceptance and usability have been removed.
- *Reduction in price*. The price reduction of GIS hardware and software and the economies of scale reflecting the increase in the size of the market have both increased the attractiveness of GIS. The significant reduction in the price of GIS hardware and software mirrors the general reduction in the IT industry. In the case of the hardware used for GIS, the well-known hardware law devised by Intel Corporation founder Gordon Moore, holds true to date. Moore's law states that computer processing power will double and its cost will halve every 18 months.
- *Availability of applications*. The GIS market has also been stimulated by the development of end-user applications which are available commercially off-the-shelf (COTS) or 'ready to run out of the box'. Within the field of GIS there is a thriving and growing community of companies which produce end-user oriented applications. In a type of positive feedback loop this further stimulates the GIS market, which in turn encourages more developers to produce applications, and so on.

GIS is now less driven by technological considerations and many decisions are based on firm cost–benefit cases (see Obermeyer, Chapter 42). Today there are strong methodologies for developing cost– benefit models and several case studies of implementations which have positive economic benefits. It is also the case that there are well understood and tried and tested methodologies for GIS implementation, customisation, and ongoing management (Maguire, Chapter 25; Sugarbaker, Chapter 43). The so-called 'institutional issues' associated with implementing a GIS are also better known. Factors such as lack of support from senior management, problems of user acceptance, establishing a strong management team, the legality of using geographical information, and conducting business in the GIS world are now much better understood.

Once GIS applications become established within an organisation it is not uncommon for GIS to spread widely (Figure 3). Much of the early focus of implementations is typically on technical issues and many of the applications are little more than spatial data processing. For some this type of activity is sufficient to warrant adoption, but it was not until GIS started to become integrated with corporate (or enterprise) information systems that it really started to takeoff. During this phase the emphasis moves from a technological to an analysis/modelling focus.

Integration of GIS with corporate information system (IS) policy, planning, and systems is an essential prerequisite for success in many organisations. Until GIS technology can utilise corporate databases, interface with existing corporate information systems, and become accepted as a core part of corporate IS strategies, the full benefits will not be realised. Most of today's large-scale GIS

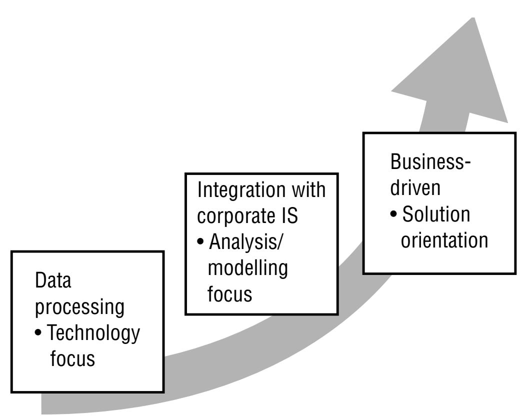

Fig 3. Changing business focus of GIS within organisations.

implementations are in this phase of GIS development. Users make widespread use of the analytical and modelling capabilities of modern GIS.

As implementations mature, GIS can become increasingly business-oriented with a focus on problem-solving and business benefits. This trend is evident within organisations even today. The initial focus of many GIS applications is technological, with data processing the major activity. As an implementation matures, the focus changes to that of integration with existing applications and there is an interest in analysis and modelling. In the most mature sites GIS is driven by business requirements and providing cost-effective solutions to business problems.

GIS can be used by organisations at the Operational, Tactical, and Strategic levels (Grimshaw 1994), as shown in Figure 4. Operational activities are the basic day-to-day activities of many organisations. They include performing site maintenance, deliveries, and scheduling. GIS can be used, for example, to create and manage inventories of facilities (sites, people, deliver routes, etc.). Much of the data relating to operational activities is collected and maintained inhouse. Operational decision-making tends to be highly structured.

Tactical activities are typically the domain of middle managers. The decision-making process is often semi-structured and is based on a combination of internal and external data. Within businesses, for example, external data include geodemographics and industry pricing information. Examples of tactical applications of GIS include locating land for 'new to industry' sites and territory management.

Strategic activities involve senior management. Strategic decision-making is frequently unstructured and intuitive. It involves ad hoc assembly and timely analysis of internal and external data, much of it collected on disparate spatial bases, at different resolutions, and on different projections. Examples of strategic activities are planning sites for a new territory or evaluating an expansion of a product line.

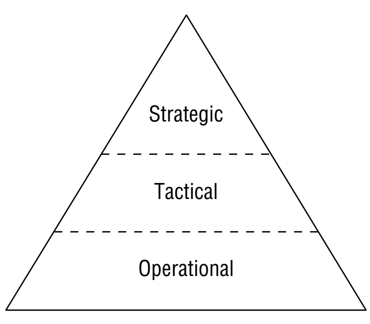

Fig 4. Different levels at which GIS can be used within organisations.

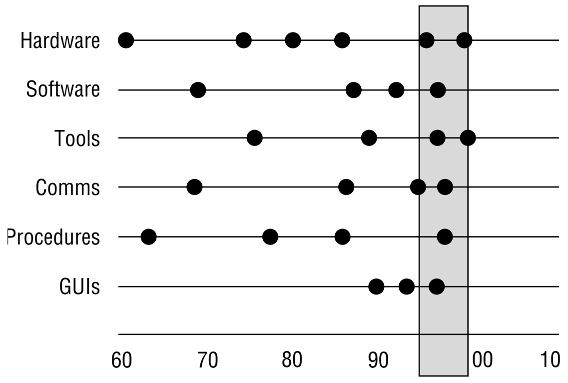

Fig 5. Innovation in GIS. During the five-year window of a typical corporate GIS application project (shaded box) it is highly likely that there will be several major technological GIS innovations (black circles) (after Maguire and Dangermond 1995).

All the talk of technological change sometimes makes people nervous about buying GIS and associated technology. It is a sobering thought that over the five-year lifetime of an average corporate application project (Figure 5) there are likely to be as many as ten significant technological innovations. This suggests that projects should be planned on an incremental rather than a 'big bang' basis and that project managers should not worry overly about the latest technology since much of it will be outdated before the end of a large project!

References

Brown R 1993 *Market focus: achieving and sustaining market effectiveness*. Oxford, Butterworth-Heineman

Goodchild M F, Haining R P, Wise S 1992 Integrating GIS and spatial data analysis: problems and possibilities. *International Journal of Geographical Information Systems*: 407–23

Grimshaw D J 1994 *Bringing geographical information systems into business*. Cambridge (UK), GeoInformation International

Maguire D J 1995 Implementing spatial analysis and GIS applications for business and service planning. In Longley P A, Clarke G P (eds) *GIS for business and service planning.* Cambridge (UK), GeoInformation International: 171–91

Maguire D J, Dangermond J 1995 Future GIS technology. In Green D R, Rix D (eds) *The AGI sourcebook for geographic information systems*. London, Association for Geographic Information: 113–22

Maguire D J, Goodchild M F, Rhind D W 1991 *Geographical information systems: principles and applications*. Harlow, Longman/New York, John Wiley & Sons Inc.