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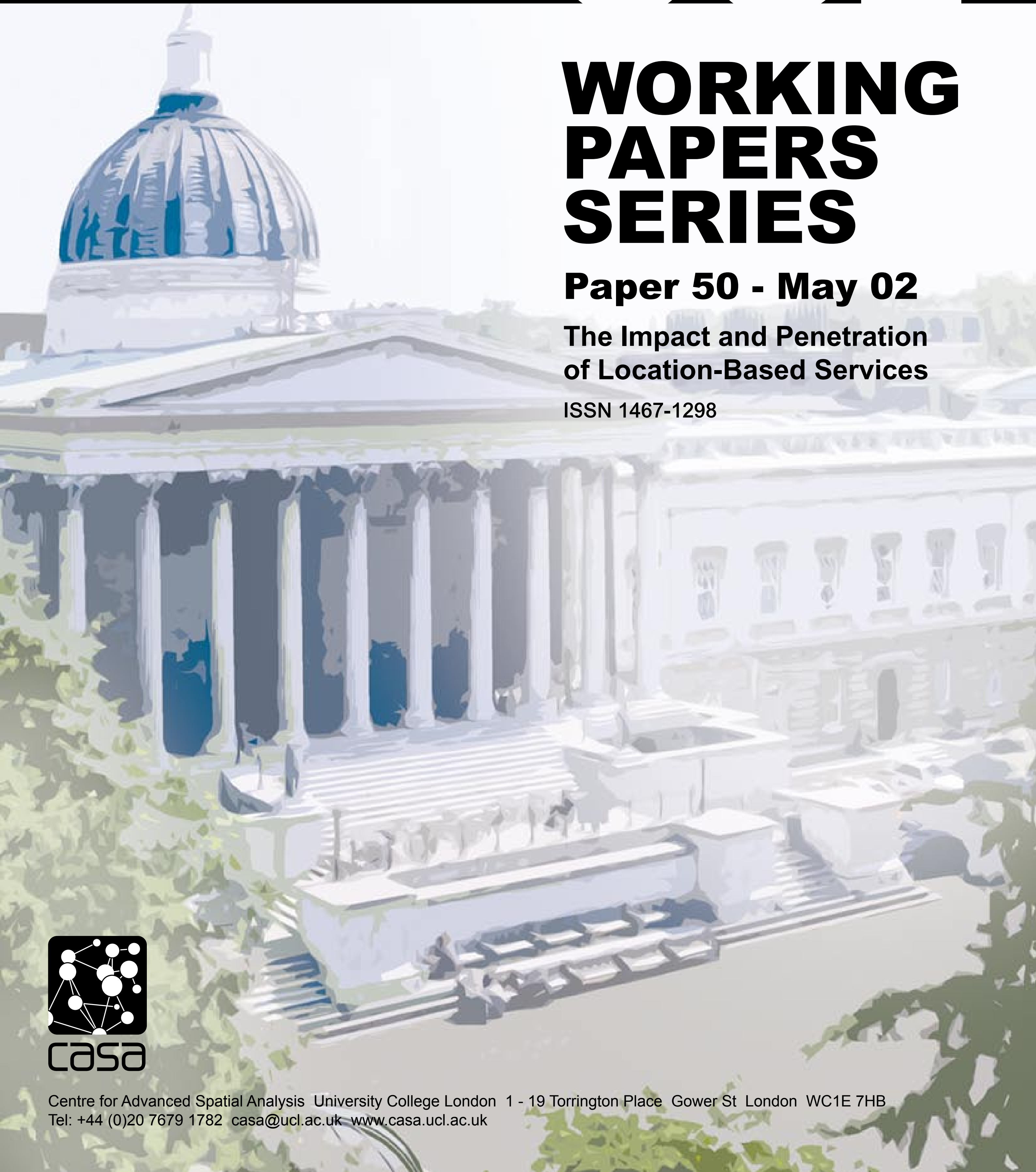

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The Impact and Penetration of Location-Based Services

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THE IMPACT AND PENETRATION OF LOCATION-BASED SERVICES

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Introduction: The Definition of Technologies

Since the invention of digital technology, its development has followed an entrenched path of miniaturisation and decentralisation with increasing focus on individual and niche applications. Computer hardware has moved from remote centres to desktop and hand held devices whilst being embedded in various material infrastructures. Software has followed the same course. The entire process has converged on a path where various analogue devices have become digital and are increasingly being embedded in machines at the smallest scale. In a parallel but essential development, there has been a convergence of computers with communications ensuring that the delivery and interaction mechanisms for computer software is now focused on networks of individuals, not simply through the desktop, but in mobile contexts. Various inert media such as fixed television is becoming more flexible as computers and visual media are becoming one.

With such massive convergence and miniaturisation, new software and new applications define the cutting edge. As computers are being increasingly tailored to individual niches, then new digital services are emerging, many of which represent applications which hitherto did not exist or at best were rarely focused on a mass market. Location based services form one such application and in this paper, we will both speculate on and make some initial predictions of the geographical extent to which such services will penetrate different markets. We define such services in detail below but suffice it to say at this stage that such functions involve the delivery of traditional services using digital media and telecommunications. High profile applications are now being focused on hand held devices, typically involving information on product location and entertainment but wider applications involve fixed installations on the desktop where services are delivered through traditional fixed infrastructure. Both wire and wireless applications define this domain. The market for such services is inevitably volatile and unpredictable at this early stage but we will attempt here to provide some rudimentary estimates of what might happen in the next five to ten years.

The "network society" which has developed through this convergence, is, according to Castells (1989, 2000) changing and re-structuring the material basis of society such that information has come to dominate wealth creation in a way that information is both a raw material of production and an outcome of production as a tradable commodity. This has been fuelled by the way technology has expanded following Moore's Law and by fundamental changes in the way telecommunications, finance, insurance, utilities and so on is being regulated. Location based services are becoming an integral part of this fabric and these reflect yet another convergence between geographic information systems, global positioning systems, and satellite remote sensing. The first geographical information system, CGIS, was developed as part of the Canada Land Inventory in 1965 and the acronym 'GIS' was introduced in 1970. 1971 saw the first commercial satellite, LANDSAT-1. The 1970s also saw prototypes of ISDN and mobile telephone and the introduction of TCP/IP as the dominant network protocol. The 1980s saw the IBM XT (1982) and the beginning of de-regulation in the US, Europe and Japan of key sectors within the economy. Finally in the

1990s, we saw the introduction of the World Wide Web and the ubiquitous pervasion of business and recreation of networked PC's, the Internet, mobile communications and the growing use of GPS for locational positioning and GIS for the organisation and visualisation of spatial data. By the end of the 20th century, the number of mobile telephone users had reached 700 million worldwide. The increasing mobility of individuals, the anticipated availability of broadband communications for mobile devices and the growing volumes of location specific information available in databases will inevitably lead to the demand for services that will deliver location related information to individuals on the move. Such location based services (LBS) although in a very early stage of development, are likely to play an increasingly important part in the development of social structures and business in the coming decades.

In this paper we begin by defining location based services within the context we have just sketched. We then develop a simple model of the market for location-based services developing the standard non-linear saturation model of market penetration. We illustrate this for mobile devices, namely mobile phones in the following sections and then we develop an analysis of different geographical regimes which are characterised by different growth rates and income levels worldwide. This leads us to speculate on the extent to which location based services are beginning to take off and penetrate the market. We conclude with scenarios for future growth through the analogy of GIS and mobile penetration.

Location-based Services: Definitions, Software, and Usage

We must now provide a more detailed definition of location based services (LBS). These are the provision of geographically-orientated data and information services to users across mobile telecommunication networks. LBS can be seen as a convergence of new ICTs (NICTs) such as mobile telecommunication system, location aware technologies and handheld devices with the Internet, GIS and spatial databases as we illustrate in Figure 1.

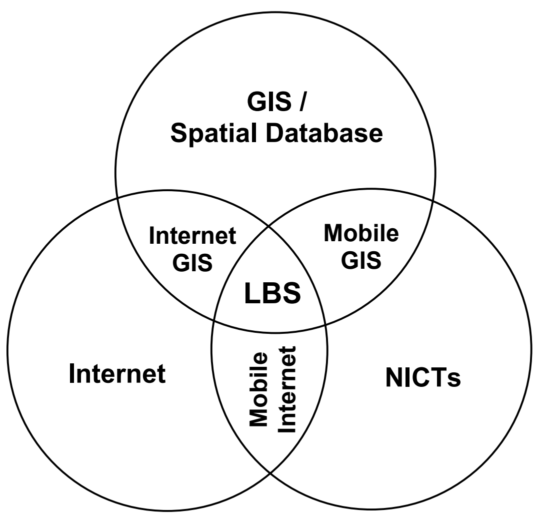

Figure 1. Convergence of technologies creating LBS (Brimicombe, 2002).

Mobile telecommunication networks have developed dramatically, from the second generation based on the Global System for Mobile Communication (GSM) to 2½ generation called the General Packet Radio Service (GPRS) with an expected third generation termed the Universal Mobile Telecommunication System (UMTS). The bandwidth of networks is moving from 9.6Kbps to 115Kbps, and will support bandwidth of 2Mbps with UMTS. Wireless Application Protocol (WAP), started in 1997, is being developed into a new standard, aiming to have "an architecture and a language which will facilitate the convergence of fixed Internet, WAP … toward one and the same mobile Internet solution." (www.ericsson.com/developerzone/). The development of mobile telecommunications also has transformed the services from focusing on transmission of voice data to various applications of transmitting information through multimedia. Handheld, mobile and small size wireless devices such as Personal Digital Assistants (PDA) and mobile phones, have been enhanced and can be connected via infrared, GSM modems or radio signals to wireless networks. With the development of location aware technologies and the increasing number of mobile device users, services providing location related information are likely to become major applications of these new technologies.

Given the location aware nature of LBS, locational information is vital for communications system set-up, navigation and system management while handling and processing such information (spatial and temporal) is essential for providing LBS in the first place. Many industry analysts see a central role for GIS which forms the foundation for many of these LBS developments. GIS has been considered as a core area in managing, processing and delivering spatial information in meaningful ways (Bishr, 2000). The META Group reported that "… about 40 percent of all mobile data applications in utilities are linked to GIS" (quoted in Wilson, 2001). Maguire (2001) notes that "… geographic data and processing are provided as a type of service over a wireless network connection", which suggests the terms "mobile geographic services" and "mobile GIS". A number of statements have alluded to GIS solutions being able to analyse the objects in particular locations with their relationships to each other, providing tools for integrating spatial information. Such developments will transform the average LBS into valuable information sources for supplying value added services (Coleman, 2001; Okunuki *et al*., 2001; Wilson, 2001; ESRI, 2000; MapInfo, 2001).

The main driver of LBS in the US is the Federal Communications Commission's adoption of enhanced 911 (E911) mandate. The E911 mandate aims to improve the quality and reliability of the emergency services by locating wireless 911 callers (www.fcc.gov/e911/). The requirement was to ensure 50 metre accuracy for 67% of calls (150 metres for 95% of calls) for handset-based solutions, and 100 metres for 67% (300 metres for 95%) for network-based solutions by October 2001. The incentive in the E911 mandate is that it provides the basis for a wide range of additional, value-added location based services. The concern for locating wireless emergency calls only began to be tackled from 2000 in Europe. Nevertheless, there is currently very fast development and deployment of both wireless and location-aware networks. Also in 2000, mobile network operators, after immense investment in 3G licenses, began to look for content driven services. Location based services in Europe are increasingly being driven by the motivation to provide differentiating and value-added services in a competitive marketplace.

IDC (www.idc.com) predicts that by year 2005, almost 50% of European mobile subscribers will use such services. The 2001 surveys by Jupiter and McKinsey report that 38% of wireless users would like to see navigation services being provided The ARC Group's figure shown in Table 1 demonstrates the wide range of potential applications and their perceived ranking by mobile users over time. With considerable growth potential in LBS, the various applications can be divided into six categories which are currently being developed and some of the applications are commercially available (Hunter, 2001). The list is still growing.

- Pushed online advertising.
- User-solicited information, such as local traffic information, weather forecasts and local services.
- Instant messaging for communication with people within the same or nearby localities.
- Real-time tracking.
- Mapping/route guidance, directing people to reach their destination.
- Emergency services for stationary location.

- Location-based tariffs

An open industry specification for delivering navigation, telematics and related geographic information services across multiple networks, platforms and devices is being promoted by a consortium that includes Panasonic, Microsoft and Tele Atlas. They are also developing a suite of APIs and protocols designed to create a development environment for LBS applications (Bastiaansen, 2001). Some companies have developed geo-spatial engines optimised for LBS applications, while others have chosen to embed existing GIS into their services.

Table 1. Range of applications and their perceived ranking by mobile users over time

Rank	**2000**	**2003**	**2005**
1	PIM*	PIM	Navigation / Location
2	Entertainment	Entertainment	PIM
3	Financial Services	Navigation / Location	Entertainment
4	Internet Browsing	Financial Services	Financial Services
5	Navigation / Location	Internet Browsing	Internet Browsing
6	m-Commerce / Retail	m-Commerce / Retail	m-Commerce / Retail
7	Intranet	Intranet	Intranet

**PIM: Personal Information Management*
Source: ARC Group (http://www.the-arc-group.com/*)*

Personal profiling has been regarded as a way to enrich and enhance LBS and supply people with the information that they are likely to need. 'Tailor made' location-based services as facilitated by such a personal profile is considered to be a significant development in the mobile data market, which will deliver information specifically compiled for the individual according to his/her interests, history and location. An example of future LBS personalised intelligent services tuned to individual's lifestyle and demands would be theatre tickets automatically reserved during a business trip away because of a user's culture profile. Information related to an individual and their location has been suggested as classifiable into short-, middle- and long-term; recent spatial and temporal trends are considered as short-term information, personal preferences as middle-term, and the person's identity as long-term (Mountain & Raper, 2000; Mountain & Raper, 2001). Personal profiling would clearly be attractive to marketeers in their pursuit of 'one to one' marketing of products and services as it would be more accurate than current geodemographic profiles.

A range of input and output methods have been proposed and offered in some of the LBS applications, thus trying to identify the desirable and effective way for delivering information. Voice has been suggested as a user friendly method for inputting requests and giving instructions. Using speech via mobile phones as navigating instructions during driving is one example. Phonetic transcriptions of city names, street names, and 'points of interest' in digital maps is another example for inputting information through voice (van Es, 2001). Despite many exciting applications of wireless services, LBS is still in the earliest stages of deploying mobile solutions. Many of the assumptions concerning usage and behaviour are untested and should not be taken for granted. There is thus considerable uncertainty still in predicting how these applications and markets will pan out.

The Market for LBS: A Model of the Development of LBS

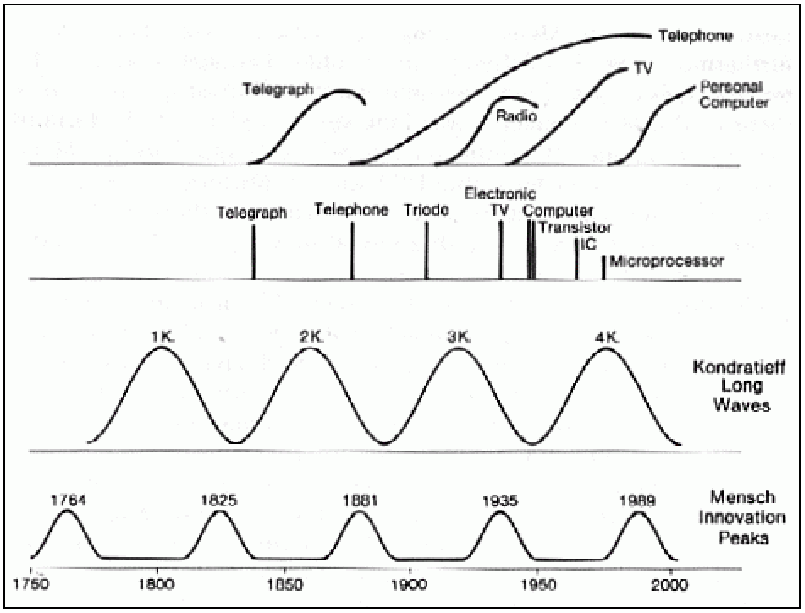

Figure 2. Schematic diagram of radical new IT innovations and the Kondratieff waves observed by Hall and Preston (1988).

Although the concept of LBS has emerged only recently, it is expected to follow the remarkable growth demonstrated earlier by other IT technologies, and the demand for various geographical information-oriented services is also likely to provide a large share for LBS industry in the IT market within the next ten years.

This wave of market growth is influenced by a number of elements and factors that are themselves growing at a rapid speed and are increasingly becoming available in the market. These include the hardware vehicle such as the WAP (Wireless application protocol)-enabled mobiles and other wireless Internet terminals, software services ranging from secure online transaction protocols to various entertainment functions, and data resource on which the LBS relies.

The series of successive waves of new IT inventions and their diffusion appear to follow a certain pattern known as the Kondratieff cycle. The Kondratieff cycle is a theory that inter-relates economics and politics, taking into consideration such events as war, discoveries, public opinion, and weather and price behaviour as integral parts of a long-term economic life-cycle (Kondratieff 1935). Within a capitalistic society, Kondratieff proposed that economic trends tend to repeat themselves every 50-60 years. This alternation of *the long wave* from prosperity to depression, complemented by many shorter cycles, lends a dynamic trend to the economy that to a large degree becomes predictable.

Hall and Preston (1988) argue that the array of innovations of IT-related technologies and services can be regarded as part of the fifth wave of innovations in this particular context (Figure 2). The figure illustrates the transition of innovations and technologies where the new generation of innovations are continuously emerging under a certain frequency, occasionally replacing their predecessors. Taking this analogy further, we can argue that the LBS-related technologies also follow the wave of innovations as a group of inventions forming the terminal period of the fifth Kondratieff wave, where these concepts will rapidly

become available in the market and will promote LBS industry to provide a transition of service types in the wireless market.
Whether or not the Kondratieff wave is theoretically robust remains still somewhat controversial, but there is a wide spread evidence which empirically support the idea that economic market and innovations curve have common ground in their periodic behaviour. We are also aware of numerous other wave or cyclic model suggested in the past. For instance, Schumpeter's Business Cycles (1939) proposed a three-cycle model of economic fluctuations or waves (1) the Kitchin inventory cycle (3-5 years), (2) the Juglar investment cycle (7-11 years), and (3) the Kondratieff long cycle (50-60 years). However, these are fundamentally inter-related to one another and are essentially pointing towards the same direction. For instance, three Kitchins make up one Juglar and six Juglars make up one Kondratieff—there is also the mid-long wave of infrastructural investment suggested by Kuznets; i.e. *the Kuznets infrastructural investment cycle* (15-25 years) where, again, we can fit two or three Juglars to one Kuznets and three Kuznets to one Kondratieff.

Here we follow the analogy of IT deployment forming the fifth wave of innovations and apply the Kondratieff cycle model to depict the market growth of LBS services and industries. Figure 3 shows the growth of some of the IT-related commodities over the last ten years. The six indices can be categorised into three different groups each of which increasing at a near-exponential growth rate but on a different scale and slope. The first group contains the basic hardware commodities that were invented prior to the convergence of the fifth wave, and these include fixed phone lines and personal computers which are well deployed and its market having reached the state of maturity over the years. The second group comprises of users of various IT services provided through such devices where the increase curve is still steep but are likely to reach saturation as it exceeds the overall growth of hardware from the first group. The last group consists of the uptake and the magnitude of newly emerging IT services such as e-, m-Commerce and WAPs. These are essential elements to LBS, and they are growing at a remarkable rate, rapidly catching up with the number of users, suggesting that the LBS market follows the same exponential growth observed in many other IT services.

In the next section, we observe the growth of the mobile industry in terms of its penetration rate amongst different parts of world, and we estimate its growth in the next five, ten years. The analysis will be primarily focused on handheld devices in general, but as the number of WAP-enabled mobile devices is increasing, it can be regarded as an indicator of the increase in the number of hardware vehicle for LBS.

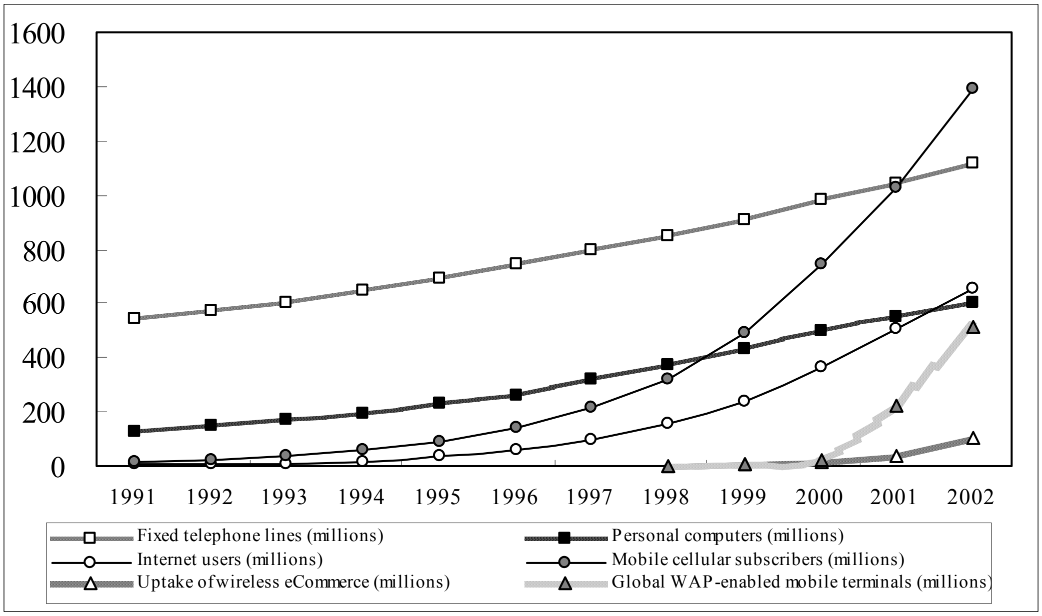

Figure 3. Growth of Some IT-related Services and Commodities (in millions) (Data source: allNetDevices, ITU).

Penetration of Mobile Devices: Predictions of Future Markets

Summary of the Growth Trend in the Mobile Market

The growth of the mobile industry market over the last ten years has been remarkable to say the least. However, as it applies to any other newly developed technologies, the growth has not been persistent in every place. The North European nations, for instance, have been known as most wired area and they have constantly enjoyed a high penetration rate of mobile devices, whilst the less-developed countries have yet to take off as a large mobile phone market. This may change dramatically over the next couple of years, as the price of mobile devices become even cheaper and more mobile network connections become available.

Figure 4 shows the comparison between the current penetration rate of fixed phone line connection and that of mobile subscription in each continent and wider region. As of December 2000, North European nations, namely Denmark, Iceland, Finland, Norway and Sweden, already see a high rate of mobile prevalence; but this is closely followed by the Western European countries and the high income Australasian nations. In terms of individual nations, high income Australasian countries such as Taiwan (80%) and HongKong (77%) and Singapore (62%) are more visible amongst the most mobile saturated nations. The rank of the actual number of mobile subscription has a strong positive correlation with the GDP of each country with economic powers such as the United States, Japan, Britain and Germany dominate the top of the list with the notable exception of China which ranks at the very top much due to the sheer size of its population (this applies to several other countries with large population such as Brazil, Turkey, and Mexico all of which having a low penetration rate for mobile phones). This alone clearly indicates a potentially explosive growth in the number of mobile penetration over the next few years as the price becomes more affordable.

The divide amongst those *who have* and those *who do not have* is more visible in Figures 5 and 6 where the groups of nations with similar economic and demographic characteristics naturally form loose clusters.

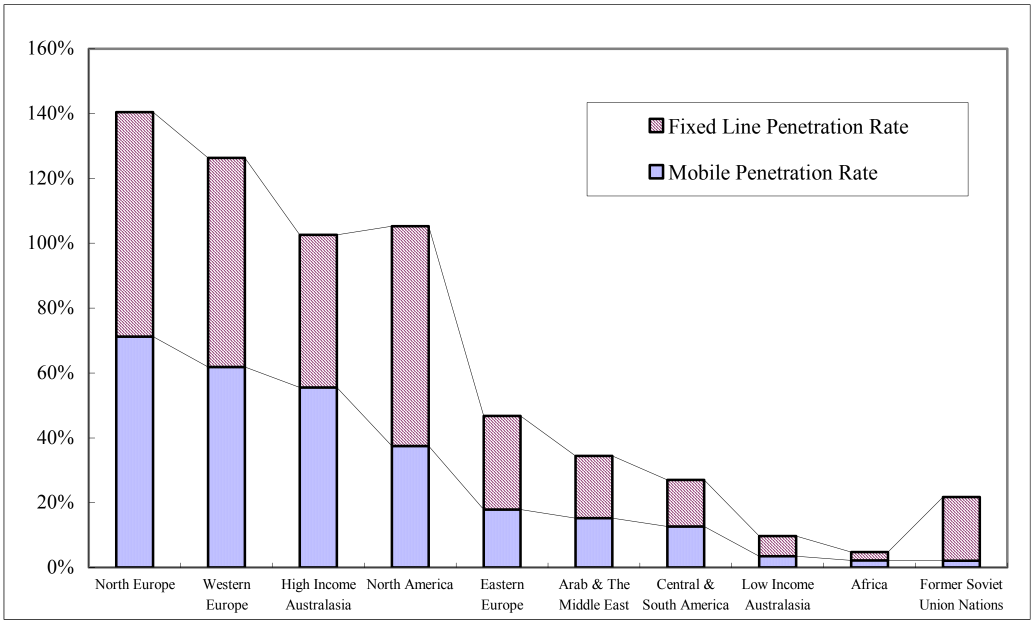

Figure 4. The Global Fixed Line and Mobile Penetration Rate as of 2000 (Data source: ITU).

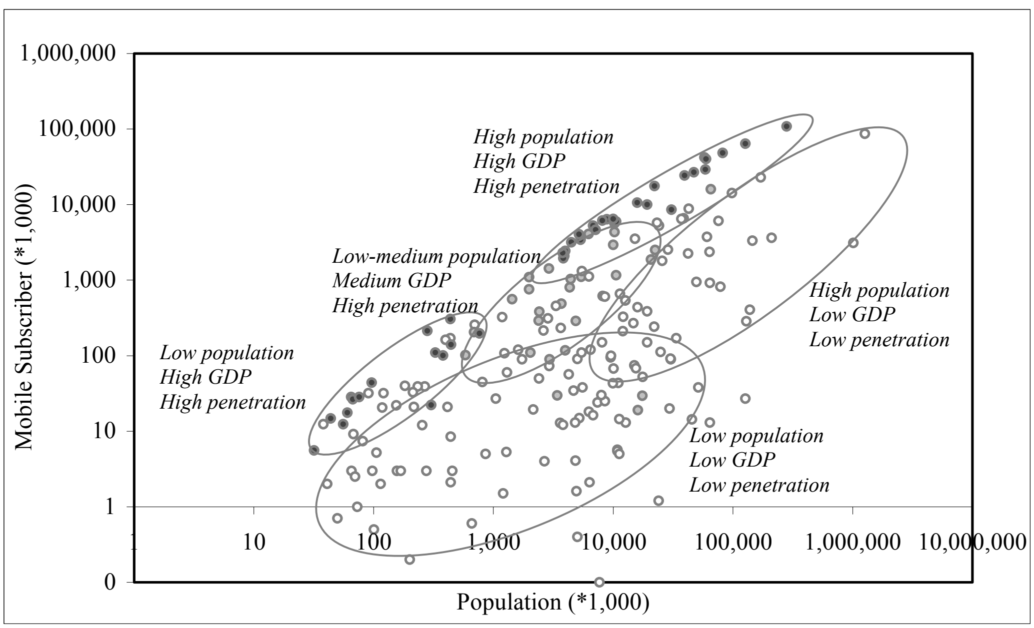

Figure 5. Log-log plot of mobile subscribers against population for each country as of 2000 (Data source: ITU). The white, grey and black dots represent countries with low GDP (per capita) value, intermediate value, and high value, respectively.

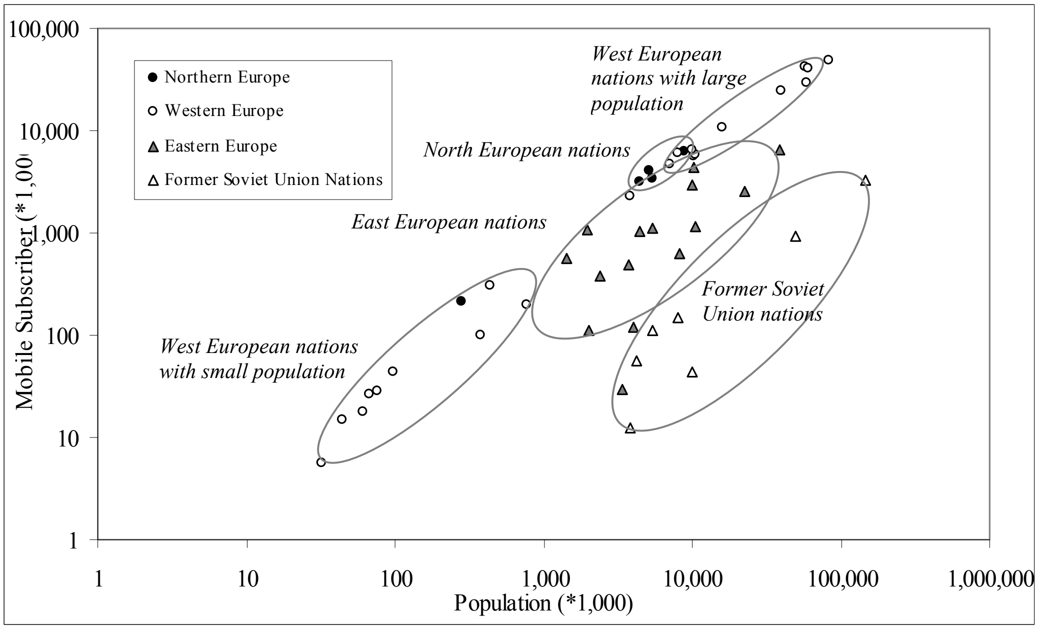

Figure 6. Log-log plot of mobile subscribers against population for countries in Europe as of 2000 (Data source: ITU).

In both figures, the more developed countries form an almost log-linear distribution towards the upper left, suggesting that they are already in a steady state (these are indicated as nations with high GDP in Figure 5 and West and North Europe in Figure 6 both of which can be predicted by a regression curve at R^2 value of over 97%). These countries may still see a healthy growth in the number of devices subscribed, but this would exceed the total number of population who are likely to use mobile phones (e.g. excluding children under 10) suggesting that the surplus will be used as a secondary device where one user would have multiple handheld devices, possibly because of different functions they offer.
Countries with medium GDP per capita rate (e.g. East European countries) which are rapidly growing in its economic presence currently form a cluster between the superpowers and the smaller yet developed nations. This group may diminish as they gradually catch up with the developed country and come to form a combined cluster of high mobile subscription rate, although the current R^2 value of 74% for its regression curve implies that this cluster is wider than the formers and may take more time before convergence.

The most controversial element would be the large cluster in the lower-right formed by less (and the least) developed countries which have low GDP figures and naturally low mobile penetration rates. Potentially, these nations may boost the mobile industry, especially in the case of nations with large population where even a small percentage increase would significantly affect the market.

These observations are rather superficial and speculative but are nonetheless confirmed in Figure 7, which shows the accumulative growth of mobile penetration rate within each continent or region can be categorised into three groups. The Northern European countries lead the first group where the rest of the Western Europe and the high income sector of Australasian nations are also catching up rapidly. North America is yet to reach the steepest penetration increase but is constantly increasing, and so are the other regions with a mixture of developed and less developed countries such as the Middle East, Eastern Europe and Central and South America, forming the second category of penetration growth. The last category consists of the least developed regions such as Africa, lower income sector of Australasia, as well as the former Soviet Union nations such as Armenia, Belarus and Russia.

The figure also shows the increasingly steep rise of overall penetration rate which can be divided roughly into short periods of 4-5 years between which there is a sudden increase in the penetration rate (possibly following the Kitchin's inventory cycle).

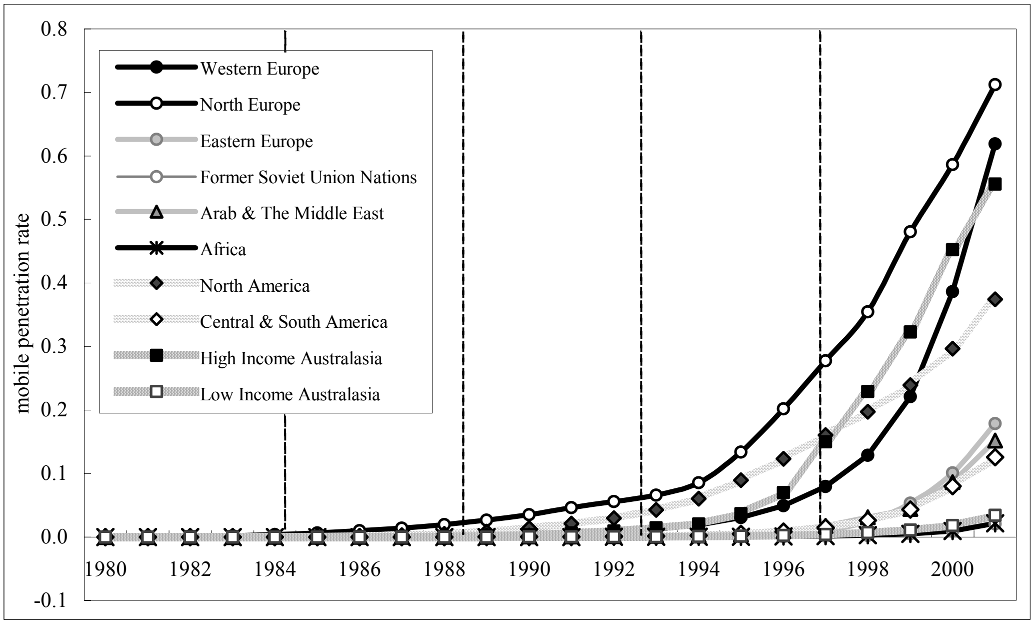

Figure 7. Accumulative Growth of Mobile Penetration Rate between 1980 and 2000 (Data source: ITU).

Prediction of the Growth Trend in the Mobile Market

In order to predict the growth of the mobile market, we apply a logistic regression model (please refer to the Appendix for details) to the annual data of mobile penetration rate between 1980 and 2000. Due to the dynamic nature and the sheer magnitude of data, the source data itself would, to some extent, inevitably consist of estimated values, and as this is combined with the high dimension of the parameter variables, the predictions made herewith are by no means accurate or decisive. We have nonetheless estimated the rough trend of how the mobile devices are likely to penetrate amongst markets in different parts of the world over the next ten years.

The model is based on the assumption that there is an upper boundary (ceiling) threshold of 100%, which effectively means that once the penetration rate reaches the ceiling, then the number of handheld device balance and its overall increase will follow the population growth. This would still account for an estimated rate of 120-170% of the actual users of handheld device (e.g. excluding children under 10), although the fluctuation would clearly depend on the demography of each region.

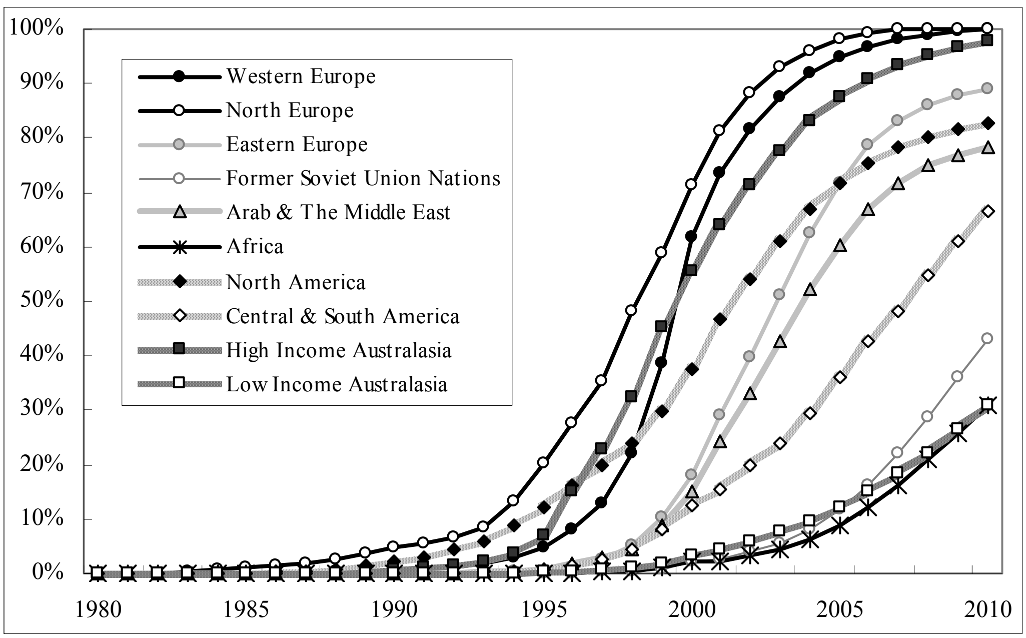

Figure 8. Prediction of the Mobile Penetration Rate over the Next Decade Using a Logistic Model.

Figure 8 shows one particular case of such prediction where the ceiling threshold is 100% and the growth rate also reflects the GDP increase within each region. The results indicate that the mobile market will come to a near saturated state in the developed countries within the next ten years or in even lesser time, and that even the least developed countries will also see the penetration figures of around 30%. Again, it should be noted that this prediction is based on the assumption that the mobile market will continue to grow under the current penetration rate.

That said, this figure indicates the rise of mobile and wireless society that will provide an ideal ground for the market penetration of LBS which will doubtless become one of the most popular utility for mobile users, provided that LBS-oriented technologies mature and deploy on time. But will these geographical information based methods truly prevail amongst other services? In the next section, we will speculate on this point through the analogy of diffusion model of GIS (geographical information systems and science), the geography-oriented techniques and science that are becoming increasingly important.

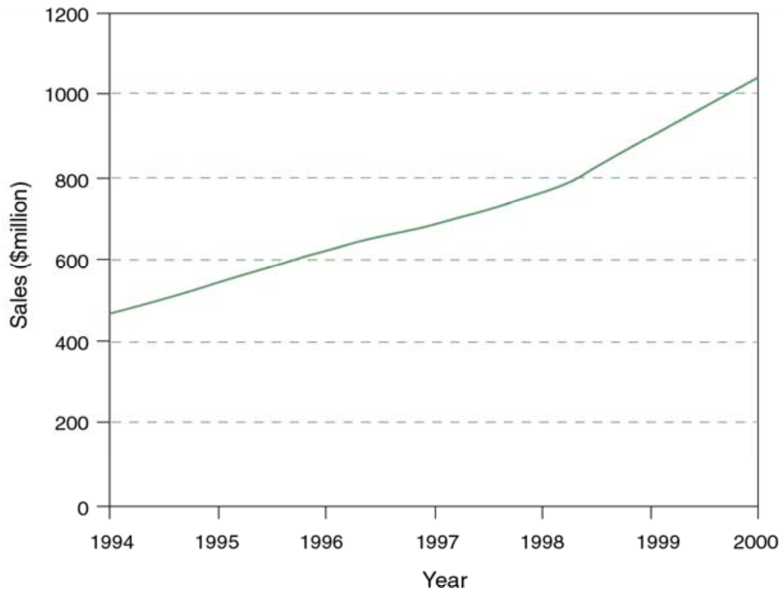

Figure 9. Increase in the Revenue of ESRI, the Leading GIS Software Vendor.

The growth of the GIS industry can be illustrated by considering the recent history of ESRI – perhaps the largest GIS company world-wide. Longley *et al* (2001) suggest that this company has many more than three-quarters of a million licensees for its different products, and that this translates to about half a million active users at any one time. ESRI incomes have risen at a compound rate of between 15% and 20% over the last decade, with the financial year 2000 revenues being $400 million; if the revenues of the partly owned ESRI 'franchises' in other countries are added in, the total revenue comfortably exceeds half a billion US dollars (Figure 9).

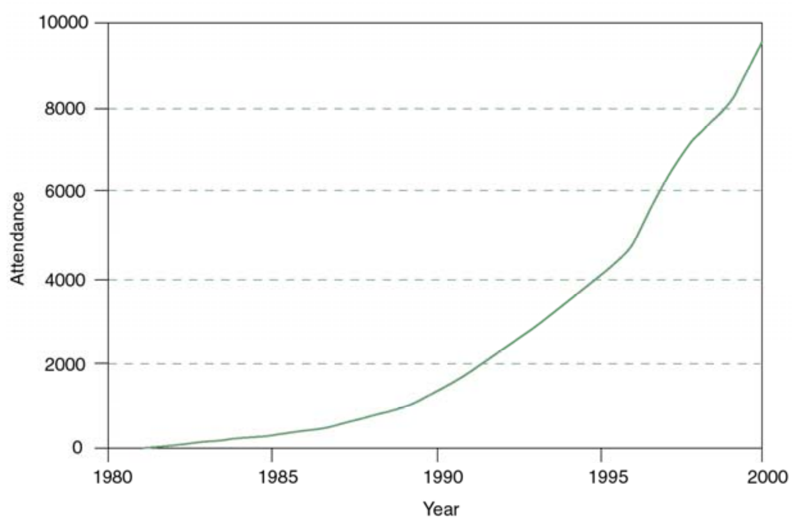

Figure 10. Increase in the Number of Attendance at the Annual ESRI User's Conference.

Another indicator of growth has been the numbers attending their annual conference: Figure 10 shows how this has changed from 23 attendees in 1981 to over 10,000 in 2000 – in many ways an allegory for GIS as a whole. The company also estimates that their activities leverage at least 15 times the revenues they get in terms of staff, hardware, training and other expenditures on the part of the users. All of this suggests that ESRI alone generates expenditures of between $5 and $6 billion annually.

If we add to this the known market share of other vendors and their own leverage, the total expenditure on GIS and related activities worldwide cannot be much less than $15 to 20 billion. Depending on how wide is the definition of GIS, it could be much higher still (e.g. if the finances of both commercial and military satellites is included). Given the number of ESRI licenses, those of other commercial firms, use of 'free software' provided by governments and other parties plus the illegal, unlicensed copying and use of commercial software which still occurs, the likely number of active GIS users must be well over one million people world-wide – perhaps 1.5 to 2 million. At least double that number of individuals will have had some direct experience of GIS and perhaps an order of magnitude more people (i.e. well over 10 million) will have heard about it and perhaps used passive Web services such as local mapping.

This illustrates the degree to which support for our day-to-day activities requires a vast array of organizations to answer the fundamental question, *where?* Today, more and more individuals and organizations find themselves using GIS to answer this question, for a number of reasons:

- Wider availability of GIS through the Internet, as well as on organization-wide local area networks.
- Reductions in the price of GIS hardware and software, because economies of scale are realized by a fast-growing market.
- Greater awareness of why decision making has a geographic dimension. GIS is now part of mainstream learning -- it is estimated that over 1000 universities now teach degree-level courses in GIS, in addition to the countless number of other courses that make reference to it.
- Greater ease of user interaction, using standard windowing environments.
- Better technology to support applications, specifically in terms of visualization, data management and analysis, and linkage to other software.
- The proliferation of geographically referenced digital data. This has arisen through the routine use of Global Positioning System (GPS) technology at high resolutions, the proliferation of value-added resellers (VARs) who update, edit, and otherwise increase the value of existing data, and the accumulation and maintenance of data by mapping organizations, census agencies, and environmental organizations.
- Availability of packaged applications, which are available commercially off-the-shelf (COTS) or 'ready to run out of the box'.
- Development of research procedures and operational workflows that are built around GIS in fields as diverse as local-government land-parcel development, business location, and climatic modelling.

The applications of GIS applications may be classified as traditional, developing, and new. Traditional GIS application fields include military, government, education, and utilities. The mid 1990s saw the development of contemporary business uses, such as banking and financial services, transportation logistics, real estate, and market analysis. The early years of the 21st Century are seeing new forward-looking application areas in small office/home office (SOHO) and personal or consumer applications.

A further way to examine trends in GIS applications is to examine the diffusion of GIS use. Figure 11 shows the classic model of GIS diffusion originally developed by Everett Rogers (Rogers 1995). 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.

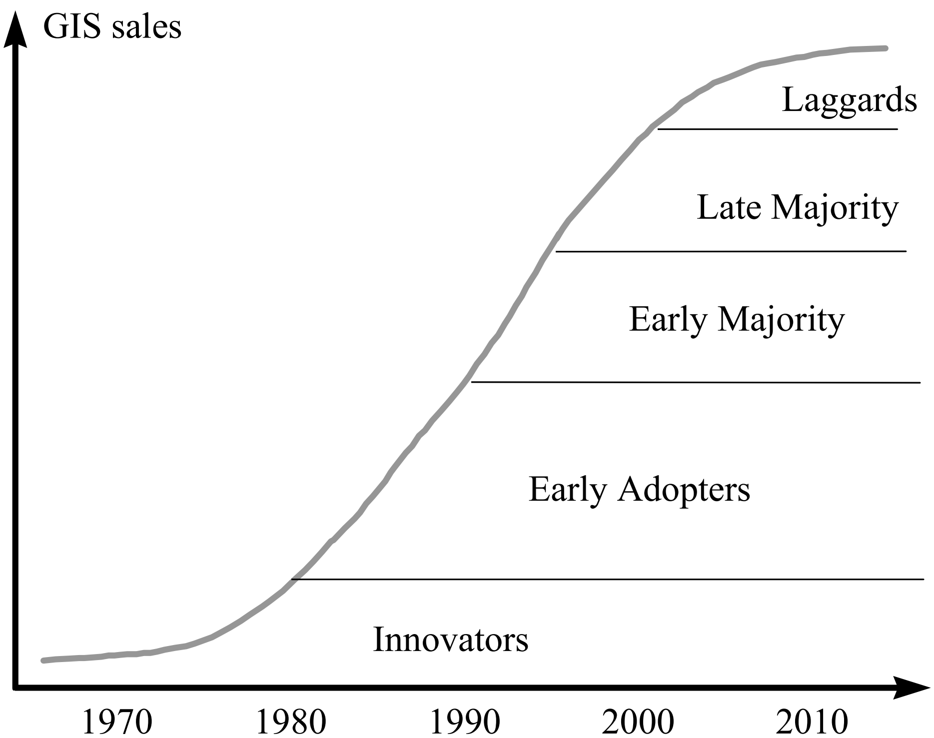

Figure 11. A Schematic Outline of a Diffusion Model of the Development of GIS (Rogers 1995).

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 organizations. The Early Adopters were the users of the 1980s, many of whom were in government and military establishments. The Early Majority, typically in private businesses, came to the fore in the mid-1990s.
A wide range of motivations underpins the use of GIS, although it is possible to identify a number of common themes (Longley *et al.* 2001). Applications dealing with day-to-day issues typically focus on very practical concerns such as cost effectiveness, service provision, system performance, competitive advantage, and database creation, access, and use. Other, more strategic applications are more concerned with creating and evaluating scenarios under a range of circumstances.

Conclusions

In this paper, we studied the impact and penetration of Location-based services through the analogy of diffusion model and the Kondratieff cycles. We reviewed the growth and penetration of mobile industry and then applied logistic-type forecasting which is based on classic diffusion-innovation trends to predict the impact of technologies. Assuming that the LBS-related technologies will grow in a similar fashion as they follow the same innovation wave as the handheld devices and other mobile hardware, we drew on the growth of mobile industry to predict the impact of LBS. We also observed some of the growing elements in the field of GIS which is the key element to support the evolution of LBS.

The success of these technologies naturally depends on the intersection of different growth profiles associated with hardware, networks, software, and data. In fact, the market for LBS and other related services is wide and diverse, involving many kinds of fixed devices and networks as well as wireless applications. It has been popularly envisaged that such services will rapidly take off in the next 5 years as networks, hand-held devices, geographic information systems technology in the form of software and data begin to converge. Our preliminary prediction supports this view in that LBS-enabled devices will penetrate well within the next 10 years following the penetration of WAP-enabled mobile devices and the deployment of online GIS and other geographical information-oriented services.

The study provides a preliminary prediction result and would certainly benefit from further analysis. For instance, whilst the difference in the economic condition of each part of the world would naturally affect the penetration of LBS and the growth of its market, but there are also other elements such as the cultural and language context as well as the demography of the area. It should be also cross-examined more carefully with the predicted growth and development of various LBS-type software features which are crucial to the success of LBS, and we hope to cover these grounds in our future studies.

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Appendix: Prediction of the Mobile Market Using Logistic Regression

A basic logistic model can be written as follows

$$P_t = \frac{L}{1 + b\exp(-at)} \tag{1}$$

where L is the upper boundary, and a and b (a<0, 0<b<1) are variable parameters.
This can be rewritten as

$$\frac{1}{P_t} = \frac{1}{L} + \frac{b}{L}\exp(-at)$$

Thus,

$$Y = A + B\exp(-at)\ where\ Y = \frac{1}{P_t},\ A = \frac{1}{L},\ B = \frac{b}{L}. \tag{2}$$

Since equation (1) is non-linear for parameter a, we apply successive approximation method(*) to estimate a. Suppose that P consists of finite set of elements n. Then the initial value for a, a_0 ($a = a_0 + \delta$), can be approximated as

$$a_0 = \frac{1}{m}\log\left(\frac{S_1 - S_2}{S_2 - S_3}\right) \text{ where } S_1 = \sum_{i=1}^{m}\log(y_i),\ S_2 = \sum_{i=m+1}^{2m}\log(y_i),\ S_3 = \sum_{i=2m+1}^{n}\log(y_i), \text{ and } m = \frac{n}{3},$$

hence

$$P_t = \frac{L}{1 + b[\exp(-a_0 t) - \delta t\exp(-a_0 t)]} \text{ or } Y = A + B[\exp(-a_0 t) - \delta t\exp(-a_0 t)]. \tag{3}$$

Let $X_1 = \exp(-a_0 t),\ X_2 = t\exp(-a_0 t),\ C = B\delta$. Then,

$$Y = A + BX_1 - CX_2 \tag{4}$$

Since equation (4) is a multiple regression with two independent variables X_1, X_2, we can obtain A, B, and C. We continue calculating equation (4) until δ converges under a certain threshold.

(*) Note that the successive approximation method may not be appropriate when n is not significantly large. Also, because of the high degree of freedom in equation (4), there are cases where δ will never converge.