Location-Based Services and Geo-Information Engineering

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Location-Based Services and Geo-Information Engineering

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Mastering GIS Series: Foreword

Since 2001 it has been my privilege to be involved with the John Wiley and Sons book *Geographic Information Systems and Science*. Through its various editions, this book and associated materials has sought to present a state-of-the-art overview of the principles, techniques, analysis methods and management issues that come into play whenever the fundamental question 'where?' underpins decision making.

Together this material makes up the organizing concepts of Geographic Information Systems (GIS), which has a rich and varied history in environmental, social, historical and physical sciences. We can think of GIS as the lingua franca that builds upon the common purposes of different academic traditions, but with an additional unique emphasis upon practical problem solving. As such, much of the core of GIS can be thought of as transcending traditional academic disciplinary boundaries, as well as developing common approaches to problem solving amongst practising professionals.

Yet many of the distinctive characteristics, requirements and practices of different applications domains also warrant specialized and detailed treatments. 'Mastering GIS' seeks to develop and extend our core understanding of these more specialized issues, in the quest to develop ever more successful applications. Its approach is to develop detailed treatments of the requirements, data sources, analysis methods and management issues that characterize many of the most significant GIS domains.

First and foremost, this series is dedicated to the needs of advanced students of GIS and professionals seeking practical knowledge of niche applications. As such, it is dedicated to making GIS more

efficient, effective and safe to use, and to render GIS applications ever more sensitive to the geographic, institutional and societal contexts in which it is applied.

Paul Longley, Series Editor
Professor of Geographic Information Science
University of London

Preface

Location-based services (LBS) are the delivery of data and information services where the content of those services is tailored to the current or some projected location and context of a mobile user. This is a new and fast-growing technology sector incorporating Geographical Information Systems (GIS), wireless technologies, positioning systems and mobile human–computer interaction. Some view LBS as the 'killer app' that will propel GIS into the mainstream of quotidian use throughout society. Geo-Information (GI) Engineering is an extension of GIScience into the design of dependably engineered solutions to society's use of geographical information and underpins applications such as LBS. Making all this possible is the tremendous technological convergence and growing systems interoperability that have taken place over the last decade or so. Most of us now own a mobile phone (if not two or three!) that has more computing power and functionality than a 1980s PC, a digital camera with more mega-pixels than could be dreamed possible in the 1990s, and a high resolution LCD screen and sufficient bandwidth to make it a Web browser, games console and TV all in one! That such mobile devices are a catalyst for LBS is not surprising.

We begin this book by setting the broader social and economic contexts for location-based services, and follow this with an in-depth analysis of a number of technologies that have developed and converged so as to make LBS technically possible. Prime amongst these will be the telecommunications networks servicing mobile devices. We then provide an overview of GIS as a key technology in handling location-based spatial queries and, therefore, at the heart of LBS. However, given that it is now nearly two decades since GIScience emerged from the maturing GIS technologies and their applications, we take a further evolutionary step to consider LBS as an early manifestation of GI Engineering. We then focus on LBS and their architecture with chapters on specific aspects of operational LBS: data, locating the user, using context, spatial queries and

communication. Each will consider technical and implementation issues. We finish the book by discussing a number of issues to do with the business of LBS, including a range of business models that providers might adopt as well as some of the ethical, legal and privacy issues that arise from the use of LBS.

Writing this book has been a longer journey than we first expected. LBS are new, heterogeneous technologies and the relevant research is spread across a number of separate disciplines. This research needed collating and synthesizing, the outcome being a definitive state of the art review of current LBS. We ourselves were conducting research that has contributed to this book. All this has meant that we have been able to articulate a new research agenda for LBS. We would of course like to thank the many people with whom we have had discussions on wireless technologies, GIScience and LBS over the last few years. We would also like to sincerely thank each other for the effort, patience and fortitude necessary to write this book. We hope you enjoy it.

Allan Brimicombe
Chao Li

Chapter 1
The Context of Location-Based Services

1.1 Introduction

This is a book about a new and fast growing technology sector delivering electronic services based primarily on location and geography. This sector is generally referred to as *location-based services* or by its acronym LBS. Because location and geography are at the heart of LBS, this book also has a focus towards *geographical information systems* (GIS), which are at the heart of integrating, managing, querying and visualizing geographical data sets. Whilst some proponents may view LBS narrowly as an application of matured GIS, and whilst we would agree that GIS is one of the underpinning technologies of LBS, they are certainly not synonymous. In fact, we view them as being rather separate technologies: GIS having developed first since the 1960s to occupy one niche and LBS having emerged only recently to fill another. Moreover, LBS have only been made possible due to the maturation and convergence of a whole raft of technologies, such as mobile phones, the Internet, the World Wide Web (the Web) and global positioning system (GPS), which had not been developed at the time when GIS were first developed. Because LBS are underpinned by so many different technologies, in the early chapters of this book both the context and the technological convergence that have made LBS possible are traced. Ordinarily this ground would be covered first before coming to a definition of LBS, such that readers would

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understand where it's coming from and where it's leading to. But this approach might also frustrate readers, who would not then have a clear definition of LBS until some considerable way through the book. So we will provide our definition here, out of context as it is, and work towards a firmer understanding of its meaning and subtleties in what follows. Thus:

Location-based services (LBS) are the delivery of data and information services where the content of those services is tailored to the current or some projected location and context of a mobile user.

How has society changed in the last quarter of the twentieth century to bring about demand for such services? What trajectory are we on that makes it likely that demand for such services will grow dramatically in the coming decade? This is discussed in the remainder of this chapter under three headings – the 'information society', the 'digital city' and the 'new mobility' – and in doing so will provide the context for looking, in Chapter 2, at the various strands of the technological convergence that are making LBS possible. It could be argued that the information society, the digital city and our increased mobility are just three facets of the same phenomenon: the digitalization of economic and social activity. However, as will be pointed out, cities are where the main economic and social driving forces of an information society reside and if the information society is in large an urban phenomenon, then this particular dimension needs to be explored. Our increased mobility is also pertinent in a number of ways. Not only does this relate to greater social and geographical mobility, but it also relates to informational and intellectual mobility. Flexibility to move across collaborative networks in a more holistic, cross-disciplinary way will be key to innovation and creativity, and hence wealth creation, in an information society. This multi-faceted mobility is a dominant driver for LBS and therefore merits separate discussion.

1.2 The Information Society

The majority of readers would agree that the age in which we now live is as different from the industrializing era of the Victorians as the medieval agricultural society must have seemed different to them. The period from the mid-eighteenth to the early years of the twentieth century is now recognized as being the Industrial Revolution. A radical

and complete transformation of society from an agrarian economy (First Wave) to a modern, manufacturing-based economy (Second Wave) was made possible by the harnessing of power to drive machines coupled with the organization and division of labour (alongside other resources) into units for mass production. For our post-industrial (Third Wave) society to have come into existence, did the latter part of the twentieth century undergo a new revolution – an Information Revolution – or did we merely see an acceleration of trajectories set in motion during the Industrial Revolution? This has been a matter of much debate (e.g. Masuda, 1990; Kumar, 1995; Dyson *et al*., 1996; Castells, 1996, 1997, 1998, 2001; Leadbeater, 1999; Robins and Webster, 1999), and for a fuller treatment of the discussion than is possible here the reader is referred initially to Webster (2004). Revolution or not, it is widely accepted that we live in an information society that has important differences from an industrial society.

What is it about this post-industrial age that makes it 'informational'? Most commentators point to the computer as being the core innovation technology and driving force, much as the harnessing of steam power was to the Industrial Revolution. But just as steam on its own was not a revolution (the machines it drove needed to be invented, assembled and used for a purpose), so too is it with computers. But there are two points to be made here. Firstly, the term 'computer' commonly refers to that bundle of technologies (screen, keyboard, motherboard, hard drive, mouse) that many of us use on a daily basis in the office or at home for work and recreation. At its heart, though, is the *microprocessor* or 'chip' (Figure 1.1). These are

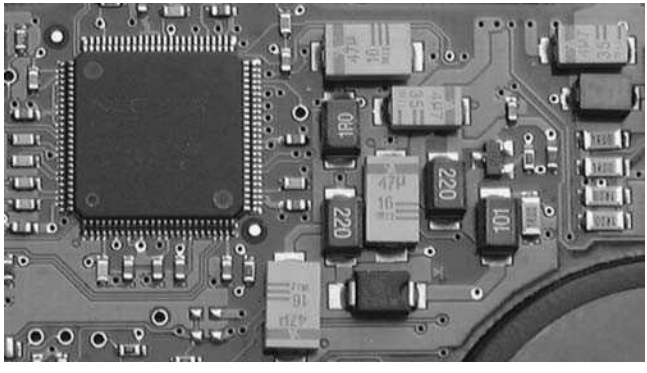

Figure 1.1 The engine of the information society – chips with everything (photograph by the authors).

not just contained in computers but are present in a wide and ever growing range of consumer products, such as mobile phones, DVD players, televisions, toasters and car engines, such that in order for them to work there needs to be a flow of data and the running of software algorithms. Thus it is not just the progressive miniaturization that is key here, but the progressive imbedding of intelligence into just about every device we use. Secondly, what has truly made a difference has been the *networking* of computers and other microprocessor-based devices using modern *information and communication technologies* (ICT) linking computers with computers, computers with individuals and individuals with each other on an unprecedented scale (Figure 1.2). By way of an example, in 2003 an average of 55 million text messages were sent every day from mobile phones in Britain. Not only do these networks 'produce complex and enduring connections across space and through time between people and things' (Urry, 2000 p. 192), they even shape our economic and social structures (Castells, 1996).

If First Wave agrarian societies are characterized by working on crop and animal production in nuclear units (family, clan) and Second Wave industrial societies are characterized by working with harnessed power and machines in massed units (factories), then Third Wave informational societies are characterized by working with digital media in collaborative networks. With each successive wave, some aspects of previous waves are rendered obsolete whilst others become

Figure 1.2 Networking the world – satellite dish farm near Canary Wharf, London (photograph by the authors).

redefined. A progressive example of this latter process would be the industrialization of agriculture through mechanization followed more recently by the incorporation of informational elements that have played a part in both the development of genetically modified crops (knowledge of gene sequences) and in the resurgence of organic farming (knowledge of environmental and nutritional consequences of pesticide use). Castells refers to the Third Wave as both the 'informational economy' (1996, p. 66) and the 'new economy' (2001, p. 22), that is 'an economy in which sources of productivity and competitiveness for firms, regions, countries depend, more than ever, on knowledge, information and the technology of their processing, including the technology of management, and the management of technology' (1997, p. 8).

Knowledge that is actionable (and hence a tradable commodity) is central to the new modes of wealth creation and *cyberspace*, the networked 'space' created by ICT, the Internet and the Web, is simultaneously a means of knowledge storage, communication and innovation – all in electronic form. Networks and the 'space of flows' (Castells, 1989 p. 348) are the engines of the informational economy; innovation is its fuel. Whilst useful information is certainly present, the anarchy of cyberspace means that it also contains false ideas, propaganda, hype, spin and deviance. It is also huge, growing and immeasurable.

To try and get a snapshot of its size and to get a flavour of its relative content, a range of keywords that represent 'informational economy', 'interrogatives' and 'typical desires' were used in a search engine to see the number of Web pages (just one dimension of cyberspace) that were offered in response. These are given in Figure 1.3. Of the keywords chosen, by far the biggest response is to the keyword 'information' with 789 million Web pages – if anybody was to spend only one minute reading each page, it would take him/her some 1500 years to get through them! The disparity in the ranking between 'information' and the keyword 'knowledge' may merely reflect that the former is commonly used to mean the latter. Of the interrogatives, the question 'what' is clearly more important followed by 'who', whilst 'where' trails by more than 100 million Web pages. This may have repercussions for LBS in that location may be of less interest in the information society – cyberspace after all acts to shrink, even annihilate, space and time. On the other hand, this may only reflect that geographical analyses and communication of information about location have traditionally been the least easy to effect, something that is rapidly changing, for example, with Web-based GIS; but more on this

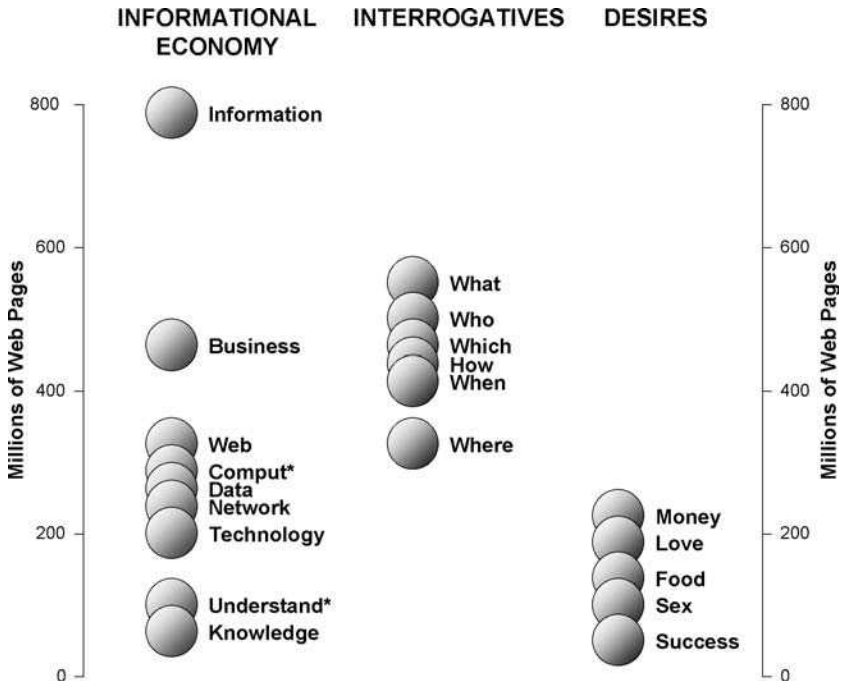

Figure 1.3 A Web survey of responses to keywords in a search engine (* indicates variants of the term, e.g. Comput* includes computer, computers, computing. Source: www.altavista.com on 16 August 2004).

in later chapters. Perhaps the best barometer of cyberspace is to compare the informational economy keywords with those of our typical desires. Keywords for these desires are considerably down the ranking by comparison, though between them of course 'money' leads 'love' by a small margin!

As an indication of the rate of growth of cyberspace, the numbers of Web pages reported in Figure 1.3 have risen 10-fold from when this mini survey was first run five years ago. However, not all that can be found in cyberspace is necessarily useful. Knowledge utility in terms of wealth creation in the informational economy is time-bound. Of highest utility is *customized* knowledge, that is the right source(s) of information combined, presented and communicated using the right software at precisely the moment it is required (Dyson *et al.*, 1996). Compare this with the definition of LBS given above and it can be seen that LBS are precisely Third Wave products and typical of what creates wealth in an informational economy.

Will we look back and see the information society as a revolutionary change? It may be too early to tell, but information, innovation and creativity have always been the sources of increased productivity and economic growth. Wiener, the originator of cybernetics, put it thus: 'to live effectively is to live with adequate information' (1968 p. 19). What has accelerated in a dramatic way is the rate of knowledge production and the rapidity of its exploitation. There are three aspects to this. Firstly, there are the collaborative networks in which communication over any distance to any number of actors has become almost instantaneous. These have increased research productivity and shortened the time in which the knowledge thus produced is translated into commercial products (Leadbeater, 1999). Secondly, and as part of this, what was a longstanding distinction between the production of knowledge and its communication (Bell, 1980) has merged into an integrated process. Thirdly, governments have assumed a leading role in promoting the information society (Kumar, 1995). In the United Kingdom, e-government has been actively promoted with ambitious targets: 25% of services available on-line by 2002, 100% by 2005 (http://www.ukonline.gov.uk), which in the end proved to be too ambitious! High level 'e-government champions' were appointed in each local authority to ensure compliance. 'Citizens will expect to reach the services they want at times and in places that are convenient to them' (www.ukonline.gov.uk). Notwithstanding this, it is seen as a means of modernizing government, making it accessible and achieving IT-related efficiency gains (i.e. holding or reducing costs). As part of this agenda, the government has also been promoting the use of computers and IT literacy through schools, universities and public libraries in a bid to assure accessibility and to create a desire amongst citizens to engage with the information society.

But the rise of the information society has had a dark side: inequalities and social exclusion, after nearly a century of decline, have been steadily on the rise over the last quarter century (Kumar, 1995; Castells, 1998; Leadbeater, 1999). Inequalities arise where individuals or social groups, relative to each other, have differential abilities to appropriate wealth (income and assets). Social exclusion, on the other hand, occurs where individuals or groups, regardless of absolute levels of wealth, find themselves systematically barred from access to, for example, average levels of services for health, education and housing or facing above average levels of risk to being victims of crime.

Both inequalities and social exclusion can be difficult to measure and track over time, but in London, for example, since 1984 incomes

have become more polarized, poverty has intensified, mortality differentials have increased and the poorest areas have seen the sharpest rises in violent crime (London Research Centre, 1999). There are a number of trends that have contributed to this. In the informational economy, businesses need to be flexible because the life cycle of products has been shortened and because sources of innovation are less likely to be internal but derived from collaborative networks. This has translated into many businesses downsizing, flattening of the management structure, outsourcing and subcontracting. Labour, in turn, has had to change with rapid growth in self-employment, part-time work and temporary work, particularly for women (Castells, 1997).

The information society is very uneven geographically. It is very strong in general in North America, Europe, urban India, urban China, Southeast Asia and Australia. It is weakest in most of Africa and rural Asia and parts of Latin America. But within those countries that are strongly engaged, there exist geographical pockets, such as the South Bronx in New York and Tower Hamlets in London, that have low levels of engagement (Castells, 1997). Thus the divide is not along the traditional opposition of First World and Third World, leading Castells (1998 p. 337) to conjecture the emergence of a 'Fourth World', which represents 'segments of societies, areas of cities, regions and entire countries' that are slipping into the margins of the informational economy. This is popularly framed as a 'digital divide' (NTIA, 2000). Hull (2003) points out that in the United Kingdom only 3% of the poorer households are on-line as compared with 48% of affluent households – digital restructuring is thus tending to deepen inequalities. Any divides caused by possession of hardware are likely to close due to impending saturation of not just personal computers (PCs) but more importantly of Internet-enabled mobile telephones. Barriers to engagement then will still be to some extent financial (the cost of being on-line, particularly from mobile devices), but are more likely to form along lines of digital skills and usage opportunities (Dijk and Hacker, 2003) which will most probably correlate with levels of educational attainment.

To sum up this section, the rise of the informational economy has provided new means of wealth creation but is still rooted in mass consumption and price utility. Information inevitably has a 'sell-by date', a finite time in which its utility can generate revenue through innovation. When it becomes 'common knowledge' its price can become minimal, but if still above the marginal cost of production (which for digital products can be close to zero) it can still generate

wealth if accessed by large numbers of customers. For knowledge-workers making a living out of the new economy, what is the half-life of their ability to produce new ideas? How long before individuals are consigned to the margins as 'burnt out', or indeed as the 'never glowed'? Lifelong learning and continuing professional development have become rooted in society. But it will be collaborative networking that will allow us to maximize our exposure to sentient knowledge and nascent ideas and, therefore, maximize our chances over a longer period (hopefully a complete working life) for coming up with new ideas, noticing opportunities and participating in innovation.

1.3 The Digital City

Like the information society, the digital city is a topic of considerable debate of which only a brief cross-section can be provided here. For millennia built environments have been created – from the time we learnt to clear land for agriculture, build villages for shelter and harness water for irrigation. Today there are very few completely natural environments left; such is our impact on our planet. We have been creating cities around the specialization of human activity from the time we could create consistent (though not always reliable) agricultural food surpluses. Cities have always been focuses of information for trade, governance (both internally and of their hinterlands) and social organization for wealth creation. The geographical location of cities has always maximized accessibility to people, goods, capital and, of course, information. From this, cities have in turn created hegemonic power. The growth of cities, both in number and size worldwide, is testimony to their endurance as the dominant means of social and economic organization regardless of political ideology.

Second Wave industrialization, through its benefits to life expectancy and its needs for massed labour and mass consumption, served to accelerate city growth and the spread of urbanization. In the first half of the nineteenth century, city populations were growing at rate of 12% per decade; by the second half of the nineteenth century this had risen to 26% per decade (Carter, 1981). In the last half of the twentieth century the growth rate had reached 46% per decade. United Nations projections (in Fox, 1984) show that the number of metropolitan areas worldwide with a population in excess of five million inhabitants will have risen from 34 in 1984 to 93 in 2025, with some

11 of these metropolitan areas likely to have populations in excess of 30 million. By 2025 there are expected to be 5.1 billion city dwellers, nearly two-thirds of world population. Cities will be huge, networked and, above all, complex.

The Second Wave industrialization, which for some two centuries had been the driving force of city building, has within a generation suffered substantial absolute and relative decline in the face of serviced-based industries (Wheeler *et al*., 2000). The so-called 'death of distance' induced by the wholesale adoption of modern ICT at business and personal levels, and which would remove the need for agglomeration of businesses and employment, was considered to herald the death of cities. Graham and Marvin (1996) and Graham (1998) have summarized a number of competing conceptualizations of the changing relationship between space, place and information technology:

Technological determinism. In this conceptualization, ICT and the so-called 'information superhighway' would direct change in some simple deterministic way. The main driver would be the massive shrinking or even death of distance which would liberate human life from the frictional effects of distance. Since agglomeration into cities has been the traditional means of overcoming these frictional effects, the removal of distance as a constraint to human interaction would lead to areal uniformity – a sort of veneer of tele-cottages – and the dissolution of cities. In this scenario we would become tele-workers, tele-shoppers and indulge in tele-socializing using networked virtual reality technologies that would provide all the richness of face-to-face activities.

Co-evolution of geographical and electronic spaces. Under this conceptualization the technological determinism argument has considerably exaggerated the degree to which ICT can substitute for face-to-face and other place-based activities. Instead, electronic networks will co-evolve with physical spaces and social processes to produce new synergies and new urban forms. Thus residents may be able to tap into digital resources to enhance their place-based experience of the city. Indeed, LBS may have a key role to play here. Such a scenario may intensify city development in symbiosis with the growth of telecommunication networks and the acceleration of their transmission rates. Cities, far from shrinking, will in fact continually be recast due to the complex evolving relations between capital, technology and space.

Recombination through actor-networks. This view relies heavily on actor-network theory, in which absolutes have little meaning and much depends on the relational process of agency. Thus networks are not fixed absolutes but are continually recombined at any moment by the actors using them and thus the specific social contexts and power struggles within which usage takes place. For digital networks, however, many of the actors are themselves algorithmically responding machines and this is likely to blur the boundaries between humans and machines to produce a cyborgian conceptualization of reality. These will act to continually produce new forms of human interaction, organization and control. However, one clear consequence of the ever increasing rate of information production and dissemination appears to be an increasing demand for face-to-face contact as the most effective means of resolving information glut. The agglomeration advantage of cities for actor-networks seems set to endure.

Looking around our cities today we can see elements of all three conceptualizations at play, though it seems that technological determinism has the least power to explain current city processes. From the introduction of the telephone through to the construction of optic fibre networks, cities have seen preferential development of telecommunications infrastructure. Indeed '... cyberspace is, in fact, a predominantly metropolitan phenomenon which is developing *out* of old cities' (Graham, 1998 p. 173, original emphasis). Cities represent lucrative concentrations of demand where revenues from ICT can be maximized with the least outlay in infrastructure. Deregulation of telecommunications in the 1980s and 1990s led to concentrations of providers in cities where they could 'cherry pick' Third Wave information-intensive markets. Cities that long benefited from excellent physical access are now the beneficiaries of excellent ICT infrastructures (Niles and Hanson, 2003) and are also centres, for example, of Internet content provision because this is where the expertise has accumulated (Kellerman, 2000; Castells, 2001).

Measuring this phenomenon is not easy, but the degree of clustering of the telecommunications industry in Britain as an urban phenomenon is illustrated in Figure 1.4. As a statistical measure of the clustering, the median distance from any one company to its nearest neighbour was found to be 778 metres – just a few street blocks away. The pre-eminence of London in Figure 1.4 as a centre for telecommunications reflects its position as a global city. International networks

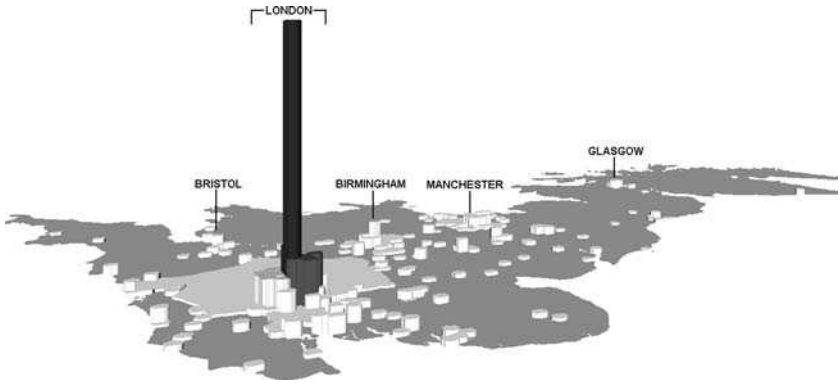

Figure 1.4 Density clustering of the telecommunications industry in Britain: a largely urban phenomenon with highest concentrations in and around London (density per square kilometre using Geo-ProZone spatial clustering technique – see Brimicombe, 2006; base data compiled by the authors from industry sources, 2001).

use cities as nodes due to their potential to maximize traffic and revenues. Reed's Law (in Rheingold, 2002) holds that the value of a network grows exponentially to the number of users, in other words, the social and business networks that are created are always far larger than the physical network infrastructure. Consequently, those nodes (cities) that most intensively use ICT and knowledge-based industries for wealth creation have emerged as global cities: their reach and ability to control and influence at a distance dramatically increases their power. For cities, 'being digital' is the key to wealth and status (Negroponte, 1995). Furthermore, to be a key node in the network of cities is to be at the heart of the world economy.

Whilst it is clear that ICT and other modes of communication can substitute for personal movement, they can also complement and stimulate it (Hall, 1999). Face-to-face exchange of information remains important. Whilst collaborative networks are becoming the basic units of innovation and production (Leadbeater, 1999), ICT cannot provide a complete substitute for face-to-face contact, particularly where building a relationship of trust is important. Given the ease of availability of information and the propensity towards overload, face-to-face activities such as listening, advising, brainstorming and negotiating, either in the formal setting of an office or in the informal setting of a restaurant or bar (or even on a golf course), remain an important means of resolving issues and finding new synergies. Castells (1989, 2001) refers to this as the 'milieu of innovation', that

is the physical concentration of clusters of people and companies networking together, both electronically and socially, to produce innovation by synergy. The term 'milieu' does not just express 'environment', it also means 'middle' – expressing the notion that the best place to be is at a node where there is maximum network accessibility to people, information services and resources. The physical accessibility afforded by cities remains an important factor and it is still the case that collaborative networks are most easily established in cities. Thus, grounded (place-based) social relations endure as an essential ingredient in the information society (Niles and Hanson, 2003).

The new economy, as well as enhancing the power of cities, has also brought important changes in structure and complexity. Whilst the value of face-to-face contact endures, not all activities require it. Thus back offices, given the 'death of distance' over networks, can be just about anywhere where there are good ICT infrastructure and suitable personnel. Thus call centres for UK companies are sited from Scotland to India; similarly, document processing for banking, insurance, law and publishing. Product development in areas such as software, graphics and CAD-based design can similarly be networked around the world. These types of activities have left the traditional city cores for cheaper premises and lower wages, often in Third World countries. In these cases ICT have lead to dispersal. On the other hand, ICT have promoted the agglomeration of corporate headquarters, R&D and high-end service functions (such as financing, marketing, protecting intellectual property rights) so as to reduce the time and cost of innovation and hence compete effectively (Wheeler *et al.*, 2000). New industries concentrate alongside these to take advantage both of advanced ICT infrastructures and the availability of financial and other services. These agglomerations, however, are not necessarily sited in the traditional central business district (Hall, 1999) but have tended to form new centres. Thus, in London concentrations of knowledge-based industries are to be found in the West End (formerly predominantly high class residential) and in Canary Wharf (formerly docks). Indeed, Canary Wharf has grown to become London's second central business district (Figure 1.5). This trend has lead to the creation of 'edge cities' and has changed the overall city structure from monocentric to polycentric (Hall, 1999). As well as city structure, ICT are also transforming public spaces within our cities (Moss and Townsend, 2000). Our experience of public spaces is already frequently augmented by simultaneous use of mobile phones and whilst in public spaces we tend to be under surveillance by CCTV and other

(a) (b)

Figure 1.5 An urban focus of the Third Wave economy – Canary Wharf, London: (a) new tower blocks containing typical knowledge-based industries and waterfront housing for its affluent workers; (b) with preserved vestiges of its Second Wave heritage in the foreground (photographs by the authors).

technologies (discussed further in the next section). Even the architectural facades in high accessibility areas such as Times Square in New York, Shibuya and Ginza in Tokyo and Piccadilly Circus in London are increasingly being designed as communicators of information and digital augmentations of place-based experience (Figure 1.6).

(a) (b)

Figure 1.6 Informational city; informational facades: (a) Ginza, Tokyo (photograph by the authors); (b) Times Square, New York (photograph by Y. Li, used with permission).