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PAN European
Link for
Geographical
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PANEL-GI

COMPENDIUM

A GUIDE TO GI AND GIS

EUR 19630 EN

Panel - GI
Pan European link for Geographical Information

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Panel – GI

Panel-GI Compendium

A guide to GI and GIS

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FOREWORD

This book has been produced under the project PANEL-GI (A Pan European Link for Geographical Information; http://www.gisig.it/panel-gi), co-ordinated by the GISIG Association.

PANEL-GI is a concerted action funded within INCO-COPERNICUS, the Programme launched by the European Commission for promoting the scientific and technological cooperation with Central and Eastern European Countries (CEEC) (http://www.cordis.lu/inco/src/projcop.htm)

PANEL-GI is then a European Network aimed at involving partners from the CEEC in the process of creating a Pan European GI Forum. The network gives an important contribution to realise in perspective, a full and integrated European GI context and to stimulate or enable GI business in CEEC.

The wider goal of the project is to contribute to the establishment of shared foundations for the Information Society in CEEC, in the particular area of GIS. The Network's main focus lies on the following GI issues: European Geographical Information Infrastructure (EGII), GIS Interoperability and Open GIS, metadata, data availability, GIS applications and European dimension.

This "PANEL-GI Compendium. A Guide to GI and GIS" is one of the main outputs of the project. It has been designed as a reference book useful to have a vision of the key issues of the GI/GIS framework. The Compendium aims at offering to the reader a synthesis of the main GI topics and should support to orient her/him in the GI/GIS field, stimulating as well new business approaches and initiatives for the development of new projects and products.

The PANEL-GI partnership has decided to pursue the policy of a wide dissemination of the project results and so anybody interested in can find the PANEL-GI Compendium also on the Web, together with other useful material and information organized in the so-called PANEL-GI Extended Package (http://www.gisig.it/panel-gi/package/pack.htm).

We do hope that this Compendium could give a significant improvement of a common awareness and a share of the most important GI issues under discussion at a European level and that it would contribute to an efficacious transfer of knowledge among European Countries and to an effective development of a Pan European GI infrastructure.

We also hope that the PANEL-GI Network and its effort for GI and GIS could give an additional contribution in pushing the development of the GI Market in Europe.

The PANEL-GI Partnership

INTRODUCTION

Information about spatial situations, so-called Geographical Information (GI), is becoming more and more important for our society. Human beings live in space and human actions affect space, therefore Geographical Information is extremely important for all decisions people make. We need to understand where things are, and how to move in the world in order to fulfil our goals and predict the effects of actions to others. Travellers need Geographical Information to follow routes to their destinations, urban planners need Geographical Information for their work, and business people need Geographical Information for marketing strategies. These are just a few areas where the use of Geographical Information leads to better results.

The invention of the computer in the mid 20th century and the resulting Information Technology (IT) provide new ways to collect, manage and present information. Today it is possible to perform sophisticated analysis of geographical data through the use of Geographical Information Systems (GIS). Geographical Information Systems are special cases of information systems, namely information systems where *data are related to locations in space and in which processing of the data with respect to these spatial locations is possible*. Computer networks give the flexibility to distribute GIS components and data between different locations, therefore making GI and GIS an important factor for different businesses.

This book aims to provide an introductory overview of GI and GIS issues. It is meant primarily for (potential) users of GI and GIS, but also for managers in private business and decision makers in the public and private sectors. It demonstrates the benefits of GI and GIS to readers who may have limited awareness of this topic.

The book concentrates on issues that a user needs to know, such as the basic technical concepts and the organisational and business aspects of GIS. Although the book tries to avoid technical details and specifics of particular systems, it nevertheless gives a short introduction into the ways in which GIS work. This knowledge should enable readers to communicate with technicians in different GIS and mainstream-IT organisations. GIS is a multidisciplinary field, both in its origins and in its user community. For that reason this book is aimed at readers from all possible backgrounds. Spatial information is everywhere.

Structure of the book

The book is organised in eight chapters, each dealing with a different aspect of the GI field. It is structured as a guide to different GI issues and each chapter was developed in such a way that the reader can look at the issues of her interest without the necessity to go through the whole book.

To facilitate reading of the individual chapters, each is preceded with the *aims, objectives and learning outcomes* of the chapter. This summarises the issues addressed in each chapter, and what the reader should have learned after reading it.

The first chapter of the book explains in detail why Geographical Information is so important in our daily lives. It gives definitions of the major terms this book is concerned with, namely Geographical Information (GI) and Geographical Information Systems (GIS). The chapter further examines the roots of GIS, describes why GIS is a product of different sciences and explains the general purpose of GIS. The importance of GI is demonstrated through explaining its effect on the efficiency of the economy. It is also shown that GI is a rapidly growing business but there are still many impediments to the use of GI in Europe.

Chapter 2 explains the basic concepts of Geographical Information Systems as a means of storing and retrieving attributes about space. It shows the stages of modelling reality in a GIS, from the conceptual data model to its implementation. The two different views of space are explained and typical applications shown. Furthermore, the chapter deals with the different kinds of questions one can ask a GIS. The chapter also reviews the fundamentals of electronics and computer hardware, as they are relevant to the addressed audience. This part includes operating systems, networks, and software engineering methods. Finally, the chapter deals with aspects such as geographical analysis and visualisation.

GIS is more than hardware, software and data. Chapter 3 therefore addresses the issues of organisational aspects and business aspects of GIS. How to introduce GIS in an organisation, the impacts of GIS on people and organisations and how to select the proper GIS are some of the questions dealt with. Subsequently, the chapter moves to business aspects of GIS and the relation to e-Commerce, to conclude with some friendly warnings about misconceptions and pitfalls surrounding this theme.

The advent of IT imposes an adaptation of the way Geographical Information is collected and distributed – from paper-based maps to electronic access using the World Wide Web (WWW). The corresponding change in organisation is substantial and summarised under "Geographical Information Infrastructure" (GII). Chapter 4 deals with GII and indicates that Geographical Information of various types must be widely available in an effective economy. The chapter points to the general goals of a GII and shows the processes necessary to reach them. It gives as an example the US National Spatial Data Infrastructure and then describes a series of other National GII Infrastructures. Finally, it outlines efforts towards a European GII and also discusses attempts to establish a Global GII.

Chapter 5 describes the process of creating a national GII based on the Portuguese example SNIG, one of the few fully operational GII at the national level. It starts with a description of the framework that allowed SNIG to be implemented. It continues to present the main components of a GII, namely the institutional framework, the network, the metadata catalogues, the applications to manipulate GI and the possibility to implement GI commercial transactions. For each of these components, the management issues and their connection with the technical alternatives are underlined. Finally, the chapter demonstrates the need to create a framework that facilitates the access to GI at different levels so that a National GII can evolve.

Chapter 6 deals with the important issues of standardisation and interoperability from a European perspective. It presents the current situation of the process of development of GI standards and specifications, in particular the CEN, ISO and OGC activities. The chapter also deals with experiences in implementing new standards. Some examples are given. The need to promote GI standards and to educate the GI community is expressed, as is the importance for GI market actors to participate in standardisation processes. The chapter further demonstrates that GI standardisation and the development of interpretable solutions are key factors for market growth.

Chapter 7 focuses on important GIS application domains. It gives an overview of the domains and presents selected case studies in detail. The domains were chosen to give a wide spectrum of possible applications. These projects deal with domains such as land cover, forestry, soil, integrated assessment, urban zones, and agriculture. They correspond to a wide range of scale and information content, and were chosen based on a clear operational dimension.

The final chapter of the book presents expected trends for the future of GI and GIS. It reinforces the statement that geographical data are crucial for the economic development of a country, central to the protection of the environment and that geographical data contribute to a democratic society. After listing some general trends, technology push versus user demand, cost-benefit assessment, and the area of distributed GIS are discussed. Other future trends concern the areas of metadata, Open GIS, small business-oriented GIS, e-Commerce and the general integration of GI into mainstream computing.

In addition to the eight chapters described above, conclusions, selected links (URLs) to GI and GIS, and a glossary are included at the end of the book.

Extended Package

There are consistently new developments in the field of GI and GIS. It is also for this reason that the content of this book is kept at a general level. Readers, who are interested in more detailed, up-to-date information, are referred to the so-called "extended package". This is published on the web (http://www.gisig.it/panel-gi/ftp/package/extpk.htm) and updated regularly.

The Extended Package intends to complement this book with any useful material such as technical documents, articles, studies, and examples in line with the PANEL GI package issue. Moreover, the Extended Package aims at fostering integration with other GI/GIS projects and the development of an engine for knowledge sharing and for the promotion of new GI initiatives.

It is organised by referencing to the structure of the PANEL-GI Compendium with an index of the available material, an abstract of each article/application and the URL to the material itself, which is made available by the partner responsible on its web site.

1. THE IMPORTANCE OF GEOGRAPHICAL INFORMATION

Aims & objectives	• Explain the importance of Geographical Information in everyday decision-making. • Define GI and GIS and their place in IT and science.
Learning outcomes	• Social and business aspects of GI - Most decision making is based on spatial elements. - GI has a large impact on the economy. • History of GI and GIS Geographical Information has been around and systematically used for a long time. Automated systems arose in the last half of the 20th century, and are moving from large, proprietary systems to component-based systems. • Lack of awareness and availability, as well as market compartmentalisation, are bottlenecks in the use of GI in Europe.

1.1 Introduction

Human beings live in space and human actions affect space. Spatial information is extremely important for all decisions humans make. We need to understand where things are, need to know how to move in the world so we reach our goals and predict the effects of actions to others. In all cases spatial knowledge is instrumental. Traditionally, humans acquired the spatial information from their daily experience of their environment. For example, while hunting in the woods, they got to know the area, its boundaries, etc. People's mobility has increased and we are often in situations where we have to use Geographical Information others have collected.

Some examples:

- Travellers use maps to gain the information about which road to follow to their destination.
- Service providers and commercial companies use statistical geo-related information for marketing analysis.
- Students use the geographical atlas to learn about foreign countries.
- Urban planners use town maps to fix the permitted construction types for each block.

The invention of the computer in the mid 20th century and Information Technology (IT) provide new ways to collect, manage and present information. The last 30 years have seen an increased application of IT for Geographical Information processing. The traditional paper map is increasingly produced by IT, databases are used to collect geographical data and Geographical Information Systems used for sophisticated analysis not previously possible. In this book we describe this new technology and how it can be used effectively.

Geographical Information (GI) is widely used in many fields and contributes substantially to the well being of human beings. It is often used in public administration (such as cadastre) where it contributes to urban, regional and national planning; it is used to improve the efficiency of transportation of people and freight. Companies use Geographical Information to make their publicity campaigns more efficient and Geographical Information is crucial to protect the environment effectively. Geographical Information Technology is applicable wherever decisions, which have spatial components, must be made; it must be adapted to the specific situation.

1.2 Geographical Information

Geographical Information (GI) is any information about a spatial situation. Geographical Information gives the location a place, indicates properties, which are found at a given location or describes the form and size of geographical objects like woods, fields, lakes or countries. GI covers many themes, from climate and weather information to statistical data about people – the common trait is always that it is information that is related to a specific location in geographical space.

Geographical Information is used in decisions. As the breadth of decisions with spatial components is extremely wide – it is indeed hard to think of any decisions, which are not in some aspect spatial – Geographical Information covers a very wide field. Geographical Information can be as simple as the instruction to turn at the next intersection (Figure 1) or as complex as a map showing wheat crop monitoring at the European scale (Figure 2).

Figure 1: "Turn"-signs.

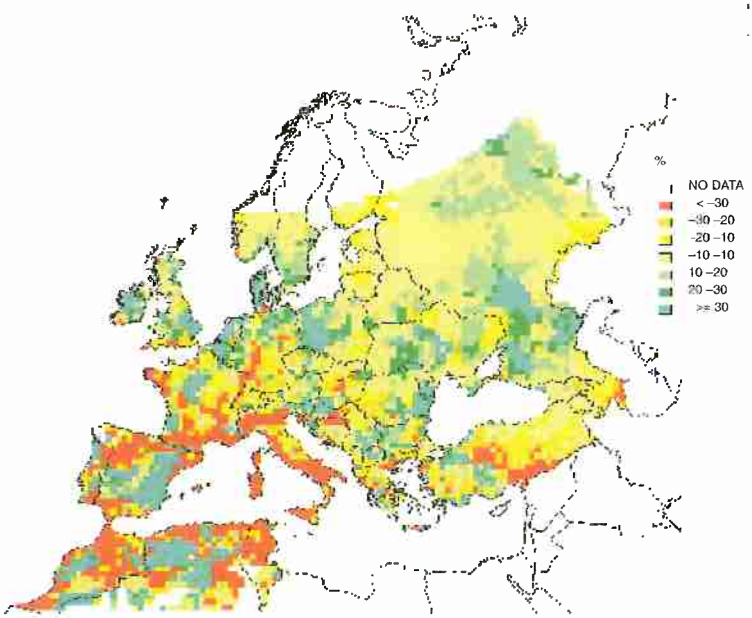

Figure 2: Example of a crop monitoring map.

People have questions. In order to make decisions, these questions must be answered. GI answers questions, which have a spatial context. We can ask "where is a certain object" or "where are all objects with certain properties" when we try to find the nearest school for a child, or we can ask "what are the properties of a certain area in space" when we try to assess the environment around an apartment we consider to rent. The same types of questions are asked in different contexts, when urban planners ask "where are building blocks where many children live" or when they assess the attraction of an urban sub-centre.

1.3 Geographical Information Systems

To produce Geographical Information we can use Information Technology. Computers can be used to store and retrieve the necessary data, they can be used to present the data in graphical format and the network technology allows us to deliver Geographical Information wherever it is used. The following two definitions of GIS are examples for a toolbox-based and a database definition: "GIS is a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes." (Burrough and McDonnell 1998, p11) "A GIS is a database system in which most of the data are spatially indexed, and upon which a set of procedures are operated in order to answer queries about spatial entities in the database." (Smith *et al.* 1987)

The technical part of a Geographical Information System (GIS) consists of the computer hardware, a set of programs and data. The computer hardware typically includes hard disks where geographical data are stored, a processor where programs are executed to analyse the data and output devices, which make the result visible to the users: sometimes as map-like diagrams on screens, sometimes as cartographic maps printed on paper. Computer networks give the flexibility to distribute these components between different locations (more details can be found in chapter 2 of this book).

Organisations run GIS typically to improve their own operations: geographical data is collected and maintained centrally and made available to different users within or even outside the organisation. The large task of maintaining up-to-date geographical data is then spread over many users. Various studies have shown that local administrations invariably maintain multiple very similar data collections at great effort; this duplication of effort can be reduced with a GIS (see also Chapter 3).

GIS are special cases of information systems, namely information systems where the data are related to locations in space and in which processing of the data with respect to spatial location is possible. Locations can be expressed as geographical co-ordinates or as conventional location indicators such as postal addresses, postal codes etc., which the system internally translates to co-ordinates. Processing of data with location can be very simple, for example, searching for all locations with a specific property within a given distance from a location (e.g., find all free taxi cabs within 500 m, Figure 3) or can be very complex spatial analysis to investigate the correlation between a government policy decision and the quality of life of the population in an area. An example is the assessment of accessibility to recreational areas for the inhabitants of a block, before and after the construction of a new high-speed road).

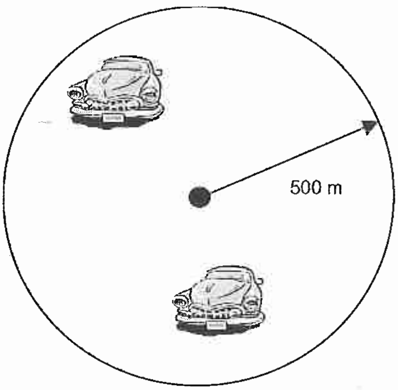

Figure 3: "Find all free taxi cabs within 500m."

GIS promise the integration of data from different sources with respect to spatial location. All data regarding the same location can be combined (Figure 4) and analysed. Data collected for different purposes and by different agencies can be brought together if only the location is known or if a reference to a place for which a location is known (e.g., a street address) is available. Geographical Information is therefore not only the base topographic data, describing the surface of the earth, the buildings, roads, rivers etc., but also information about the people living there (demographic information, typically collected by national statistical organisations), the commercial activities etc. Companies having records of their clients can produce maps that show where their clients are located in space!

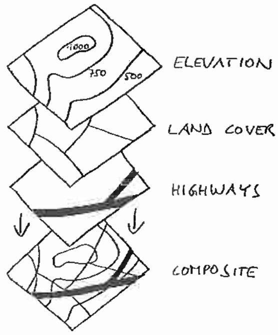

Figure 4: Different data combined.

In the traditional Input – Processing – Output analysis of computer programs, GIS can be said to be deriving answers to specific questions from structured collections of spatial data. Spatial analysis research (Longley *et al.* 1999) describes various methods that can help us to better understand the spatial interactions between humans and the environment; some of the commercially available systems include very sophisticated collections of tools (Eastman and Warren 1987) but many of today's practical problems can be dealt with by using very simple spatial filters based on distances, shortest paths, accessibility etc.

The data in a GIS is either collected directly or digitised from previously established maps. The integration of business processes (Hammer and Champy 1995) in comprehensive information systems for organisations makes it increasingly possible to capture the data only once when it enters the business and use the same data later. For example, public utilities design changes to their network in the planning phase and update this data during the construction to include it afterwards in the network data. This permits the organisation to see at any instance in time what is planned and what is built; the effort is minimal, as all data is entered only once. Consistency for all business decisions is increased as the same data is used everywhere.

1.4 The History of GIS

Collecting and managing spatial information is by no means a novel task. It has been going on for hundreds of years, but without the help of computers and information systems. It was only during the last decades that computerised systems made it easier for people to do these tasks. Strictly speaking, the first map drawn on paper can be considered a Geographical Information System of sorts. Nevertheless, in this text GIS will be understood to be only computerized systems.

Administration needs spatial information for many decisions and has been forced to systematically collect spatial data for their regular operations. Scientists, from geography to archaeology collect and analyse spatial data (Allen *et al.* 1990). Thus, a basis for the understanding of GIS may be a list of traditional tasks, which pushed GIS applications forward.

The tasks depending on spatial information and thus the tasks GIS are typically used for, can be grouped into three major ones, namely *inventory, planning and administration.* Under inventory all activities are subsumed to systematically collect information about land for multiple uses and include primarily the topographic mapping efforts, but also census activities, national thematic atlases etc. There are a number of public administrations and agencies, which must collect spatial information to manage spatial objects, e.g., cadastral surveying organisations (producing maps and other information about real estate property, which are used for taxing purposes and for the protection of ownership in real estate), public utilities, and departments of public works and highways. Urban and rural planning, at the national, municipal and small tract level requires the collection and presentation of spatial data to make rational decisions. Planning regulations and the connected requirements for measurement and mapping are not as new as one might think: they go back to rules for urban construction in medieval times.

Each of these groups saw a use for computerised processing of spatial data to serve their individual purpose. The first computerised GIS, the Canadian Geographical Information System, came about because the Canadian Ministry of Mines and Resources recognised in 1965 that the maps necessary to keep track of the immense natural resources of Canada could be produced only with a computerised system. The public utilities and town administration realised that computers were useful to edit the detailed town maps and relate them to the corresponding administrative information. Other agencies and organisations contributing to the GIS development were the military, the forest management, the postal services, and the space agencies.

Within the first period (earliest beginning in the 60's till end of 70's) research groups in the U.S.A., Canada, United Kingdom, Germany and Switzerland experimented with computer graphics systems and applied them to cartography. The digitiser was invented as a means to translate existing maps into digital format and the graphical display file (Newman and Sproul 1979) was adapted to cartographic use. The use of line printers to produce a crude form of thematic map was introduced in the 70's. Research at UC Berkeley and ETH Zurich in the late 70's showed that GIS had much in common with database concepts. They used databases optimised for commercial data processing and studied data structures to achieve quick access to data based on spatial location (Frank 1981; Guttman 1984). The extension of query languages to include spatial attributes was also explored (Frank 1982).

At the end of the 70's a number of programs for GIS, or automated mapping as it was more often called, appeared. The two leading companies today, Intergraph and ESRI, date back to this period, Intergraph concentrated on the public utilities, while ESRI served the urban planning market. These commercially available software packages were the foundation for many attempts to use GIS practically. Municipalities all over the world learned about the potential of GIS for spatial data management and a series of several specialised conferences started.

In the early 80's, GIS technology was used experimentally. Only a few companies had the level of knowledge to use GIS technology profitably and in day-to-day use. Public utility companies were among the first to report consistently that GIS was cost-effective and replaced the traditional record keeping with less expensive computerised GIS technology. Since the late 80's, GIS has grown in many countries by 10 to 20% annually. In most cases, growth has been limited by the availability of trained, specialised personnel. GIS education has become an important part of the GIS industry; vendors increasingly offer training to overcome this limitation.

In the 90's, GIS was moving towards becoming a mature technology. Specialised companies were selling alternative systems for special markets, sometimes built on top of a general purpose GIS (such as ESRI, Intergraph, Siemens, Unisys, and Smallworld), sometimes built on independent software. Specialised markets are either application specific (property registration, hydrographical data etc.) or they are national markets with special demands for local language support, specific administrative procedures and training needs.

The present trend is toward components in an "Open GIS" environment (Buehler and McKee 1996), where new companies do not offer a complete GIS, but only some specialised components. These companies cooperate with the vendors who sell broad platforms. A number of "small GIS" have only a limited functionality, usually one restricted to viewing data organised and prepared within one of the comprehensive systems. The market for systems with very limited capabilities affected the decision of Microsoft to include the MapPoint viewer for geographical data within the Office suite.

A crude decade-by-decade characterisation of the different stages of GIS can be found in the following Table 1.

1960's	1970's	1980's	1990's	2000
Hardware	Software	Data	Applications	Networking

Table 1: Historical stages of GIS.

1.5 GIS as a Product of Different Sciences

Different sciences have influenced the development of GIS and each claims GIS as their own. Geography, cartography and surveying are only a few. Each field in combination with an application area has contributed a particular viewpoint to GIS:

Computers were seen by some geographers as tools that would complete the quantitative revolution in academic geography. The data from social statistics became manipulable, spatial statistics could be practically used and the results of thematic analysis could be quickly mapped.

Cartographers used computers as an electronic pencil: editing map originals became much easier. Updating a map only required change in the parts affected; everything else was quickly redrawn from the old file.

Surveyors propagated the extension of the real estate cadastre to include data from other users; a multi-purpose cadastre for a municipality could serve many users and spare the effort of each one updating their own data. This means reduced costs through the sharing of data.

Land use planners and landscape architects often have to identify areas which fulfil complex conditions; for example, find an area facing south that is close to a railway line, in an industrial zone. Overlaying several thematic maps allows finding all areas with a desired attribute combination to be found. The manual methods are limited by the number of layers that can be combined and their possible combinations.

1.6 The General Purpose GIS of Today and Tomorrow

The GIS software was developed over the last 30 years from special purpose systems into systems that fulfil many different needs. Organisations wanted GIS that were more versatile, so systems were developed to integrate more and more features from other application areas in order to become more "general purpose". The added functionality has its price: the general purpose GIS of today has quite a few functions that make its use complicated. They require extensive training and very often the interface for the end user is programmed for a specific application. This customisation has become a major business.

In the early 90's the large monolithic GIS, produced by a single company and compromising more and more functionality, reached its zenith. The development of the past five years has been towards a GIS which

- integrates with other parts of the data processing environment in a company: the GIS is just one component and must import and export data to other business processes;
- communicates through an open interface to other GIS and similar systems.

1.7 Importance of GI

Geographical Information seems to have a minor role in the statistics of national economics. Geographical Information shares this problem with a number of other activities that are not widely performed "for a fee" and which are not considered as economic activities (e.g., child education or food preparation at home). Contrary to appearances, GI is very important, because space is fundamental for all human activities. It is a widely accepted estimate that 80% of human decisions affect space or are affected by spatial situations (Albaredes 1992). This estimate is low and it is difficult to find examples for purely non-spatial decisions; even decisions about persons (from marriage to selection of commissions for the EC) are influenced by spatial considerations.

To assess the value of Geographical Information, we have to consider how it contributes to the production of economic goods: Information about the spatial situation, if available, improves all spatial decisions. Today, in a large majority of decision situations, this spatial information is not readily available and is therefore not used, which leads to higher use of resources and a reduction of efficiency. In other situations, GI is collected by the decision maker at the point of its use: for example, street information is collected from street signs where the decision to turn left or right is made. The value of Geographical Information is the improvement of the decision. An assessment of the value of GI for a specific decision is possible: it is the value of the improvement of the decision with respect to the desired goal. The value can consist of:

- a reduction of the resources used to achieve the goal,
- a reduction of risk, which means that the decision is "on average" improved,
- a reduction of the cost of taking the decision.

In any specific case, the value can be assessed in terms of reduction of resource use, i.e. in standard economic terms. The increase in efficiency of processes through spatial information is substantial, as the next example demonstrates.

Logistics is one of the few applications where value can be easily assessed. Logistics is considered widely as the sector of moving persons and goods to the places where they are desired. It is a very large part of today's economics and its importance is increasing. GI in logistics helps to improve routing of regularly scheduled transports (from school buses to waste collection), it improves dispatching of emergency vehicles and reduces the crucial time until a victim receives medical aid, and it improves distribution of goods and services.

In all cases where the economic benefits of using GI in Logistics where documented, savings of around 20% are documented (Leiberich 1997). A recent case in Europe documents an overall improvement of performance of a large, Europe-wide service organisation of IT products by 18% through the use of GI. A recent study of the reduction of the trip length for service personnel for a public utility in California has indicated that trip length can be reduced by more than 20%. In this region air pollution from vehicle traffic is high and a politically sensitive issue. Requiring all companies with large fleets of vehicles to use GI and routing algorithms to reduce travel and thus reduce air pollution and contribute to the protection of the environment is now under consideration. Similar results have been reported previously for the length of school bus runs or the effort to collect waste in towns.

In the long run, we are justified in assuming that Geographical Information can contribute to similar improvements in other areas:

- Agriculture and Forestry with balanced production, achieves production goals with minimal use of resources, and thus in particular reduce environmental pollution from nitrates coming from over-fertilization. Precision Farming is an already visible use of GI.
- Transportation Business where the economic contribution of information is significantly underestimated: free acquisition of GI for public transportation from widely available street signs favours individual road transportation. Tomorrow's increased request for mobility with public transportation will only be manageable if automated information systems for door-to-door, multi-mode trip planning using public transportation are widely used.

The rapid changes in our built environment, especially in the transportation infrastructure, reduce the importance of the traditional sources of GI for transportation. Within a few years, driving a car on a legal path in a city without a navigation aid will be a challenge. If public transportation is to increase – which environmental goals dictate – then the information must be provided to potential users in a much better way.

1.8 Effect of GI on the efficiency of the economy

A consistent estimate of a 20% efficiency improvement for logistics is widely documented in individual cases (Leiberich 1997). Logistics is the case where the use of GI is probably simplest - because the decisions are simple - and most advanced. GI is documented as fundamental for public utilities, which spend internally around €20/year and customer for GI (at a relatively low level of usage) and can document that this is cost effective; further investments are underway which bring more efficiency gains.

There are good reasons to believe that the use of GI in other sectors would be as effective, and one can even assume higher. A recent study by the British government has indicated substantial inefficiencies in the process of real estate selling and buying. A new computerised network should improve the flow of information between buyer and seller and other parties involved (e.g., banks, real estate agencies, etc.) and make the process of buying or selling a home faster, more secure and in the end less costly for the citizen.

One can therefore boldly conclude that the potential of GI to improve the overall efficiency of our economy is in the order of 15%, because 80% of all decisions are spatially affected and the contribution of GI in documented cases brings a 20% efficiency increase. Increase in efficiency in the economy does not mean that workers become redundant, but it means that society can spend this much of its resources on better goals, goals which contribute more to the general well being of the citizens. Increase in efficiency of the economy also means less environmental pollution.

It is obvious that this potential will not be realised in a few years, but it demonstrates that a long-term strategy is appropriate to realise this potential over the next decades. The strategy must consist of elements to have immediate, medium term and long term effects – which means help for existing business, efforts to improvements of policies and practice, investment in skilled personnel and knowledge.

1.9 GI is a rapidly growing business

The UN and national experts estimate that around €100/person are spent on explicit Geographical Information yearly (mid 90's, Europe or USA). That is around €30.000 million for Europe. This is a conservative estimation, consisting mostly of the cost of collecting spatial data and managing it in paper based or electronic archives. It does not include the implicit collection or acquisition of GI in business activities like transportation, logistics (unless it is IT supported), real estate management, etc., which is the sector with the highest growth and highest potential for contributions to the economy.

Very high growth figures in single sectors have been reported over the past years. Overall it must be expected that a figure of €500/person and year is realistic for 2005 to 2010. The speed of development is not limited by economic factors, but mostly availability of data, skilled persons, and knowledge.

Figures of €100 to €500 per year and person can be used to assess the current size and importance of GI in national situations. They can be translated, for example, into people involved: consistent estimates give 1 person in 1000 who should be educated and trained as a Spatially Aware Professional, which indicates the very large need for training at all levels for all European countries.

1.10 Impediments to the use of GI in Europe

The market for GI in Europe has different dynamics than the corresponding market in the USA. In the USA, the United States Geological Survey (USGS) and the Bureau of Census have a mandate to collect and disseminate essentially free of charge bare geographical data, covering topography and population statistics. In Europe, topographic and demographic data are collected by National Agencies, which operate under different jurisdiction and have different mandates. The American market was fuelled early when these two agencies converted their data to electronic format. The integration of topography, street network and demography in datasets, which cover the entire nation at small to medium scale, became freely available on the Internet for the cost of reproduction. This made experimentation and the development of applications possible. A similar development did not occur in Europe for several reasons, the three most important ones are (Meixner and Frank 1997):

1.10.1 Lack of Awareness

Often GI is not used because the potential users are not aware that they are making spatial decisions, that the decision could be improved by acquiring more information. It is not known what information is available (e.g., only few businesses make use of the widely available spatio-demographic data collected by national statistic bureaus – see GISMO, GeoMarketing Internet Service for small and Medium enterprises using OpenGIS, http://www.gismo.nl/), where it could be acquired and how it could be used.

1.10.2 Lack of Availability

It is not primarily that geographical data is not collected, – indeed Europe probably has better collections of geographical data than the USA, but the data collected is not readily available. The list of impediments include: data is not available in electronic from, the form does not meet the form required by the user (lack of standardisation), bureaucratic procedures, pricing schemes that are based on cost and do not consider the benefits the user can maximally draw from the data.

1.10.3 Compartmentalisation of the Markets

In addition to the individual impediments in each of the national GI markets, Europe is hindered by compartmentalisation in small markets. There are only minimal European data sets available, procedures, policies and legal ties for GI in each country are different and make it impossible to develop solutions, which work in the larger European market with the corresponding economies of scale.

1.11 Conclusion

GI is very important for all decisions that affect space – which are most decisions we make. The importance of Geographical Information is underestimated because it is most often acquired when needed from the environment or available seemingly without effort because it has been learned over extended periods of living experience in an environment. In today's world of high mobility and an environment shaped increasingly by technology, GI must be dealt with specifically.

Geographical Information Systems use Information Technology to systematically collect, manage and present to users the Geographical Information they need. They have evolved from systems to produce maps with computer assistance to sophisticated tools to analyse spatial information and present the results in graphical or tabular form most appropriate for decision makers.

Geographical Information is a rapidly growing business and will become an important part of Information Society Technology. Within a few years, it will amount to €500 per person and year and more than 1 person in 1000 will need knowledge and skills to handle Geographical Information in the course of her/his business.

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2. BASIC CONCEPTS OF GIS

Aims & objectives	• Introduce basic IT knowledge required for understanding GIS. • Explain the difference between the real world and a GIS model of the real world, and how to get from one to the other. • Explain concepts of GIS data organisation and manipulation.
Learning outcomes	• Hardware, software and networks (at a managerial level). • How the real world can be modelled in a GIS: raster vs. vector formats, (spatial) objects and databases. • Basic GIS concepts, such as reference systems, accuracy of data, visualisation, generalisation and spatial analysis.

This chapter introduces the basic concepts of Geographical Information Systems as a means of storing and retrieving attributes about space. Two different views of space are possible (see 1.3): a view towards objects at locations or to properties of locations. We can ask: "Where is x?" or we ask "What is at location x?"

In section 2.1, the fundamental concepts used to model spatial or non-spatial data are introduced. Section 2.2 discusses spatial concepts relevant in a GIS. It starts with a brief description of reference systems and the issues of uncertainty and accuracy of spatial data. It then explains the field and raster approach, which are used to represent space and spatial objects. Finally, it deals with the geometry of spatial objects and gives a thorough example of a vector structured data model.

Section 2.3 reviews very briefly the fundamentals of electronics and computer hardware, as they are relevant for GIS users. Hardware components, Operating Systems, and networks are characterised.

Section 2.4 gives an overview on geographical analysis that can be performed in a GIS and shows different examples. Finally, section 2.5 demonstrates different issues of visualisation in GIS. It focuses thereby on the structure and production process of maps, cartographic generalisation and interactive cartography.

2.1 Modelling Reality in a Geographical Information System

An information system can be widely defined as a collection of people, procedures, and equipment designed, built, operated, and maintained to collect, record, process, store, retrieve and display information (Ralston and Reilly 1992). Usually, the term is used in a more limited sense though, referring to a computer system for storage, manipulation and display of digital data.

Although early information systems have been using individual files for data storage, modern information systems are based on database systems (Figure 5). Database systems are more than just a database for storage purposes. They also contain a database management system (DBMS). The database management system is a piece of general-purpose software on top of the database that allows easy building, structuring, maintenance, and query. Specific application software (such as for instance a GIS) can access the data through the DBMS.

Data models are used to describe the structure and content of a database. High-level models, such as the Entity-Relationship Model, are used during conceptual design and do not contain any implementation details. A data model provides the concept with which the data of an application are described and captures the entities and their relationships in a clear way. Implementation models, such as the Relational Model, which describes application data as tables and operations between them, are used during logical design. Thereby, the database schema is represented in a data model supported by the selected database management system. Low-level models are used during physical design to define how data are actually stored.

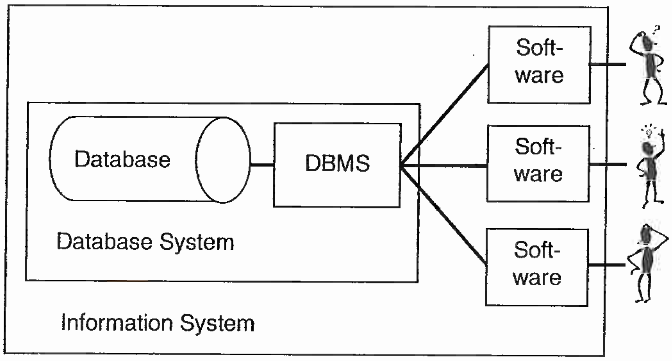

Figure 5: Information System based on Database System.

2.1.1 Conceptual Modelling

The conceptual data model is used to express the structure of the information in the system, that is the types of data and their interrelationships. It should act as a mediator between users, systems specialists and the machine level (Worboys 1995).

One of the most widely used approaches to forming a conceptual model of an information system is the Entity-Relationship Model, first introduced by Chen (1976). The Entity-Relationship Model describes the application environment in terms of entities, properties of these entities, and relationships between these entities. An entity is an object that exists in the considered application environment and is distinguishable from other objects (e.g., maintenance vehicle with license plate number L-3417, highway H10). Attributes represent properties of entities. For example, one property of the maintenance vehicle is its license plate number L-3417. A relationship associates two or more entities. For example, relationship *owns* relates the maintenance crew to its maintenance vehicle (i.e., the crew owns the vehicle). Usually, an application environment is modelled at the level of entity types and relationship types, which collect similar entities and similar relationships (Figure 6).

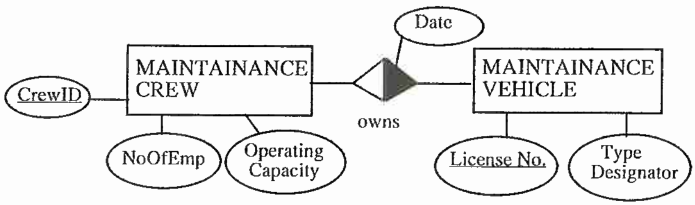

Figure 6: Example of an E-R-diagram.

Increasingly, the Unified Modelling Language (UML (Booch *et al.* 1997)) is used to describe the conceptual model of systems, that is database and applications together. UML is an effort to bring different methods of conceptual modelling together. It integrates the E-R model with object-oriented design: for the entities (i.e., objects) operations can be defined. UML allows multiple viewpoints and levels of details. Computerised tools are available to facilitate its application.

2.1.2 Logical Database Design

During logical design, a conceptual database schema is transformed to the Relational Data Model of an existing database management system. From the Relational Model it is an easy step to implement the actual database. Today, many commercial database management systems (DBMS) are based on the Relational Model. The Relational Model, introduced by Codd (1970), represents data in a database as a collection of relations. A relation can be thought of as a table of values representing a set of similar real world objects and their relationships. The rows of a table, called tuples, define real world objects or relationships between real world objects. The columns of a table represent attributes and attribute values, respectively (Table 2). The Relational Model is value-oriented. The ability to define operations on relations whose results are again relations and the support for powerful declarative languages are the main reasons for the popularity of the Relational Model. The standard language for retrieving data in a relational database system is SQL (Structured Query Language) (Ingram and Phillips 1987). One of the limitations of SQL is that it does not directly support spatial operations. Therefore object-oriented databases with corresponding object-oriented data models have been proposed to overcome the limitations of SQL with object generalisation and specialisation. Recent developments led to spatial standards so that spatial information can be stored and managed with the same SQL language as used for non-spatial data (Scarponcini 1999).

CrewID	NoOfEmp	Operating capacity
1	4	5
2	2	6

Table 2: Exemplar table for maintenance crew.

2.2 Spatial Concepts as Implemented in GIS

In implementing spatial concepts in GIS, there are two possible views of the world, namely a *field view* and an *object view* (Couclelis 1992). Real-world processes with a field characteristic are continuous and can be represented as an infinite set of points with associated attributes. The data collected approximate a continuous surface. Examples are changes in temperature or elevation across the earth's surface. In the field view one can ask "what is at location X", e.g., "what is the height at (x,y)"? These processes are usually represented in raster format.

Other processes are based on objects and therefore space is determined by discrete entities. Examples for such entities are roads, buildings, towns, etc. In this case, the GIS contains both thematic and geometric (spatial) information on the represented objects. In the object view one asks "where is object X", e.g., "where is the car with license plate number L 1968"? The geometry of spatial objects is generally represented in vector format. Important aspects in this respect are the choice of a reference system, and accuracy of the spatial data. Conversion between the field and object views is possible but not without loss of information.

2.2.1 Reference Systems

Position and orientation can be expressed through a given co-ordinate system as a reference frame. The position of each point will then be represented as a pair of co-ordinates. Orientation of edges can be expressed by the angles these edges have with the co-ordinate axes. The shape and size of geometric figures can be expressed without any reference to a co-ordinate system. These measures are derived from the length of the edges of the figures and from the angles between the sides. Topological relationships between objects can be described without reference to their position, orientation, shape and size. These are relationships such as "inside", "adjacent" or "intersect".

GIS software is most often organised to use a Cartesian co-ordinate system, which approximates the curved surface of the earth. National grids or national reference systems as well as the widely used UTM system can be used. Difficulties occur when seamless systems for large countries or the integration of data from different countries in trans-border regions must be achieved and data with reference to different systems is integrated.

Geographical position on the surface and the height of a point above mean sea level are quite different and only for exceptional cases the treatment as 3-D Cartesian co-ordinate systems (X, Y, Z) is appropriate (e.g., for the computation of GPS co-ordinates). Height reference systems are defined by surfaces of equal potential in the gravity field. Again, national reference systems are established and can be used in GIS. Attention is necessary, when integrating data from different systems.

2.2.2 Uncertainty and Accuracy

Uncertainties and errors are intrinsic to spatial data and may have effects on data analysis and modelling (Burrough and McDonnell 1998). Such errors can occur at different stages from observing a spatial environment to the presentation of such an environment in a GIS. Analysis of spatial data quality in different countries led to a consensus on a set of elements (Guptill and Morrison 1995) of spatial data quality:

- The *lineage* of spatial data includes the description of the source material from which the data were derived and the methods of derivation. Such information is very important because it affects all other components of spatial data quality.
- *Positional accuracy* includes measures of the horizontal and vertical accuracy of the features in the data set. Such accuracy in determining geographical location depends on the surveying skills, the methods used (e.g., photogrammetry, GPS), and the choice of map projections.
- *Attribute accuracy* is linked to the variation of the phenomenon in question, the accuracy of the measuring device, and a possible bias of the observer.
- Another important element of spatial data quality is *completeness*. Completeness describes the relationships between the objects represented in a GIS and the universe of all such objects.
- *Logical consistency* deals with the fidelity of relationships encoded in the data structure of the digital spatial data.
- *Semantic accuracy* is concerned with the meaning of things in reality and refers therefore to the meaning of the geographical object rather than to its geometrical representation.
- Finally, *temporal information* describes the date of observation, the type of update, and the time period during which the spatial data records are valid.

All this data is part of the so-called metadata – data about data. For companies working with spatial data, good documentation of datasets is extremely important to make sure that they can still be used after changes of employees, software and hardware (Strobl 1995). Data providers need to tell users what they have and what it can be used for. Metadata is destined for this purpose (Timpf *et al.* 1996).

2.2.3 Fields and Rasters

In the field view, the values of the terrain attributes are treated as functions that take a value at any position in a two-dimensional space. Such terrain description can be based either on randomly distributed positions or on positions that are regularly organised in a grid (Figure 7). The irregular point pattern occurs when attribute data are collected in field surveys, such as soil surveys, vegetation surveys or the collection of height data. The application of remote sensing techniques results in a raster structured terrain description (see figure: point and cell raster).

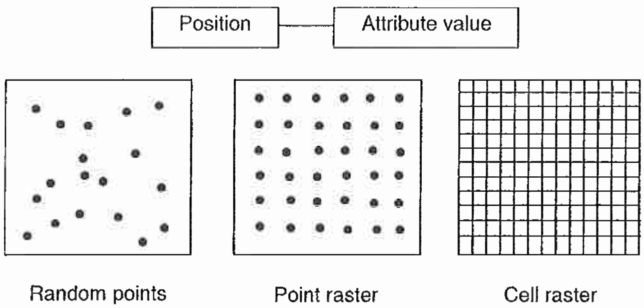

Figure 7: Several configurations for linking attribute values to position.

A raster is a collection of points or cells that cover the terrain in a regular grid. Raster elements in a point raster contain thematic data referring to the position of the terrain point represented by the element. In a cell raster the thematic data refer to an area segment represented by each element. Positions of raster elements are either indicated by means of indices (i, j) or co-ordinates (X, Y). The step sizes DX and DY define the resolution of the raster, the smaller the steps, the larger the resolution. A large resolution means that many raster elements are required to cover the terrain (more data), whereas a small resolution will reduce this number (less data).

The thematic aspects of the terrain description are expressed by the thematic attributes of the raster. If the raster describes only one thematic aspect, it will have only one attribute, e.g., altitude or land use. A user can now retrieve raster data and derive new data from the stored data by performing analyses or arithmetic operations. An example for selection by attribute value would be: Give the position (i, j) of all raster elements of which the attribute value is w.

Often, the user wants to combine several different attributes per location and use them as input for functions of multiple values (Tomlin 1990). A simple query on elevation and slope serves as an example: Looking for areas with slope < 15% and elevation > 750m, one can overlay two digital maps of the same area. The result can be seen in Figure 8.

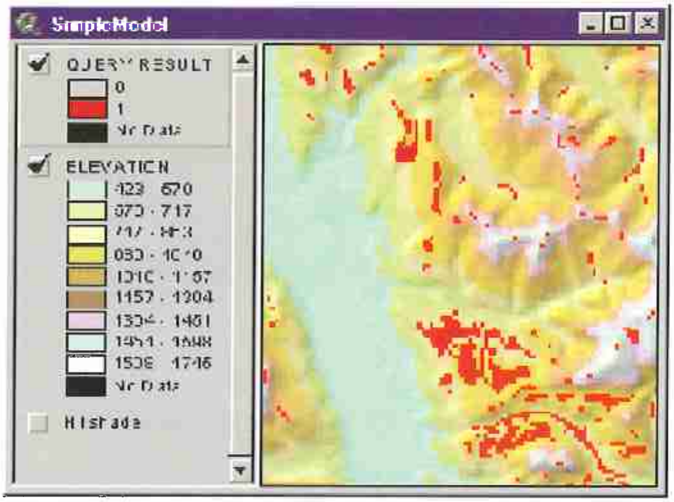

Figure 8: Result of a simple overlay operation (taken from http://esrnt1.tuwien.ac.at/MapModels/MapModels.htm).

2.2.4 The Geometry of Spatial Objects

The choice of how the geometry of objects is represented in a GIS needs to be adjusted to the way the geometric information will be used. For each thematic class of objects a decision has to be made whether the objects will be represented as point-, line- or area objects (Figure 9). For point objects only the position is stored. For line objects position and shape are stored, *length* is the only size measure given. For area objects position and shape will be given, the length of the perimeter and the area are the size measures.

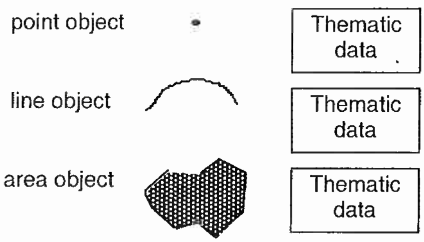

Figure 9: Three geometric object types.

The geometric structure of objects can be either represented as a raster structure or as a vector structure. Representation of objects in a raster is best done in a cell raster. The cells represent area segments, therefore this geometry is most suitable for the representation of area objects. Each cell then gets a label that indicates to which object it belongs. Rasters are less suitable to represent point objects or line objects. The description of a terrain situation in a vector structure represents the geometry of terrain objects by its linear characteristics. That means that the linear structure of line objects, the boundaries of area objects and the position of point objects will be represented. The geometric elements for a vector structured terrain representation can be seen in Figure 10. The elementary relationships between these geometric elements have been formulated in mathematical graph theory (Wilson and Watkins 1990; Gersting 1993). A graph consists of two sets: a set of *nodes* N = {n1, n2, ..., nN} and a set of *edges* E = {e1, e2, ..., eA}. In the geometry of a terrain description points are treated as nodes and line segments as edges.

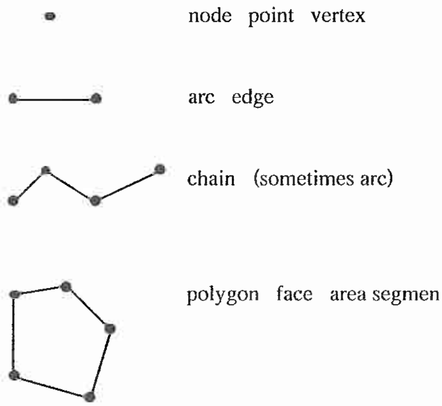

Figure 10: Geometric elements for a vector structured terrain representation.

2.2.5 An Example of a Vector Structured Data Model

Conceptual Data Model (see also 2.1.1)

The representation of a terrain presented as a simple example here (Figure 11), consists of two geometric element types (i.e., nodes and edges) and three terrain object types (i.e., point-, line- and area objects). Position information is linked to the nodes in the form of two attributes, one for the X-co-ordinate and one for the Y-co-ordinate. Thematic information can be linked to the objects also in the form of a list of attributes. The example in this section is kept simple, the only thematic information given for the objects is an attribute specifying the thematic class to which they belong.

Logical Data Model (see also 2.1.2)

The conceptual model needs to be translated into the structure of a database model that can be handled by an information system (i.e., into a logical model). The table structure of the relational model is taken as an example of such a logical model. Figure 12 shows how tables can be defined for the entities of the conceptual model and their mutual relationships. The figure contains four area objects, two line objects and two point objects.

These data can be stored in tables as shown in Figure 12. The first table is called *points,* each tuple of this table represents one point object. The first attribute *id* gives a number for the identification of the point object. The second attribute gives the thematic *class* of the point object. The third attribute *nid* gives the identification number of the node that contains the position information. The second and the third table give information about the line- and area objects. The fourth table gives the node numbers and the co-ordinates of the nodes. The fifth table contains information about the edges. Each edge can be identified by the combination of its begin node (*b*) and end node (*e*). The attributes *le* and *ri* refer to the area objects on the left-hand and the right-hand side of the edges.

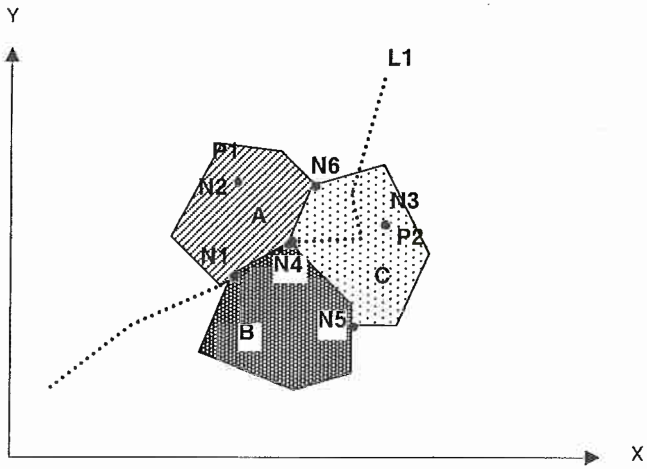

Figure 11: An example of a vector structured terrain description.

points

id	class	nid
P1	mill	N2
P2	house	N3

lines

id	class
L1	road

areas

Id	class
A	agriculture
B	forest
C	city

nodes

id	X	Y
N1	127.1	153.7
N2	.....	.....
N3	.....	.....
N4	.....	.....
N5	.....	.....
N6	.....	.....

edges

b	e	le	ri
N1	N4	A	B
N4	N5	C	B
N4	N6	A	C

Figure 12: A table structure for vector data.

The position information of the objects in this example is given by the co-ordinates of the nodes, the shape information can be derived from the combination of the node and edge data. The topological information is contained in the edge table.

Examples of Queries Applied to Vector Data

Queries can be formulated to extract from the database information about the position and thematic aspects of individual objects:

- What kind of object is object with id 7?

The system can search the object tables until it finds the value 7 for the attribute id. This value occurs in the table *point object*, the attribute class has the value *mill* for this object, and therefore the answer is "Object nr. 7 is a point object that belongs to the class *mill*."

Other examples for queries of this type are:

- Where does object with id 7 lie?
- Where is the area object with id C?

General examples for queries about object topology are:

- What areas border a specific city?
- Which areas are connected to a specific railroad?

2.2.6 Object Hierarchies

Object classes are defined by characteristics that their members have in common. For example, terrain objects can be divided based on their geometric characteristics (i.e., into point, line and area) or based on their thematic characteristics. Then we speak of thematic classes. The classes are typified by the fact that the objects that belong to the same class share the same descriptive structure. The following example explains this concept.

pasture land

id	W_1	W_2	W_3

W_1 = grass type
W_2 = biomass production
W_3 = fertilizer

arable land

id	A_1	A_2	A_3	A_4	A_5

A_1 = crop type
A_2 = sowing date
A_3 = fertilizer
A_4 = herbicide
A_5 = crop type last year

Figure 13: Tables for two classes of land.

Given is a farm that consists of both arable land and pastureland. The farmer manages these two sorts of land differently; therefore he needs different types of information for the management and use of these lots. If he is to use an information system, he must deal with two different object classes. In Figure 13, the columns W1, W2 and W3 represent the thematic attributes of the class of *pastureland* and the columns A1 to A5 are the thematic attributes of *arable land*. Each class has its own attribute structure and for each object a value will be assigned to every attribute. One could now extend the list of attributes of both classes with data concerning area, soil water level and soil type. By creating a new table with these attributes, one arrives at a more generalised description of the objects. The distinction between *arable land* and *pastureland* is then a further specification of the objects. Figure 14 presents a class hierarchy for land.

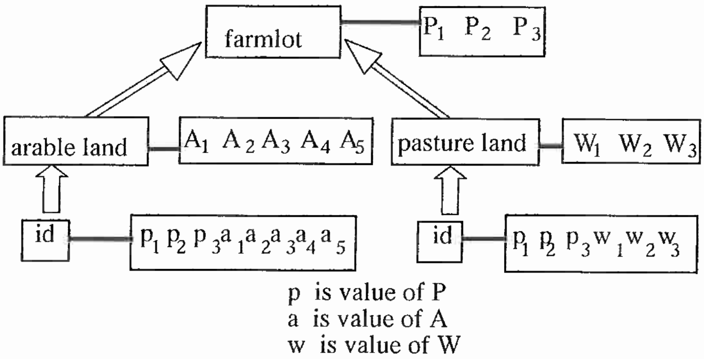

Figure 14: Class hierarchy for land.

We speak of *farm lot* as a generalised class or super class above the classes *arable land* and *pasture land.* An object that belongs to the class *pastureland* inherits not only the attributes of this class, but also those of the super class *farm lot.*

An aggregation hierarchy describes the way in which composite objects are built from elementary objects and how these composite objects in turn can be combined to form even more complex objects. Figure 15 shows such aggregation hierarchy.

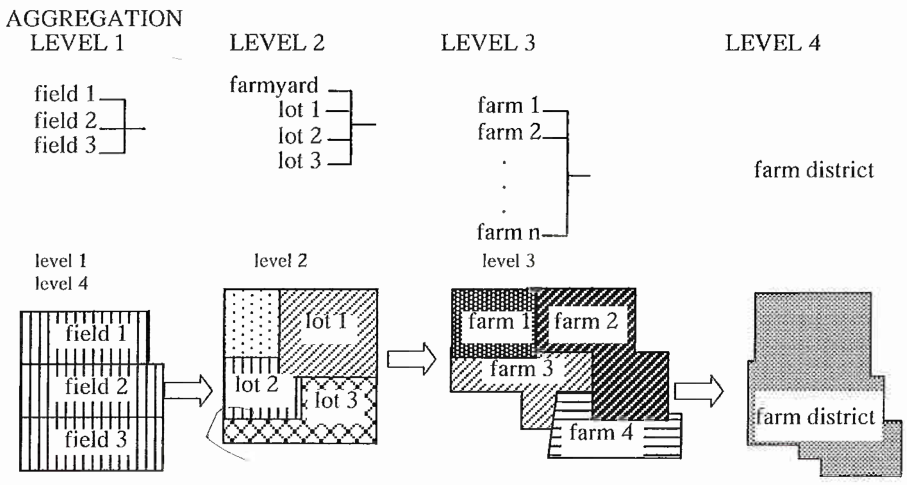

Figure 15: Examples of aggregation of objects.

In the first step from level 1 to level 2 fields are composed to lots. Next, these lots are combined with a farmyard to form a farm. In the third step, a number of farms are combined to form a farm district. In an aggregation hierarchy, the compound objects inherit the attribute values from the objects of which they are composed. If elementary objects are combined to form a composite object, their attribute values are often aggregated as well. Farm yield is the sum of field yields, and district yield is the sum of farm yields (Frank *et al.* 1997).

2.3 From IT to GIS

A GIS consists, as any IT installation today, of computer hardware components possibly connected by communication networks and controlled by software. This section mentions the most important concepts and indicates how current trends in technology affect GIS.

2.3.1 Hardware

The hardware components of a GIS include at least a central processing unit (CPU) with main memory to which devices for storage, input and output are connected (Figure 16). During the nineties, computers evolved from single autonomous systems to components in a worldwide network. A GIS installation today includes typically several components, all controlled by a processor, which specialise to provide certain services most effectively.

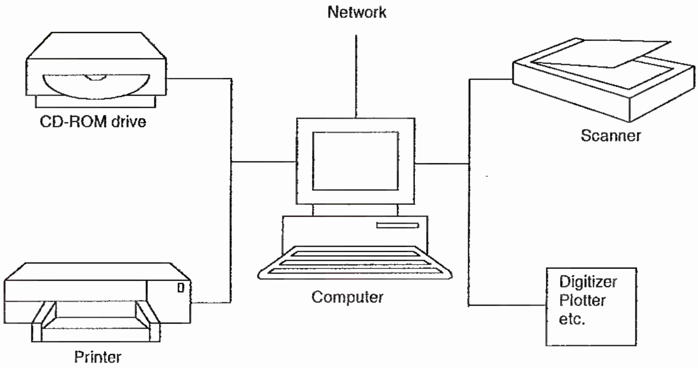

Figure 16: Hardware components of a GIS.

2.3.2 Operating systems

In the sixties, one might have defined operating systems as the software that controls the hardware. Today the goal of operating systems is seen as generally *managing resources*, which include processor capacity, storage space and communication channels. Operating systems often consist of several layers between hardware and generic tools such as for scientific, business, office automation, production management, and geoinformatic applications as depicted in Figure 17.

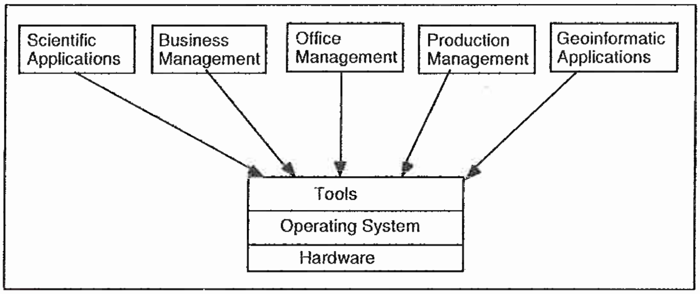

Figure 17: Operating systems as layer between hardware and application software.

Resources management allocates processors, storage, input/output devices, communication devices, and data to tasks. Operating systems perform many functions such as implementing the user interface, sharing hardware and devices among users, allowing users to share data among themselves, preventing users from interfering with one another, scheduling resources among users, facilitating input/output, recovering from errors, accounting for resource usage, facilitating parallel operations, organising data for secure and rapid access and handling communications.

The role of an operating system is to abstract the hardware to the user in order to facilitate the running of the computer programs. Generally speaking, one can distinguish operating systems according to the number of users who can work simultaneously. Apart from PC's and some dedicated computers, presently all operating systems manage multiple users.

Examples of operating systems are:

UNIX

UNIX is a well-known multi-tasking operating system. Bell Laboratories initially developed it during the seventies. One of its characteristics is its very simple directory system and a very elegant way to deal with files. Through its pipe mechanism it permits the creation of links between programs. UNIX is de facto the standard operating system and many GIS products are run under some variant of this system.

Mac OS

Mac OS is the standard operating system for MacIntosh computers. Recent versions of Mac OS improved especially in the area of performing tasks in a network environment.

DOS

DOS (and MS-DOS, marketed by Microsoft) was the standard operating system for PC's. It deals with single tasks. Its command language resembles UNIX in some aspects. It runs on millions of PC's worldwide and is the foundation for 50 000 applications - the largest set of applications in any computer environment.

Windows

Built on MS-DOS, Windows was initially designed as a visual interface replacing DOS as the command language. Now, due to the evolution of Windows, it evolved into a new operating system, specifically in its versions Windows 95, 98.

Windows NT

Windows NT (New Technology) added to the graphical user interface also a multi-user environment, robustness and security, originally found only in UNIX based systems. Designated mostly for use on workstations (Windows NT Workstation) and servers (Windows NT Server) it continues to evolve as Windows 2000 Professional for workstations, Advanced Server for servers and Data Centre for large installations.

Linux

Linux is a free operating system. It uses Internet and industry standard components and protocols giving a system with complete network integration. The operating system can act as a server for most major file serving protocols, and provide all the major Internet applications.

2.3.3 Networks and communication

Network and Distributed Database

When the database approach began to develop, it was anticipated that an organisation's database would reside on one central computer, with users accessing the database from terminals. Due to the rise of the internet and the World Wide Web (WWW), however, there has been a dramatic shift towards distributed processing, with networks of computers being linked together to distributed computing systems. Databases are designed today for distribution of data storage across several nodes. This allows local users in a network to retain as much data as possible locally, without losing the benefits of integrity and security that a centralised database provided. GIS systems evolve rapidly to conform to distributed database standards and be acceptable as part of corporate information systems of the future (Reeve 1994).

LANs and WANs

Computer networks are conventionally divided into Local Area Networks (LANs) or Wide Area Networks (WANs). LANs are groups of computers located within a short distance of each other, often within a single building, linked together by a dedicated cable. A LAN can consist of microcomputers, minicomputers and /or mainframe computers. A WAN can consist of a number of computers or connect separate LANs through a common carrier, for instance, a telephone or satellite system. A WAN network might link computers that are spread over a considerable distance: for example, airline booking databases literally span the globe. An organisation might have both LANs and WANs.

Distributed processing

In LAN networks, the system can be based on the file-server, which is a computer with a large hard disk, on which all database files reside. Users on other machines access the data files across the network. The speed of data transfer must be high enough so that they are not aware that the data is not on their own machines' hard disks. Often, users want to abstract data from the file-server to process them using software on their local machines. To accomplish this, a 'FrontEnd-BackEnd' solution is used, with the local software being the FrontEnd, the File-server DBMS acting as a BackEnd and SQL statements being used to transfer data between the two across the network. Recently, this FrontEnd-BackEnd solution has been further expanded by the emergence of 'middle-ware', which, as the name suggests, is software that sits between client applications and backend servers on a network. The purpose of middle-ware is to provide efficient and flexible transfer of data between the various applications and several servers that might exist in a network.

Distributed Database Management Systems (DDBMS)

Consider the following example from (Reeve 1994): A company has a WAN spread over a large geographical area. It would be impractical to retain a centralised database because of the slow response times across the network. To allow each site to develop its entirely separate database, however, would lead to duplications and inconsistencies. Distributed database management systems (DDBMS) allow data to be split between sites, each fragment of the total dataset being allocated to the site where it will be most frequently used, and yet which retain the integrity and management advantages associated with the database approach.

"Open Systems" computing

Computer manufactures have traditionally trapped customers into long-term commitments by producing hardware and operating systems that were not compatible with any other manufacturers' products. This made networked solutions very difficult. Recently, customer demand has forced the vendors to commit to "Open Systems" computing. This means that they are beginning to collaborate to produce common hardware and software standards (see chapter 6 of this book for more detail on Standardisation and Interoperability). The commitment of major suppliers to developing common standards will clearly give even greater impetus to the trend towards networked computer systems. In the very near future there is unlikely to be much of a market for hardware and software products that cannot easily be used in heterogeneous networked systems (Reeve 1994).

GIS and Network

The growing importance of network and distributed databases represents a major challenge for GIS vendors. Vendors make much of the value of GIS as components in corporate information systems, but in reality many earlier GIS systems were designed essentially as stand-alone application packages. Ellisor (1992) emphasised the stark challenge that the new "Open Systems" era of computing represents for GIS vendors, stating that GIS must take advantage of new technologies and thereby evolve from a single-purpose system into a specialised component of a computing environment that can achieve its desired GIS functionality more successfully while maintaining with the rest of the enterprise.

McLaren (1990) provided a summary of the levels of integration that GIS packages can achieve with external databases. At the lowest level there is what he refers to as "temporary importation", where data are not permanently managed in the GIS but are temporarily passed to the GIS for analysis and then discarded. Typically, data files are downloaded from an organisation's corporate database, and then read into the GIS. This approach is adequate for project-oriented work, but is clearly impracticable for systems, which regularly involve large data transfers. "Permanent importation" requires that the GIS system takes over responsibility for all data management functions, i.e. replaces DBMS. This, however, assumes that the GIS is technically capable of taking on this task and that the organisation is prepared to tolerate such a major upheaval in its computing procedures. Except where a GIS predates any other database developments, permanent importation is not acceptable to an organization because it would force them to restructure their data processing arrangements just to accommodate GIS.

Distributed Geographical Information Systems

The emerging need for Distributed Geographical Information Systems is demonstrated by the following EC-funded project:

DISGIS - Distributed Geographical Information Systems

Rationale

The EC-funded DISGIS project aimed at joint solutions for the two technology domains: Distributed Information Systems (DIS) and Geographical Information Systems (GIS). The possibilities for realising Distributed Geographical Information Systems are supported through emerging international standards and state-of-the-art distributed object technology. For the GIS domain, the main supportive standards are OGC's OpenGIS Specification and those of ISO/TC211 Geographical Information / Geomatics. For the DIS domain, the main supportive standards are ISO's Conceptual Schema Modelling Facility, OMG's UML, the ISO/IEC Reference Model for Open Distributed Processing (RM-ODP), and W3C's XML. Enabling technologies for communication and information infrastructures are OMG's CORBA, and Microsoft's DCOM with COM+/ActiveX, Java Enterprise Beans and others..

Aims

The objective of the project is to provide models, methods, tools and frameworks for the development of open distributed systems in general and open distributed Geographical Information Systems (GIS) in particular, and apply the methods, tools, and frameworks in two pilot cases, at two Enterprise GIS test sites, to demonstrate and validate the usability and viability of the DISGIS results.

The business objective of the DISGIS project is to develop methods and tools that will decrease the cost of geodata management and distribution for European Enterprise GIS' and further increase the return of investments of geodata collection and establishment. The project is user-driven by the requirements in the area of GIS. The distributed system technology (DIS) partners incrementally transfer their technology to the Geographical Information System partners, and get requirements and user experiences back.

Customers: Norwegian Mapping Authority, Quadri Components (GIS provider)

Users

Norwegian Mapping Authority, GIS Denmark, Sysdeco GIS

Application Description

The approach of the project was to apply the emerging Reference Model of Open Distributed Processing standard (RM-ODP) in combination with existing underlying distributed object technology to the application domain of Distributed Geographical Information Systems. The project focused on the total life cycle of system development and delivered ODP-compliant methods and tools that assist in the transformation from models to working distributed systems. The project was user driven by the requirements of the GIS domain, with the Norwegian Mapping Authority establishing the premises in the area of European and international GIS standards and national and European Geographical Information infrastructure.

Results

Client Mapping Framework; UML models with implementations: geodata, API, query and action; Code Generation Tools; GI XML Browser; Distributed Communication Framework; ODP Modelling Tool; ODP UML Methodology. In addition there are pilots using the results to demonstrate the interoperability between three proprietary clients and servers.

Partners

Norwegian Mapping Authority, Numerica-Taskon, Sysdeco GIS, SINTEF, GIS Denmark, INESC.

References

Ostensen O., Spilde D., The DISGIS Project, Distributed Geographical Information Systems-Models, Methods, Tools and Frameworks, Proceedings of the Third EC-GIS Workshop, Leuwen, Joint Research Centre, EUR 17715 En, 1997.

Web URL http://www.disgis.com

Point of contact

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Problems Important challenges: • introducing interoperability between proprietary data servers and clients • decreasing development time when implementing models that change with time • relating to the emerging (but not yet complete) GI standards from ISO/TC211 and OGC
Recommendations The project adopted the following strategy. Interoperability was established by a three-tiered architecture introducing: • a common geodata model that coheres with the emerging international standards; • a common API to transfer data between server and client; • a mapping framework to establish mappings to and from the clients' and servers' proprietary formats; • a distribution and communication framework separating the application's functionality from the distribution-specific issues; • a language and platform independent data exchange format (XML).

2.3.4 Current GIS Database Issues

Current commercial DBMS provide services as requested by the major administrative applications. GIS makes additional demands to manage data, which are organised as objects with complex linkages between them, which increase over time, and which include relations that are more typical for Expert Systems than databases.

Object-Oriented Database Systems

Many existing GIS are built upon general-purpose relational databases. In many related application areas, such as computer graphics, CAD and CAM, the object-oriented (OO) approach has attracted much support. Central to this approach is the concept of an *object*. The idea of the OO approach to databases is based on the desire to treat the dynamic behaviour of a system, and not only the static aspect of information, as with the relational model. The dynamic side of an object is expressed through a set of operations that can be performed on the object and are stored with it. Consider, for example, an object *boundary*, which is not only statically stored as a set of points, but which has operations such as *length_of_boundary* attached to it.

Many observers within the GIS community have suggested that the OO approach may be inherently more appropriate as a model for GIS databases than the Relational Model (Egenhofer and Frank 1989; Worboys 1994). However, the emergence of industry-strength OODBMS has been much slower than initially expected.

Time and GIS

Temporal information is critical for many GIS applications; therefore time has to be integrated in a GIS (Frank 1998). However, this raises both technical and conceptual problems. Time is modelled differently for different applications. People use a number of models depending on the circumstances. Treating time as calendar time is simple because the powerful model of real numbers is immediately available. It also permits integration with current GIS software. Unfortunately, in such cases, one cannot deal with temporal information that is not in calendar form, such as temporal information available as relative order between events, which is an important data source in geology, archaeology, etc.

In a temporal GIS, changes can be added as new timed facts, which do not replace previous knowledge. Realistic GIS must also include provisions for changing data that prove to be in error when better knowledge becomes available. Models for dealing with error correction and other improvements of existing data are more difficult, because they are non-monotonic.

Expert Systems, Artificial Intelligence, Intelligent Knowledge Based Systems and GIS

During the last decade, Computer Science has made enormous strides in developing techniques that allow "fuzzy" information and inferential reasoning to be integrated into computer databases. Within the GIS community there has been considerable speculation about the ways in which Artificial Intelligence (AI) and Expert Systems approaches might be introduced into GIS. Perhaps

GIS systems might, for example, have map design "knowledge" incorporated into their software, so that the GIS itself could take responsibility for designing appropriate map layouts. Or perhaps at the input stage GIS systems could be "taught" to recognise valid geographical features from scanned images, and thus greatly reduce the severity of the data input bottleneck. There are few, if any, major commercial GIS systems, which presently incorporate AI techniques, but AI is being actively pursued as a GIS research topic. It is almost certain that GIS packages incorporating some aspects of AI will begin to appear as commercial products within a few years.

2.4 Geographical Analysis in GIS

GIS can perform spatial analysis on the spatial data it stores. Examples for simple analyses are:

- finding all objects within a certain distance from a point (such as all free taxi cabs within 500m, see 1.3) or
- computing the slope of a field for the calculation of compensation to a farmer.

Often, more complex analysis is needed, such as

- finding areas where the spatial access to a hospital is insufficient,
- finding areas where a factory can be built without affecting the beauty of a protected landscape, or
- identifying areas where some health patterns are more common than others.

The main types of analytical operations are reclassification, overlay, calculating distances and connectivity, slope and aspect calculation, buffer construction, visibility checking, and interpolation.

Reclassification, which simplifies the classification of attributes of objects or raster cells, is used to reduce irrelevant details in the analysis. If we are working on a regional development plan, we can suppress the difference between forest stands and reclassify all wooded areas as simple forest, differentiated from agricultural or residential home areas.

Overlay allows us to find areas where some properties coincide. For example, to find areas suitable for a new family home, we could ask for parcels, which are

- zoned as residential,
- not yet built on,
- oriented towards south or south-west, and
- within 300 m of a school.

To solve this question, individual layers for each desired property are constructed and then combined with an overlay operation. In the overlay function not only logical combinations like 'and' or 'or' can be used, but other operations are possible (Tomlin 1994).

Calculation of distances in a GIS is not limited to distances 'as the crow flies', but we can also ask that distances are calculated following a street network. It can then become apparent that an area where every family lives within a short Euclidean distance from a school may have areas, where the path to the school along a street is longer than acceptable. Even more sophisticated is the calculation of distance in 'driving time' taking into account different road classes and congestions.

The calculation of *slope* steepness and *aspect* (i.e., the direction in which the slope faces) can be important for environmental planning and assessing the value of farmer's fields for subsidising purposes. There are different methods for computing slope or aspect values, depending on whether the data is stored as a raster grid or a triangulated irregular network (TIN). The resolution with which elevation data have been sampled is also likely to influence the results.

Buffers around features are often required: For example, a forest law may prescribe that wood harvesting is not permitted in a 50m buffer zone around rivers, or a city ordinance may disallow certain trades within the vicinity of a school, defining 'near to a school' as within '100 m of the school entrance'. Buffers represent such zones.

Given a digital elevation model of the terrain, one can compute which areas are *visible* from a certain point. This is useful to find locations where a necessary but not very attractive object (e.g., a waste water treatment plant) can be hidden in the landscape with minimal visible impact.

There are, of course, also military applications for visibility analysis and lately, the location of antennas for mobile phone systems require the same type of calculations.

Spatial interpolation allows for determining the (most likely) value of an attribute at a location where it was not measured using the measured values at other locations.

Spatial analysis can be used for resource allocation and path selection.

Resource allocation is the wide set of decisions, where a resource in space is allocated. Many political and planning decisions fall into this class. The decision where to construct a hospital, school or university is eminently spatial and should be guided by considerations of how the maximum number of citizens can be served. Private business makes similar decisions when deciding where to locate a new store. For example, a multiplex cinema should be located such that several thousands of people live within half an hour of driving distance.

A resource allocation problem in general is a question of 'find an optimal location' for something, which requires the definition of optimality and the search for the location, where these criteria are best fulfilled.

The simplest *path selection* question is 'what is the shortest path to x'. In our daily operations we make many such decisions using our knowledge of the environment. In a larger environment or when more complex optimality criteria are applied, it becomes difficult: What is the best route for a truck from Sofia to Bari – taking into account driving time, road tolls, ferry availability etc.?

More complex is also an analysis of the best path in the terrain, considering different terrain conditions. Such questions are often asked in emergency rescue operations, but they are also applicable to the design of a new road.

Spatial analysis operations are influenced by the unavoidable error of the data. Some analysis functions are very sensitive to error in the input data and others are not. For example, Peter Fisher has investigated the influence of error in the terrain height, which includes the unknown height of land cover (such as trees), on the viewsheds (Fisher 1993). Simple rules are not available and tests with slightly perturbed input values are recommended to understand the sensitivity of analysis functions to the uncertainty in the input data.

Spatial analysis operations are often optimised for raster or vector representations and specific packages are available on the market (Foresman 1993). In principle, the same operations are available for raster or vector based systems: the coverage of a plane for some attribute value, represented as raster or vector data should follow the same rules. In practice, some operations are more easily performed on one or the other representation and therefore it is customary for certain applications to select a raster or a vector representation.

Increasingly, GIS should model more of the spatial processes. It is not sufficient to know where a smoke plume emerges from a factory, but we would like to combine this information with data about prevailing winds to compute the average concentration of pollutants in the environment of the factory. To do so, a model of the diffusion process of the pollutant in the atmosphere under wind conditions must be integrated in the GIS. Fortunately, similar process models apply for many different concrete situations: diffusion is not only relevant for pollutants in the air, but also in surface water and groundwater, and even aspects of traffic or the spreading of illnesses can be seen as a diffusion process.

2.5 Visualisation in GIS

In a GIS the visualisation of the results means the conversion of spatial data into graphics, mostly map-like products. During the visualisation process, cartographic methods and techniques are applied. These can be considered as a kind of grammar that allows for the optimal design, production and use of maps, depending on the application.

Although considerable progress has been made in computer cartography, the automation is only complete in the mechanistic sense that relates to the plotting. The computer packages provide little guidance on decision regarding the design of the map. It is for the user to decide what data should be plotted, and with what projections, symbols, colours, typography, titles and legends.

2.5.1 Graphic elements and symbology

Graphic symbols can be classified according to the type of spatial objects that they represent (Kraak and Ormeling 1996; Jones 1997). Symbols are divided between point, line and area, each of them spatially referenced. The type of symbol chosen depends upon the degree of generalisation of the phenomena being represented. A city can be represented by a point symbol at a small scale, an area symbol at a medium scale, and a complex combination of point, line and area in a large scale. The two dimensional graphics elements can be modulated graphically in various ways to help in communicating different types of information. Bertin (1983) (Jones 1997) describes several graphics variables to be used – hue, lightness (value), size, texture, orientation and location (Figure 18).

Hue refers to the use of colours as we distinguish them by names. Hue is commonly regarded as of most use in map for representing qualitative rather than quantitative information and is typically used to distinguish between major classes of point, line and are-referenced phenomena.

Lightness (or value) refers to the lightness of darkness on an apparently uniform area of pigment. Because lightness can be varied continuously across the range, it is well suited to representing ordinal and numerical variation in data associated with map symbols.

Size is a graphic variable that is applied to some symbol classes much more often than to others. The size of point and line symbols can be varied to distinguish between values of ordinal, numerical and sometimes nominal data. Point and line data that are varied in size according to an associated attribute are described as graduated symbols.

The *shape* of a map symbol can be regarded as a variable for the purpose of communicating information about an attribute associated with the location of the symbol, in particular points. There are abstract symbols (circle, cross, square) and pictorial symbols, where the shape of the symbol is intended to suggest the phenomena being represented (e.g., symbol of a tent to represent a campsite).

The graphic variable of *pattern* describes the internal graphical structure of a symbol, in particular lines and areas. The inside of a symbol might consist of a distribution of parallel lines, or cross-hatching, or a set of dots.

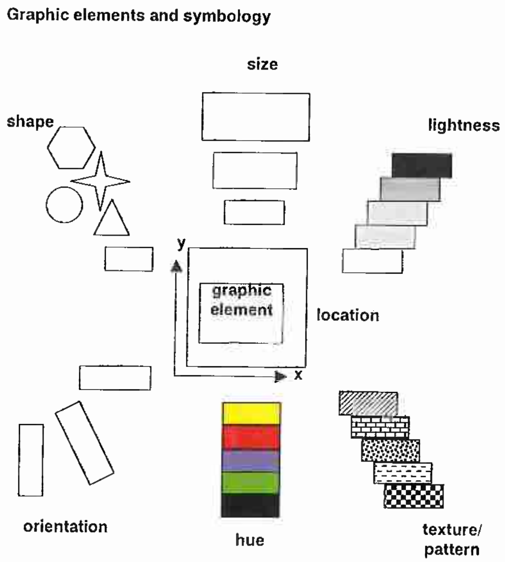

Figure 18: Graphic elements and symbology (following (Bertin 1983)).

Orientation can either be used to represent an attribute associated with a symbol location (wind direction), or it is an inherent spatial property of the structure of the spatial object that the symbol represents.

For large-area maps, the effects of map projection must be considered, but for large-scale maps of small areas this does not pose problems.

A GIS must provide methods to define map symbols by the user to adapt to existing mapping standards, and have flexible methods to associate data with graphical representation. If high quality maps are derived, specific tools to manipulate graphical symbology independent of the database are required.

2.5.2 Map structure and design

A map is traditionally composed of three fundamental elements: the map body, the title and the legend (Mueller *et al.* 1995). The title corresponds to the external information and is independent from the cartographic representation. The legend corresponds to the internal information and provides the key, through visual variables, to understand the represented information. The small areas of the main map used to magnify parts of it that must become more visible are called insets. This could be useful when the main map presents particularly crowded areas, or when there is an area more important than the others are. Finally one should not forget to draw the graphic scale in order to allow relative distance measurements.

In addition to graphic variables it is necessary to identify several issues to be considered when designing a map (Jones 1997). Particular attention should be paid to clarity and legibility, visual contrast, visual balance, hierarchical organisation, and text placement on the maps. Only a small amount of the knowledge concerning map design has found its way into computer mapping systems.

2.5.3 Goals of map production

A map is designed for a particular application, for a decision situation. It must show all the facts that are relevant for the decision and should avoid showing irrelevant ones. Paper maps can only present a compromise, as the map layout is fixed and must serve a multitude of users and decision situations. For example, maps designed for road navigation (road maps and road atlases) present different aspects than a map for hiking (scale, level of details).

Using GIS, different maps can be produced for different users and decision situations. It is therefore possible, to adapt the map more to the particular use and to specialise the layout. Interactive users of a GIS lead to dynamic maps, where the user can zoom into the map when more detail is needed, and the selection of elements can be changed as the user expresses its needs.

2.5.4 Cartographic generalisation

Cartographic generalisation is the process of selection and simplified representation of geographical phenomena (including their relationships and structure) appropriate to the scale of representation, purpose of representation, nature of represented geographical area and used graphic features.

There are many concepts as to how to implement cartographic generalisation into a digital environment. Nowadays, the majority of commercial GIS software packages divide generalisation into philosophical conditions (above mentioned in the definition), cartometric conditions (i.e. measurable evaluation of representation) and operators, which provide transformation into more suitable representations. These operators are the following:

- Selection of represented features based on attributes.
- Elimination: Selective elimination of features, which are too small, too short, and too insignificant to be presented in the final map.
- Simplification and smoothing: Removing unnecessary geometrical details without destroying its essential shape.
- Aggregation, amalgamation and merge: Combination of features in close proximity or adjacent features into a new area feature.

- Collapse: Reduction of a feature dimension or the representation of its spatial extent; for instance, changing an area feature to a linear or point feature, changing a multiple-line feature to a single-line feature, and so on.
- Typification and refinement: Reduction of feature density and the level of detail while maintaining the representative distribution pattern and visual impression of the original feature group.
- Exaggeration: Increasing the spatial extent of feature representation for the purpose of emphasis and legibility.
- Reclassification: Grouping of features sharing similar geographical attributes into a new, higher-level feature class and representing it with a new symbol.
- Resymbolisation: Change of graphic representation.
- Conflict Resolution (Displacement): Detecting feature conflicts and then repositioning the less important conflict features or adjusting feature extents to meet the threshold of separation and other cartographic specifications.

It is important to remember the effects of cartographic generalisation when data from existing maps are digitised and entered in a GIS. The data entered then shows all the effects of cartographic generalisation as initially applied. Digitalisation converts map symbols at locations into codes with co-ordinates, but the co-ordinates are the ones from the map symbol location, not the true location of the object!

2.5.5 Visualisation of 3D data

Most of the display facilities in GIS packages are concerned with data represented in two dimensions. There is, however, increasing interest in 3D data display. The main type of geographically related data that represent phenomena in three dimensions is that of Digital Terrain Models (DTM). Three-dimensional visualisation of landscape features can be achieved by superimposing, or draping, a 2D representation of geographical features, such as roads, rivers and soils, onto a digital terrain model (Jones 1997).

To structure the DTM data one can choose between two basic approaches – grid and triangulation. The first results in a regular network of points covering the study area. Height values are determined at these points. A triangular network incorporates each of the original data points in the model. This offers the opportunity to consider local relief characteristics. Triangulation is usually treated with the Delaunay algorithm resulting in a Triangular Irregular Network (TIN). Characteristics of a Delaunay triangle are that its edges have the shortest possible length, and the angle between two edges is as large as possible.

In a GIS environment the DTMs are used to execute surface analysis. Two of the surface attributes, slope and aspect, play a prominent role in calculations related to the surface analysis (Kraak and Ormeling 1996).

2.5.6 Interactive cartography - maps and multimedia

During the last few decades, many computer users have become involved in making maps (Morrison 1994). Many of these maps are not produced as final products, but rather as intermediate products to support the user in his or her work dealing with spatial data. The map, as such, has started to play a completely new role. It is not just a communication tool but also a tool to aid the user's (visual) thinking process. This process is being accelerated by the opportunities offered by new technology developments. New distribution media such as CD-ROMs and the WWW not only allow for dynamic presentation but also for user interaction (Kraak 1998). Specific software toolboxes have been developed, whose functionality is based on two key words: interaction and dynamics. If applied in cartography it offers the user the possibility of instantaneously changing the appearance of a map. Interacting with the map will stimulate the user's thinking and will add a new function to the map (Figure 19).

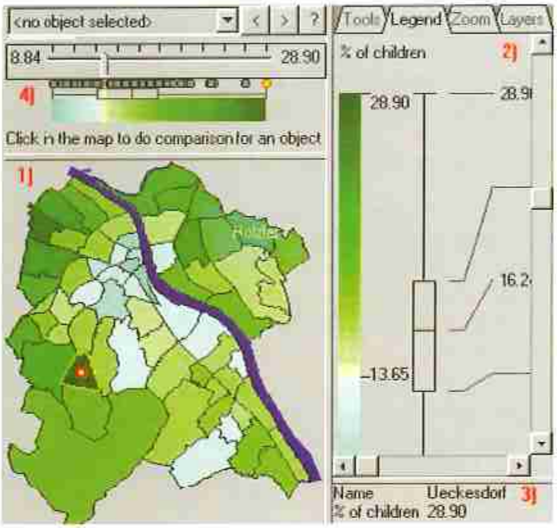

Figure 19: From (Andrienko and Andrienko 1998): An example of a map window with dynamic cartographic manipulation tools. A map window is divided into several areas: 1) the Map area where the map is drawn, 2) the Legend&Tools area, 3) the Data area, and 4) the Manipulation area. The areas are separated by moveable borders.

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3. ORGANISATION AND BUSINESS ASPECTS OF GIS

Aims & objectives	• Show methodologies of how to introduce GIS in an organisation. • Show GI and GIS from a business and economic perspective.
Learning outcomes	• Strategies for the introduction of GIS in an organisation. • How to do economic and feasibility assessment of GIS projects. • The impact of GIS on people and organisations. • How to design and/or select a GIS. • GI and GIS from a market perspective: how to price geographical data and the relation to e-Commerce. • Some common misperceptions and pitfalls.

The bulk of this chapter is concerned with introducing GIS in an organisation. Two complementary strategies are described.

The first strategy proposed here for the introduction of GIS starts with identifying the users who have to make spatial decisions. What information do these users need to make their decision and how is this information best presented to them, so they can react quickly and without error? From these questions follows the *'spatial information product'*, which provides the users with this information. Once the spatial information product is designed, the logical and physical organisation of the data necessary to produce it, and also the required hardware and software become clear. The concept of a 'spatial information product' helps also with the economic assessment of a project, in particular with estimating the benefits. It provides a crucial point for the discussion with the user in his own terminology. From this the GIS professional deduces the technical and organisational detail, which are usually difficult to understand for the user.

As a complementary strategy, *User Centred Design* (UCD) is outlined in paragraph 3.1.2.

While in the first approach the users' problem is considered from the point of view of setting up a system for Geographical Information management, in the UCD approach the same problem is considered by the symmetrical point of view of how to conceive the technical tools that allow setting up that system, and how to comply with the current European regulations.

The present concern is then about organisational aspects of GIS implementation and also the related business aspects.

The chapter continues with the description of needs analysis and feasibility study, i.e., the decision phase of introducing a GIS (paragraph 3.2). Needs analysis determines the information needs of the organisation. The feasibility study first determines the scope of the project in realistic terms. What can be achieved given the technical, financial and organisational constraints?

After this, the chapter reflects in 3.3 on the influence that the introduction of GIS can have on an organisation and the people in that organisation. Positive and negative effects are examined.

A very visible step in the realisation of a GIS project is the selection of the actual system. Paragraph 3.4 explains the evaluation process and the tasks, which must be solved. It is followed by an analysis of the organisation, which wants to introduce the GIS from a technical point of view and a description of how the technical requirements and benchmarks are set up. The evaluation of the offerings of different GIS vendors is difficult and a multitude of criteria must be considered and weighted. The subchapter concludes with a brief description of the steps involved in the development of a GIS application.

The chapter continues in 3.5 with a reflection on the economics of Geographical Information. Economic considerations are extremely important in the decision for a GIS. The cost of the project should be less than the benefits it yields. The difficulty is in assessing and comparing the cost and benefits. This subchapter concentrates mostly on the Cost-Benefit Analysis as it applies to GIS. It shows in detail how financial feasibility can be demonstrated and helps to present the GIS project in terms the business leaders understand. Closely connected with the business aspects is the issue of electronic commerce in GIS.

Finally, there are some words of warning in the form of a list of myths and legends around GIS and some common "pitfalls" around GIS.

3.1 Strategies for the Introduction of GIS

The introduction of modern GIS technology in an organisation is a complex process. The first method proposed here consists of a series of executable steps, which are connected by a consistent theory. The method centres on the tasks the users of the GIS have to fulfil, and the required spatial information. It is possible to describe the tasks for which the GIS should be used and the information expected in detail and in a form understandable to the users. The technical details follow logically from the document the user can understand and agree to.

A second, complementary, strategy is the User Centred Design (UCD) approach. Also starting from the user perspective, UCD is less focussed on information flow, and more on end-user functionality.

3.1.1 An Information Centred Approach

A factory transforms raw materials into a product, which is sold on a market. This metaphor can be applied to GIS. The spatial data collected serve as raw material, the software represents the factory and the information in the form 'output from the system' is the product. The output from the GIS is the 'information product'. This indicates that it is produced by the GIS, it is the result of the GIS seen as a production process, transforming raw materials (i.e. the spatial data collected) into a valuable product for a user.

The metaphor is important because it stresses many important aspects linked to the GIS:

- is the GIS producing information somebody uses?
- is the product of value in a decision process?
- is the quality of the product adequate for the user?
- is the product easy to use?

The product metaphor draws attention to the marketing issues, which need to be addressed for GI. But the information product also points to the applicability of economic theories that are well developed for industrial products.

Concentrating on the user of the GIS - not the technology – is the first step towards the successful introduction of the GIS:

- What are the tasks the users are involved in and for which they need additional information the GIS should produce?
- Which information is necessary for these tasks?
- Which form of information is easiest to understand for the user?

From these user-oriented questions most of the answers for the technical design of a GIS follow:

- Which data are necessary to produce the desired information?
- What data quality is required (for the information produced, for the data collected).
- Which functions are necessary to transform the data into the desired information?
- Which hardware and software are necessary? What is the overall architecture?
- How to perform the economic assessment of the GIS project

Information needs depend on tasks of users

The GIS is introduced in an organisation to improve its functioning. It is crucial to understand the goals of the organisation and how they are achieved. Typically the GIS is set up to serve specific users in the organisation. The future users of the GIS have a certain function in the organisation and fulfil some tasks within it. The GIS must support these functions, these tasks - nothing else.

The first step in introducing the GIS must be to analyse the tasks within the organisation, which require Geographical Information. Which information is required for which specific step of the task? How does the information influence the outcome of the task? What happens if the information is not available, not available in time, or available but not correct? For instance, to be able to respond to an emergency request, a 'path to the emergency location' must be available. If it is delivered too late or contains errors, the response may be too late and people could die.

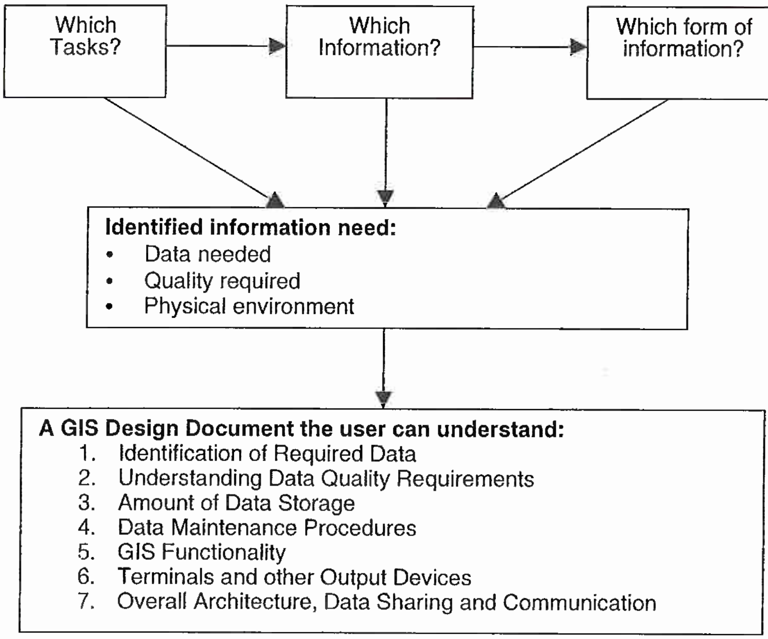

Figure 19: An information-centered approach.

What information is required to perform the task?

Having identified the task of the users, which the GIS should support, we must proceed to the information needs of the users performing these tasks. The information may be compulsory - the task cannot be completed without the information, or it may be additional. The performance of the task is improved with this additional information. For example, for a building permit, the location of the proposed building in respect to the parcel boundaries must be present in order to check clearance.

In many cases the user is not free to select the information he wants to use. Administrative decisions follow rules set forth in a law or additional regulations, indicating which information must be considered, often giving details on its presentation, data quality etc. These rules are part of the instructions from the legislator and regulate how a decision must be reached. They have to be observed to assure that the administrative process is equitable, not using information of different quality levels.

It is highly recommended to visit the users in their offices and observe them at work. Collect a copy of the documents consulted, of forms filled in and other information included in the decision process; this collection will be very helpful for the following steps.

How is the information presented to the user?

The next step is to identify the form in which the information is presented to the user. Understanding the task a user needs to perform and having identified which information the GIS can contribute to it, we can decide on the channel to communicate this information to the user. A 'path to location' information product for instance, must contain a sequence of streets and turns to guide a driver to the desired location.

In most cases, spatial information is communicated in a map. To use graphics is recommended in order to assure that all the required information is present, that it can be understood from the context and that the quality of the information communicated is sufficient for the task at hand.

Considering the usage of the information, not only the graphical presentation of the information should be discussed, but also its medium. If the task requires a small amount of information quickly, a graphical screen is the optimal solution. For decision processes, which require a large amount of complex information, but progress slowly, output on paper can be more appropriate. If documentation of the decision and its justification is important, a paper copy must be printed and added to the case documentation. A building permit obviously needs to be printed on paper, to provide physical evidence, whereas in an emergency vehicle, spoken information may be more useful.

What follows from the identified information need?

From the identified information need should follow all, or at least most, of the elements necessary for the design of the GIS:

- The information requirement defines the data needed and the GIS software functions to transform these data into information.
- Understanding of the tasks and the decision process determines the quality of the required information.
- The physical environment, in which the information is used, determines the hardware and communication channel to pass the information to the user.

Benefit: a GIS design document the user can understand

After these steps it is possible to produce a design document, which is deduced from the 'user understandable' requirement document:

1. Identification of required data.
   From the description of the information product, not only the necessary data, but also the non-necessary data are identified.
2. Understanding Data Quality Requirements.
   Information products also give an indication of the data quality required. Data quality is a widely discussed issue, but operational rules are seldom provided. Elements commonly perceived as determining data quality are accuracy, completeness and maintainability.
3. Amount of Data Storage.
   For the technical design of a GIS installation the amount of data storage is important. From the description of the data necessary and some measuring of the amount of data per area or the number of objects and the amount of data per object quickly follows the amount of data to be stored. This figure must be increased for storage overhead.
4. Data Maintenance Procedures.
   The data used must be maintained; this is often the most difficult organisational problem and a very substantial part of the cost of running a GIS. The description of the information product indicates what level of update must be achieved. Observing the organisation and its present mechanism to assure that the data used for a decision are up to date gives us further insight in the requirement for data maintenance.
5. GIS Functionality.
   The operations necessary to translate the stored data into the desired information are immediately identified. The comparison of the data stored with the desired information shows what kind of spatial analysis, database retrieval, graphical presentation tools are necessary. This allows us to decide what kind of GIS software will be necessary for the application.
6. Terminals and other Output Devices.
   Having identified the users and the form of the communication of the spatial information leads to an estimate of the type and number of terminals necessary for the users to access the information. If the information product is a printed paper map, quality of plotters can be deduced from the examples provided.
7. Overall Architecture, Data Sharing and Communication.
   The user level document shows the data that are shared among the users. It describes the users and where they are located. This helps to define the requirements for the distribution of

data between different sites (move the data to where they are used!) and the communication lines between these sites.

3.1.2 A complementary strategy: User Centred Design (UCD)

In this approach, the focus is more on the point of view of the user. In fact, the User Interface is the actual "view" that most users have of a GIS and that implies a proper GIS development process that should include a user requirement analysis and various user-oriented steps leading GIS implementation.

When dealing with GIS applications it is fundamental to focus the attention on the role and the centrality of users and their involvement in the GIS application development process. No technical tool can be expected to have real use if it is not able to target the whole context of potential users.

On this side things have largely improved during the last years: the general evolution of Information Technology and Software Engineering have created the conditions, and presumably the trend will be positive in the coming years. However, the difficulty of targeting final users during GIS project implementation demonstrates that the GIS process still needs to improve, with the end-users who determine in which direction the improvement should go. For example, a proper compromise must avoid either too much functionality (additional burden on the user in selecting functions) or too little functionality, causing users to search for tricks and shortcuts during task execution.

The above issues are addressed by the User Centred Design approach (UCD), a mature professional practice that has emerged and supports the development process of interactive software systems. It is based on the assumption that the success of new products depends on the efficiency and effectiveness of steering product development by user and customer feedback. UCD consists of processes, techniques, methods, and procedures that help to achieve user and customer orientation (Gould and Lewis 1985; Norman and Draper 1986; Preece *et al.* 1994; Rubin 1994; ISO 1997).

The ISO/DIS guideline 13407 "Human-centred design processes for interactive systems" provides guidance on human-centred design activities throughout the life cycle of interactive computer-based systems. It is a tool for managers of design processes and provides guidance on sources of information and standards relevant to the UCD approach. ISO 9241 "Ergonomic requirements for office work with visual display terminals (VDTs) (An employer's guide to the Display Screen Regulations)" and the "European directive 90/270/EEC on minimum health and safety requirements for work with display screen equipment" are closely related to UCD.

The UCD approach is highly relevant for GIS applications. However, GIS development is different from other software development processes. GIS functions and their user interfaces are so complex that in order to be usable they must be tailored to specific user needs.

To a large extent the UCD approach to GIS is concerned with the development of the User Interface, which is the part of the system that is visible to the end-user and which is needed for the dialogue between the user and the GIS. User-centred customisation implies then mainly user interface design which is either performed by GIS vendors and suppliers, by experts offering customisation services, or by the end-users themselves.

The major principles of GIS user-centred design are:

- Focus on end-users, because they can contribute a lot to GIS user interface design by providing their knowledge of the GI application domain, prior experiences with GIS, their work tasks and responsibilities. The community of GIS end-users is extremely diverse ranging from Geographical Information domain experts to general public users with little GI knowledge who are assumed to be using Geographical Information much more frequently in the future. The utility of a GIS application within a company or an organisation can be greatly enhanced when the GIS user interface can be tailored to groups of users with specific knowledge and experiences. To conclude, GIS interfaces tailored to user needs will be much easier for the end-users to learn and will cut down end-user training cost. Any user involvement will increase the likelihood of user satisfaction with the final GIS, of commitment and acceptance. The provision of user feedback about GIS use to GIS developers is an invaluable source for GIS evolution and for the development of new GIS.

- Iterative design, whereby the GIS design, improved repeatedly, helps to shape the product onto the user needs. It allows preliminary and alternative design solutions to be tested against real world scenarios, i.e. a realistic set of tasks the prospective end-users intend to perform with the GIS application. It is commonly accepted today that the quality of technology products is mainly a function of the number of completed 'design / test & evaluation / redesign' cycles. The quality of GIS functionality will depend to a large extent on the effort (manpower and time) invested in the development process and the efficiency (use of experience and best practice) of development procedures. Iterative design if applied early in this process will help to avoid design errors and failures. This will speed up development so that new GIS can enter the market earlier, and the effort of customisation may be reduced.
- Appropriate allocation of functions between end-user and GIS. GI tasks cannot always be fulfilled using a single GIS function. More often a procedure, i.e. a sequence of GIS functions, must be executed. It may be advantageous for end-users if GIS functions can be hidden behind macros for task execution, which better map to the end-users' knowledge and capabilities. It must be specified which functions shall be carried out by the GIS application and which by the end-users. This task is performed taking into account limited human information processing capabilities (Card *et al.* 1983) and limited performance of technology in terms of reliability, speed, accuracy, flexibility of response, cost, importance of successful or timely accomplishment of tasks etc.
- Multidisciplinary design team. GIS user interface design requires a variety of skills: substantial knowledge of the Geographical Information domain, expertise of GIS technology and user interface design skills. Representatives of all stakeholders, i.e. persons with an interest in GIS use and the results produced with a GIS application, should be involved in GIS user interface development and customisation: end-users, their managers, purchasers, trainers, etc. Such a multidisciplinary design team does not have to be large. It is only required that members of the user-centred design team represent all the relevant different roles and skills.

GIS developers, those who customise GIS as well as customers and end users must be enabled to use best practice for GIS development, customisation and purchase. This goal can be achieved by promoting the UCD philosophy. The most important activities to be taken into account are user needs and requirements analysis, benchmarking and cost/benefit assessment. These are described elsewhere in this chapter.

UCD has been investigated by many projects for many different IT application domains. For example, the UPI project funded by the European Commissions Telematics Applications has collected and integrated this information and is currently creating the VNET website (http://www.acit.net/vnet), which will explain user and customer orientation in the product creation process. With the UCD paradigm another EU project, BEST-GIS, has been developed, which is aimed at coping with the analysis of Best Practice in the GIS field and has produced the "Guidelines in User Interface for GIS" (http://www.gisig.it/best-gis).

Both strategies for introducing GIS in an organisation that are mentioned here focus initially on the user. The Information Centred approach uses this focus to determine the information product the user needs and defines the required GIS characteristics from there. The User Centred Design approach remains focused on the end-users, designing the GIS interface from their perspective and defines the GIS functionality based on this.

Exploiting the complementarity of these two approaches brings a more comprehensive GIS process implementation, tailored to the user's actual needs.

3.2 The Decision to Realise a GIS Project

3.2.1 Economic Assessment

The assessment of the economic viability of a project requires a comparison of the cost with the benefits. The total cost of a project must be less than the total benefits it produces, otherwise the project should not be realised.

The cost of the solution can be estimated by combining cost of hard- and software, data collection, user training etc. To estimate the benefits, there are two approaches available, based on the Information Product Metaphor. The 'avoided cost' approach compares the cost of producing the information product by GIS, with the traditional method used. Assuming that the traditional method is beneficial (i.e. not running at a loss), the costs of the traditional method can be taken as a minimum estimate of the benefits it contributes to the organisation.

Estimating a fair price for the information product is the appropriate method if the same information product is not currently being used. The idea is to consider how much a user would pay for the information product. A user is willing to pay at most the amount he benefits from the information; therefore we consider the task, the risk involved in the decision, how much the risk is reduced by the information received etc. Reduction of risk is comparable to buying insurance - its value to the user and thus its market price can be assessed. The economic aspects of GIS are further discussed in paragraph 3.5

3.2.2 Technical feasibility

Technical feasibility is a complex issue and the measure of feasibility depends on many factors. Having criteria by which to select the most appropriate technology for each application or set of applications is of greatest significance. These criteria are the result of a detailed understanding of the business functions to be supported and to what level of sophistication. Basic support functions such as data query and display are far less complicated to implement than complex decision-making.

Without adequate decision criteria directed by the strategic vision, the likelihood of becoming "technology driven" is high. That is, solutions are looking for problems to solve. In this environment technical feasibility ceases to be an issue. The right technology is always available, because "right" is defined by what is available. A broader more systematic view of technical feasibility is required to avoid becoming technology driven.

In evaluating technical feasibility, part of the evaluation relates to the use by the end user and to the amount of training and technical support necessary to use the application. One way of dealing with technical complexity is to hide it from the end user by implementing sophisticated easy-to-use machine interfaces. The human-machine boundary is a conceptual meeting point of the operator and the computer. The more the complexity of the computer's work that can be hidden from the user, the easier the computer is to use. More "user friendliness" generally means more software development, but also lower training and start-up costs for the end user.

It has been demonstrated through various projects that significant reductions in training requirements and learning curves can be achieved by customising software for specific job functions and through effective user interfaces. However, that often translates into higher development costs per application unless the software development can be shared.

Technical feasibility is further complicated by the likelihood that GIS technology will be acquired over long periods of time. Acquiring technology over a period of time involves both benefits and risks. By purchasing only what is required for each application, the organisation can benefit from the rapid advances in information technology. The risk is not being able to properly or readily combine the technology. The risk can be managed by defining a technology strategy and architecture, by adhering to as many industry standards as practical, and by closely monitoring technology trends.

3.2.3 Institutional feasibility

Institutional feasibility deals with the willingness and ability of an organisation to accommodate change and to work across traditional lines of authority. When a planned GIS implementation will serve many organisational units and require several years to be completed, institutional feasibility is important. Technical feasibility needs to be aligned with the ability and willingness of the organisation to sustain a large project over the life of the planning horizon. Budgets and management support will need to be sustained at required levels, staff education and training may need to span several years, and technology acquisition may be spread over several fiscal years.

Institutional feasibility, more than technical feasibility, is tightly bound to the scope of the project. Some additional factors to be considered in evaluating institutional feasibility and establishing the project scope are discussed below.

- Is the GIS to be multiple or single purpose?

A system designed to support a single organisational function is simpler to specify, design, and implement, than one that must support a variety of functions. However, if the single purpose implementation depends on data from other parts of the organisation, or if other parts of the organisation also have an interest in GIS, then a single purpose project attempt may fail. Implementing a GIS in one organisational unit and not in other related units may also create imbalances in the overall functioning of the organisation.

It is often advisable to make a plan for a phased introduction, thus achieving the simplicity of a single purpose system with the institutional support for a multi-purpose (long-term) goal.

- Will the GIS be implemented to automate line-management or support functions?

Many organisations have begun by implementing computer aided drafting systems to automate map production. That technology will likely not be adequate to support line-management functions that require complex information retrieval and modelling.

- Who is the computer system being developed for and what type of computer system is required?

If the system is being implemented to support management planning and decision making, the system will be significantly more complicated than if it is being implemented to perform routine information handling tasks.

In general, projects should start with a modest, well-defined scope and expand over time as the organisation learns about GI-use and GIS technology.

3.3 Organisations, People and GIS

The application of GIS in different aspects of life changes the ways of collecting, storing and using spatial data. This reflects not only on organisations creating or using geodata, but on people as well (ordinary consumers or serving staff). Positive and negative sides of these influences are reflected upon in the following sections.

In general, GIS projects are similar to other projects where technology changes the way an organisation works efficiently. Such change creates excitement in some of the staff and anxiety in others. Projects succeed if people can be motivated to address the changes and challenges and are insulated from the potential negative effects.

3.3.1 GIS influence on organisations

Several positive effects of the introduction of GIS in organisations can be distinguished, leading to improved spatial decision-making. First of all there will be a larger commitment to using spatial data. Furthermore, new methods for analyses and management can be used and unification of data with different features is possible.

On an organisational level, facilitating the communication among separate administrative groups in different organisations and departments is a positive influence. Also the opportunity for a more rational use of specialists' knowledge, creating a potential to reduce the number of staff, and minimising administrative mistakes by automating workflow can be mentioned.

The goal of GIS projects in an organisation should be mostly to improve the organisation's efficiency and contribute to its goals of quality production for its ultimate uses. It is dangerous to describe GIS projects in terms of the reduction in staff, etc. Experience shows that demand for GI increases in an organisation more rapidly than technology reduces staffing levels; the same number of staff produces more and better Geographical Information, and finds more fulfilling jobs.

But of course there are also negative effects possible. Structural changes in the organisation and changes in legislative and normative base could under certain circumstances be perceived as negative. Also the introduction of GIS often leads to increased requirements for data collection and representation, needing additional staff skills and therefore training.

3.3.2 Influence of GIS on people

GIS effects people not only by its technical features, but also by changing social relationships and norms. Some negative attitudes towards GIS by staff are created in organisations adopting this technology. These are connected with the needs of additional staff training and the increase in the required skill of the staff. However the introduction of GIS also leads to some positive trends, such as staff qualification improvements, reduction of the time spent on activities connected with data collection and representation and easier communication with other specialists working in the same or other organisations.

GIS makes it possible for customers (of public sector organisations for instance) to get better, faster and more detailed information on their inquiries. It should be noted however, that this is not an automatic result from introducing GIS in public sector offices. Additionally, it often requires a change in staff attitude and workflow processes. On the other hand, GIS implementation in the public sector requires the customer to learn about the changes in the way information is made available to him or her.

The opportunity for widespread publishing of spatial data is maybe the most significant effect of GIS usage. This increases the danger of privacy-sensitive data becoming public. This danger should be taken into account seriously.

3.4 Methodologies for System Design and Selection

After explaining how to determine the organisational requirements for a GIS in the first part of this chapter, this section explains the methodology for a systematic approach how to evaluate and select a concrete GIS, leading to a rational choice of system. Also, it describes the basic steps in the development of a GIS application.

3.4.1 The GIS Evaluation Phases

There are some simple rules to pay attention to when evaluating a GIS:

- If the available money is only sufficient for buying hard- and software, you should rethink your project scope again. Money will be needed for training, data, maintenance and technical advice as well!
- Investing into larger GIS solutions will take 3 to 5 years before it yields major benefit. Phase the project and make sure there are initial benefits to be shown within the first year.
- During the implementation period of GIS qualified and motivated staff are required. In certain cases the old and new system need to be run in parallel.

The major phases for the selection and evaluation of a GIS are:

1. Planning
2. Decision
3. Installation
4. Operating phase

Planning phase

The planning phase starts with setting up an expert team, consisting of four to six members who bring in their expertise concerning the organisation and the given tasks. In most cases they are not GIS experts, but will gain expertise during the evaluation process. However, adding one or two outside experts with GIS experience may avoid many costly errors. If not already available, the expert team should conduct a needs and feasibility study (see paragraph 3.1).

The outcome of this study forms the basis of a pre-evaluation of systems. The number of GIS products on the market is large; the pre-evaluation should reduce this number to an acceptable range. A rough pre-selection of feasible GIS products may be made based on published material. These materials can be obtained from vendors, trade magazines, independent market research organisations, university institutes or consultants. Criteria that should be considered during the pre-evaluation are hardware, operating system, choice of database, performance, vendor and functionality, as described in the GIS design document (see paragraph 3.1.1).

The final part of the planning phase is the benchmark design. A benchmark is an unbiased mechanism to measure the suitability and efficiency of a supplier's proposed solution within the context of the buyer's application and environment. During the evaluation process the benchmark is the most important step to judge the feasibility and performance of products.

The purposes of a benchmark are:

- objective technical comparison of alternative solutions
- check compliance to functional and performance specifications
- determine resource utilisation
- motivate and commit personnel
- evaluate user response to GIS technology
- gain experience with leading edge GIS technology

In designing the benchmark, the expert team chooses criteria by which to evaluate the systems that survived the pre-evaluation phase, and selects a method of testing these criteria.

Decision phase

The decision phase consists of two steps:

A decision to go forward with the project based on the feasibility study and overall economic assessment.

The decision for a specific GIS from a particular vendor.

For the go-ahead with the project only overall cost information is required and assurance that at least one vendor can provide the technology.

The decision for a specific vendor must follow the accepted rules for procurement, typically with a call for tender and a rational, impartial selection of the best offer. The cost of this selection process is quite high and it is highly recommended to get assistance from vendor independent GIS experts as consultants.

Benchmarks to establish whether a system is capable of fulfilling the requirements are typically used to help assess the systems. Benchmarks are useful, but they stress properties of a system, which can be measured easily, – especially the speed of returning some function. These are often less relevant in day-to-day operations than the quality of the user interface or the ease of learning the system, which are much more difficult to assess.

Installation

After deciding for a GIS, the implementation may start. With the installation the GIS evaluation process stops partially, but nevertheless, the customer has to continue looking at the GIS market. Experience shows that within a year or two, further equipment is needed; additional tasks may be fulfilled and so on. The installation phase includes the training of the operators, possibly further software development, installation of the hardware and software.

The system configuration is installed; a pilot project may be started under the leadership of the vendor. The production process may start after the staff has been trained. Training and education may take up to half a year. It may be necessary to customise the GIS to the user demands. Customising the GIS to the users may take a year or more. A pilot project may run several months before production starts.

Operation phase, expansion and updating

Within one or two years it might be necessary to expand or update hardware and software. Additional hardware may be needed; more equipment, more or better workstations. The supplier usually offers software updates and revision once or twice a year. Additional software modules may be bought to serve additional applications. Continuous education and training of the staff is necessary. Experienced staff will leave the company, additional or new personnel will need to be trained. The updating and revisions of data depends on the demand of the user. Data are the most valuable part of GIS, so keep them up-to-date. Upgrading data may become necessary with new software revisions. With a growing customer base further data exchange modules may be needed.

Renewal of the GIS cycle

A few years later a new GIS evaluation cycle may start. The renewal of the GIS can be required whenever major changes in the production process, the organisation and its workflow occur. It is also necessary when the technical equipment becomes out-of- date. The GIS evaluation process will follow the same steps, but with more knowledge.

3.4.2 Alternative Evaluation Procedures

There may be several reasons why the described evaluation phases may be shortened or other sequences may be necessary. Some major reasons are:

- limited budget,
- restricted resources and skills,
- corporate computer suppliers pressure,
- limited window of opportunity.

In the following different alternatives are illustrated and discussed.

Pilot projects to reduce risk

This approach expands the previously described steps with one or more pilot projects. The risk is minimised, but takes more time. During the pilot project the organisation learns a lot about GIS. This approach is recommended for organisations that have little experience with GIS. It is closely related to a phased approach, as the pilot can be seen as a first (small) step in a larger project, which is adapted further based on the experiences gained during the pilot phase.

Desktop approach

The desktop approach tries to select a GIS without a benchmark. All evaluation phases are more or less based on paper studies. A GIS team is created and starts the strategic study, typically expanded by outside GIS experts and consultants. Pre-evaluation of systems is done from market surveys or literature. A request for information is sent out to a small number of vendors remaining from the pre-evaluation process. The user requirements analysis (operational requirements) is done based on the existing know-how on GIS. A tender follows. The GIS is selected and installed. A pilot project and benchmark are done to demonstrate the functionality. This usually takes longer because in this approach it is the company's first experience with GIS in the company. If the pilot project runs successfully, production can start afterwards.

The risk is that the selected vendor cannot fulfil the benchmark and the process has to start again. This risk is low today, as functionality differences between GIS's are small.

Project driven approach

The shortest evaluation process runs under pressure from outside the organisation. For instance, if a contract would be lost, for not being fulfilled with GIS technology. This procedure may work fine when knowledge on GIS technology and the GIS market exists in the company. A small number of vendors are pre-selected. The operational requirements may only be related to the project. Still, one should do the user requirements analysis very carefully to know and analyse the demand. From the tender one selects a GIS, starts installation and immediately goes into production. The risk is that the selected GIS is only useful for a specific project.

3.4.3 Development of a GIS application

Once an organisation has chosen and installed GIS software, it can start development of additional applications. As we have seen, in some cases a (small) application or pilot project can even be part of the evaluation process.

Application development does mean not rewriting the GIS software, but instead customising applications to meet specific needs. The applications may be as simple as a set of preferences that are stored for each user group or individual and are run as a macro at start-up. Or they may be a very complex query that selects a group of layers, identifies features of interest based on attribute ranges, creates variable width buffers, performs a series of overlays and produces a hard copy map. In either case, an application is required to convert the user's ideas into a usable, stable product.

There are three approaches typically used by organisations to develop GIS applications. Organisations can develop these applications in-house from scratch, interface with an existing 'over-the-counter' GIS application or use a GIS framework as the foundation for their customised

GIS application. The strengths and weaknesses of each approach will be considered here. The details of application development depend on the selected technology, but the general recommendation is to follow the steps proposed.

Building a GIS application in-house

The primary advantage to building a GIS application in-house can be summed up in one word: "control". Because one is using their own staff, there is more control over what functionality is delivered, and when it is delivered. However, this control comes at a price. Building a GIS has its own unique set of challenges not found in other types of applications. One needs user-interface experts, graphics experts, database experts, and performance tuning experts. Does the staff have the expertise? Do you have time or budget to train them? The lack of availability of these experts can significantly stretch the delivery time of your project; even prevent the project from ever being completed.

Interfacing with an 'over-the-counter' GIS application

Using an 'over-the-counter' GIS application as the nucleus of your own application allows you to deliver a completed system much more quickly than by developing it from scratch using in-house developers. It's likely that the application will contain a much more comprehensive set of GIS functionality than one would ever get trying to develop it in-house. Likely it will be able to deliver the application more quickly than by building it all yourself. There are also problems with this approach, though. While the GIS system vendor may know about GIS, they do not know your business, and so may not implement the GIS functions in the most efficient manner for your needs. Even when the vendor product has the necessary functions, one is forced into doing things their way. And if the requirements change, or there is a need to add new functionality at a later date, the vendor package may suddenly not meet the requirements.

Using a GIS framework as the basis for an application

What is needed is a solution that leverages someone else's GIS expertise while allowing customisation of the application to the specific business needs. That solution is to use a framework. A framework has most of the hard work already done. It provides the foundation for an application that contains all the GIS functionality. It allows for building the business-specific parts of the application on top of that foundation. And it allows customisation of the GIS behaviour to meet the specific needs of the application. It takes full advantage of the power of object-oriented programming to maximise reuse and minimise the effect of changes. One gets the benefit of using someone else's GIS and graphics experts while using one's own business experts.

The development of an application can also be contracted out. Typically the vendors of GIS work with software companies that build custom applications. The companies have the experience with the software and may even know the application area from previous contracts.

In general, today's business philosophy of concentrating on the 'core competence' of one's business and contract out most of the aspects that are peripheral fosters this approach. The risk is in future additions or changes to an application, where one either goes back to the initial contractor, hoping that they have maintained the skills, or is faced with a decision to redevelop the whole application (which may be less costly than to make the change!).

3.4.4 Basic Steps in the Completion of an Application

Irrespective of the chosen approach, application development should go through a minimum series of basic steps. These steps are:

- Basic preparation of data sources,
- Data and process modelling,
- Test project.

Basic Preparation of Data sources

For the same region in space various data material may already exist. The first step is to analyse which type of data exists in your organisation or outside that is related to the application you are dealing with. The different sources include maps, images, tables, file-cabinets, publications, reports, and sensor data. Field surveys may help to prepare an inventory on what exists at a specific place. How are these data available, either in digital or analogue form? Do they exist or do they have to be created?

A data evaluation sheet may be prepared extracting all the relevant information about the data. This may be viewed as an analogue meta-information system. Whenever it is possible this analogue system should be transferred into digital form during the installation process of a GIS. This has major advantages concerning the information flow, the workload on communication systems and the selection process for data.

The most important aspects to keep in mind during data preparation are:

- Consider getting data from someone else. Avoid own data capturing whenever possible, but keep in mind the quality you expect from these data.
- Prepare evaluation sheets for your data and assess carefully the data quality aspect. This may require field checking for a subset of the data.
- You need to have the sources in your hand or on your computer before you start working in your project, otherwise you lose time.
- If you require the data from another source, arrange for future updates and regular maintenance of the data.
- You need to consider legal issues such as intellectual property rights and privacy of data (see also section 4.3).

Data and Process Modelling

Data base design

Data modelling is meant to structure the existing data in a way that multiple usage is possible. The data model is an abstraction of the real world, which incorporates only those properties thought to be relevant to the application at hand, usually a human conceptualisation of reality. In order to determine how a collection of data is ultimately presented in digital form it has to be divided into different groups or levels.

This abstract data model has to be realised independent from a specific system (see paragraph 2.1). This allows for recognising bottlenecks in the implementation on top of a specific GIS. These bottlenecks have to be overcome, either by additional or redundant information or by customisation of the existing GIS.

Information model

Information modelling is intended to analyse the workflow in the organisation and tries to establish an appropriate way of supporting the workflow with a GIS. The processes that lead from data capture through storage and processing to the results must be laid out. This leads to an identification of all parts of the organisation that are involved in the project.

Update of data

Data will change from time to time. The rhythm of change, – how often and how important the changes are, very much depends on the type of application. It will be necessary to analyse the update frequency of the data and propose an update procedure. Data may also be incomplete and become complete only after a longer period of time or by adding additional data from other departments. The model should be flexible enough to handle these problems. Preliminary solutions might be necessary. In some cases it may be necessary to collect completely new data instead of updating them, and this may be less expensive than to foresee regular maintenance.

In general most of the cost of maintaining the application will be in the maintenance cost of the data. This needs careful planning from the start. The important rule is simple: store only data that are actually used by your application. Data that are not used tend to deteriorate quickly and if used later, will not have the quality required and a completely new collection will likely be needed.

Maintenance of data is costly because:

- It is hard to schedule and triggered by outside events;
- Maintenance tends to discover errors in the existing data that will need to be fixed;
- It often requires inspection in the field.

- It is therefore difficult to automate and requires highly skilled personnel. It is sometimes less expensive to recapture the complete dataset in a planned and well-organised process, where economies of scale reduce the price per element considerably.

Small test projects

Before starting the production process, small test projects should be carried out. Each GIS project differs from the other. Thus, a prognosis of the workload and the data amount is not easy. Small test projects in a new and specific field of application put these estimations on a more solid background. Similar projects may be used to predict these numbers.

Preparing small test projects allows analysis of the time and data amount needed for processing. During the capture and processing of data, times are measured together with the number of objects and the total amount of disk storage. Data amount and costs estimations for larger projects can be extrapolated. This makes the feasibility decision to go ahead with the project much more reliable (see also paragraph 3.2.2).

3.5 The Economics of Geographical Information

The objective of this section is to examine the economic aspects of the implementation and use of Geographical Information Systems so that one can identify the potential costs and benefits of introducing a GIS into an organisation.

Economic considerations are extremely important in convincing people of the importance of a GIS project. Technical problems are very interesting to solve and organisational issues pose important challenges, but projects are executed because they improve the way an organisation works. Economic analysis is the major method to assess the utility of a project, GIS or any other.

GIS projects, like other projects, should not be executed when they do not contribute to the overall benefit of an organisation. The difficulty lies in the assessment of the full contribution of a GIS to an organisation. It was typically found that other and additional benefits of GIS projects than those included in the original project plan were more important than what was included in the original cost-benefit analysis. The approach described here is designed to reduce this difference and to make cost-benefit analysis for GIS more reliable.

3.5.1 The Economic View of GIS

The implementation of a Geographical Information System requires investment in hardware, software and data. It also requires investment in people. In the short term, the most expensive element is the collection and conversion of the data, a process that can account for around 60% to 80% of the total initial costs of setting up a system. As a simple rule, the costs of hardware and software must be multiplied by a factor of 4 to 10 to obtain the approximate costs of installing a Geographical Information System and populate it with useful data. Costs of training and the continuing professional development of staff are also important and are counted higher than the cost of hard- and software.

Having set up a system, it will be necessary to maintain it, which requires resources. The actual cost of implementing a GIS for the first time is not a one-time payment but rather a long-term commitment to expenditure.

The GIS system also produces benefits that are the effects of the improved information available. The data collected must be valuable for the users, not just costly to accumulate. A product from any system, including the information product from a GIS, is valuable only as far as it is used and creates valuable goods during its use.

The information available from the GIS is often used internally to improve the functioning of the organisation that has set it up. But in other cases, the information can be sold or distributed to others. In any case, the information is used and the additional information provided leads to an improvement: a decision is made more quickly, is less risky or leads to an improved result.

A business case makes an argument that a specific project (e.g. a GIS) is a sound investment of resources and will positively contribute to the business objectives, i.e. to add a net benefit to the balance sheet of the organisation. A business case lists all the resources a project requires and expresses them in monetary terms. These are compared to the expected value of the benefits. Technically it is necessary to make the 'one time' cost of setting up the GIS, and the recurring cost of running the system comparable with benefits, which may be reaped only later.

3.5.2 The Market for GIS Data

Cost-benefit analysis will in part be based on the price that can be obtained for Geographical Information. The price of a good is based on its market value. The market for Geographical Information is usually very different from the ideal market around which economic theory is developed.

Price is one of the key elements of marketing, but not the only one. A complete market strategy considers the users, their needs and their willingness and ability to pay, the channels used to distribute information about the product and distribution channels for the product. Nevertheless, we can use a discussion of price in a cost-benefit analysis; even if a GIS produces information that is only used within the organisation.

The general theory of economics was developed around 'real' goods e.g. the produce from agriculture: potatoes as a prime example. The equilibrium price results from the balance of supply and demand. But maps or cadastral information cannot be produced by many agencies in parallel, competing for the users on a market – this would be an enormous waste in data collection! Also, maps are very different from potatoes. They can be easily copied and used many times.

Information markets are substantially different from other goods (Varian 1996):

- information can be replicated nearly without cost, therefore
- multiple users can use the same information (but only one person can eat a potato)
- producing the information has a high cost curve initially, but reproducing has a low cost curve
- a buyer can use the information but also resell it (even multiple times).

3.5.3 Determining the Price

Determining the optimum price that can be charged for Geographical Information is difficult where there is no already established market. As we have seen in the previous paragraph, information as a commodity does not behave in the same way as physical products.

The price of Geographical Information can be established in several different ways. Consider for example a digital map sheet. The price can be set on the basis of the costs incurred during its production, to which a margin for profit would be added. This would then be divided by the estimated number of maps expected to be sold to give a market price. That might suggest, say, a price of € 200. However, the technology exists to put 3000 such map sheets on one CD-ROM at marginal additional cost. Yet obviously, such a CD would be unlikely to sell if the price were € 600,000. So a different approach to price setting is needed.

An alternative way to establish the price could be to find out what the market will bear. If the price is too high, the products will not sell and if they sell very rapidly then it might be possible to increase the price.

A third strategy would be to find out what savings could be made through the use of the product in comparison to current practice. Thus, if the possession of a paper map saves a motorist € 20 per year in fuel through more efficient selection of travel routes, and if the map is likely to last a year before becoming worn out, then it would be worth € 19 to the motorist, but not € 21 unless other factors came into play.

The necessary aspects to assess the contribution of GI to the users' process are identified from the design documents established from the description of User Centred Design (paragraph 3.1). We have described the decision process (and the value it creates) together with the contributions the GI makes to this process. From this the contributed value of the GI can be estimated. This is the value of the GI for this decision. It is multiplied by the number of such decisions made per year, and initially reduced for uncertainties in the estimates.

Too often prices are set in relation to the cost, especially in engineering. This works in cases where there is an established market in equilibrium. Economic theory predicts, that for perfect markets, cost equals the price equals the value of the good. This is not the case for spatial information. The production cost is high for the first map printed – all the data collection is necessary to produce only one map – but all the additional copies are produced at low cost.

Setting a price to recover cost requires at least an estimate of how many copies will be sold, which is difficult with new products like GIS. The additional uses that will be found for the data later, make estimation of the correct price difficult.

3.5.4 Market Differentiation

To sell GI on a market, and this will become more important as companies concentrate on their 'core competence' and contract out other services, another tool for product marketing becomes important: to produce differentiated products, which serve different markets.

If different user classes use the same data with very different economic characteristics then charging all the same price is not the best strategy. Assume you sell a street network that can be used for navigation and shortest path determination. Savings for ordinary car users are € 20 per year (in fuel, not considering time savings). Professionals save with the same device € 1000 per year, because they value their time. Companies that distribute large quantities may save € 1,000,000 per year. What is the correct price? Selling at € 20 you sell to, say, 10,000 users (total gross € 200,000), selling at € 500,000 you may sell to only 4 users, grossing a total of € 2,000,000.

The solution is market differentiation. Create three different products, which serve each of these groups particularly and sell them at three different prices. The difficult trick is to assure that the company does buy your € 500,000 product and does not just use the 'professional' edition for € 300 or the standard edition for € 20. As a successful example, consider the airline pricing: staying over Saturday night reduces airfares considerably, but the business traveller, who has more money, would lose a 'day with her/his family', thus cannot use the cheaper fare.

3.6 Electronic Commerce in GIS

3.6.1 Introduction

The Internet is likely to become the Geo Information Shop of the future and will provide access to Geographical Information and services. The technology is becoming available, and the data providers and service providers are taking serious steps to deliver Geographical Information services to a large Internet audience. e-Commerce is a key component in this service and demands expertise that is normally not available to the geographical data providers; a partnership with a professional e-Commerce organisation may therefore be advisable.

Internet Geographical Information Services (I-GIS) will allow suppliers to sell all their products, information, and services over the Internet. The client does not require specific hardware or software; a simple PC with a standard web browser will do the job. The Geo Information application will run on the Server of the supplier. This is a so-called Multi-Tier environment.

These I-GIS offerings can be provided at several levels of sophistication, such as:

- Access to and viewing of static maps, followed by copying or printing.
- Dynamic access to and search for different maps that can be composed into an integrated map, followed by copying and printing.
- Dynamic access to and search for different maps and text data that can be composed into project information. This information can be analysed and reported with thematic maps and reports, which can be downloaded and printed.

The more sophisticated a system is, the more complex it becomes. But the complexity is with the supplier; the user should always have a simple "User Guidance."

3.6.2 User Guidance

However sophisticated the services are, they must be easy to use, and the User Guidance is the key. The user guidance, operation and navigation of the Internet Service, can, for instance, be implemented with a web tree. This type of operation is familiar to every computer user. So, any user can operate the service, and no training is required. This is an essential prerequisite for solutions to be built on the Internet. The strength of the Web Tree is that it is fully configurable to the requirements of the services offered.

As an alternative to the Web tree, the user can search based on product properties, like map number, city name, province, etc. The User Guidance is then a Web page on which the user defines what information he needs through a selection of properties. Another option is a search through a geographical User Guidance by pointing to an area on the map.

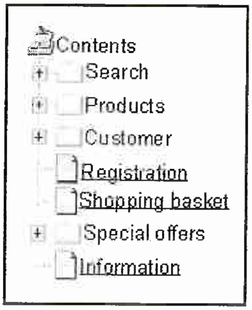

Figure 20: Example of a web tree.

3.6.3 Registration, Authentication and Authorisation

Prior to becoming operational, administrative and security issues need to be addressed. After accurate registration and checking of the client, all his details are stored, including access rights. Registered clients can be authenticated by a log-on dialog. This grants him access to all the areas of the I-GIS to which he is entitled. Non-registered users are only granted access to those parts that will give them an idea and explanation of the services offered and an invitation to register (Wenzl 2000).

3.6.4 Pricing and the Shopping Basket

After the information search and the selection of products, the client is informed of the price before he orders and puts the product in the shopping basket. Pricing can be done using the required pricing parameters like area size, processing time, number of reports and maps, etc.

Payment can be set up in different ways. Options are invoice, credit card, or bank credit. e-Commerce can be the preferred method, but in many cases an invoice is still required.

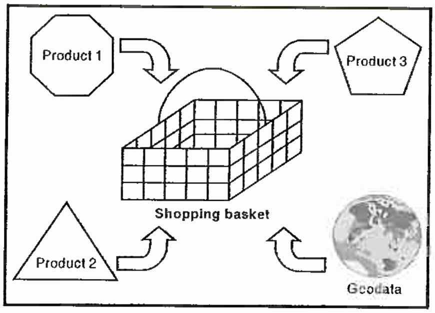

Figure 21: The Shopping Basket.

3.6.5 Conclusion

The Internet and electronic commerce are becoming major contributors to the more widespread and better use of Geographical Information. It will be the channel to offer and distribute the information to the clients. Suppliers of large amounts of geographical data should investigate the Internet Geographical Information Services. However, today very little information (geographical and otherwise) is actually *sold* over the Internet. It is likely that services provided today are too general. More specific services, adapted to specific decision processes, must be built. Maps or aerial photographs are available on the net today. But the business is slow. More likely, a demand would exist for applications, for instance to help farmers with support applications where their field boundaries –and therefore GI and aerial photography – would pay an important role.

3.7 Misperceptions and Pitfalls

Around any new technology a number of experiences tend to get generalised into widely accepted folk beliefs, myths or legends. They continue to be believed, even long after their empirical base has been superseded by further technological development (and some were perhaps never true). As an illustration, we mention some myths, legends, and pitfalls in the next sections.

3.7.1 Myths and Legends

"GIS will lead to better decisions"

Consider it in detail:

- "GIS will lead to better information for the decision maker"
  Which is only true if the decision maker uses the information products from the GIS; it is therefore important to provide the required information and only the required information.
- "Better information will lead to better decisions"
  This belief comes from the foundations of out rational culture, but it is very difficult to substantiate in general.

"All GIS products are the same"

It might be true that commercial products often have comparable functionality (and price), but there are very different products on the market. They originated in different GIS application areas and are optimised for different purposes. Therefore they use different representations, have different links to other products, etc.

"Small prototypes can be scaled up into full-scale solutions"

Using today's powerful tools it can construct prototypes quickly with "pretty" interfaces. This not only gives managers a false sense that the problem has been solved; it also misleads decision-makers and experts. The heart of the problem is whether the problem-solving method used in the prototype - which solves only a small portion of the problem - will scale up to solve the entire problem (Ionita 1999, p.165).

"Applications based on GIS are easy to build"

The ease of building an application depends on the amount of work required to map the problem into software, which can vary from easy to difficult.

"Managing GIS differs from conventional project management"

Due in part to academic ignorance of requirements for building production-level systems, an incorrect belief prevails that managing GIS should differ from managing conventional systems engineering. Rapid prototyping is an important means for acquiring problem requirements and specifications and for eliciting and verifying knowledge maps. The success of rapid prototyping indicates that the waterfall model of software development is inappropriate for many GIS projects. Instead, the spiral model of progressive development is the most suitable means for managing the construction of conventional and GI-based systems alike (Ionita 1999, p.166).

3.7.2 Common Pitfalls

Observation of GIS projects, especially the ones that failed, shows a number of common errors. Observing these potential pitfalls is a major step towards successful GIS implementation (Ionita 1999, p.77-78).

Failure to identify and involve all users

Users in an operational GIS environment consist of operations, management, and policy levels of the organisation. All three levels should be considered when identifying the needs of your users (see section 3.1).

Failure to match GIS capability and needs

A wide spectrum of GIS hardware and software choices currently exists. The right choice will be the GIS that provides the needed performance for the minimum investment.

Failure to identify total costs to make the system operational

The GIS acquisition cost is relatively easy to identify. However, it will represent a very small fraction of the total cost of implementing a GIS. Ongoing costs are substantial and include hardware and software maintenance, staffing, system administration, initial data loading, data updating, custom programming, and consulting fees. It is important to conduct a thorough economic assessment, as described in paragraph 3.2.1. Many projects failed because the initial budget provided only for hard- and software acquisition.

Failure to conduct a pilot study

The GIS implementation plan concerns itself with the many technical and administrative issues and their related cost impacts. Three of the most crucial issues are database design, data loading and maintenance, and day-to-day operations. The pilot study will allow you to gather detailed observations, provided it is properly designed, to allow you to effectively estimate the operational requirements. Especially the assessment of data quality issues is very difficult without a pilot study. GIS projects often fail by underestimation of difficulties; pilot studies help to become realistic.

Failure to consider technology transfer

Training and support for on-going learning, for in-house staff as well as new personnel, is essential for a successful implementation. Staff at all levels should be educated with respect to the role of the GIS in the organisation. Education and knowledge of the GIS can only be obtained through on-going learning exercises. Nothing can replace the investment of hands on time with a GIS, but up to a point experience can be 'bought' by using outside consultants wisely.

Failure to manage expectations

Trying to achieve too much with too little. GIS projects tend to involve many parts of the organisation and during the requirements analysis many possible applications surface. A GIS project may fail because too many expectations were raised, which cannot all be fulfilled with the available resources. So build a clear phased implementation plan, in which everybody can see when 'his' part will be done.

Failure to manage complexity

A GIS project may fail from sheer complexity: too many different demands cannot be reconciled, even when the resources are available. The complexity increases exponentially with the number of applications. Realise a first step and add later – even under the risk that some changes may be required. Do not attempt to get it right the first time.

Suggestions for further reading

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4. GEOGRAPHICAL INFORMATION INFRASTRUCTURES

Aims & objectives	• Describe the current development of modern Geographical Information Infrastructures (GII) at the local, national, multi-country and global levels. • Explain the vision and benefits of National Spatial Data Infrastructures (NSDI) and how to get there.
Learning outcomes	• What a GII is. • Why GII are important and why effort should be put into developing them. • A short history on the development of GII. • Legal issues for GII. • Examples of GII at the local, regional, national and global level.

The availability of Geographical Information is widely recognised as an important production factor in today's Information Society. The advent of IT imposes an adaptation of the way Geographical Information is collected and distributed – from paper-based data to electronic access using the web. The corresponding change in organisation is substantial and it is summarised as "Geographical Information Infrastructure" – Geographical Information of various types must be widely available in an economy and counts as infrastructure the same way as the physical infrastructure of water, telephone and electricity providers and the services like regulated markets, health providers and education in every country.

This chapter should point to the general goals for GII and show the processes necessary to reach them. It starts with a brief analysis of the situation in many countries. It describes briefly the effort in the USA, the Netherlands, Finland, Hungary and some other Central and Eastern European Countries (the important effort of the Portuguese government is described in detail in chapter 5) and then describes some initiatives to develop GII at the local and international level. It concludes with a brief analysis of the main GII issues.

4.1 The birth of Geographical Information Infrastructures

The development of Geographical Information Infrastructures (GII) has started in Europe in the mid 80´s, due to the emergence in the market of GIS as ready to use computer software packages. Until then these were very sophisticated tools and their users were basically the official planning and management agencies, together with consulting companies that worked for these same agencies (engineering firms, landscape architecture firms, agriculture firms, forestry firms, etc).

The efficient exploration of GIS would require a new type of access to geo-data, and the idea of an infrastructure, an electronic network from which the desired data could be extracted, came naturally. The implementation of a national GII meant a significant effort, consisting of conversions of existing datasets, metadata implementation, development of interfaces to make efficient access possible, and the creation of a computer network that would connect GI producers and users.

The major benefits of implementing GII are the stimulation of economic development, the promotion of better government and the fostering of environmental sustainability. Other results of implementing GII are an easier data access and an increased use of GI during decision-making processes. Moreover, the implementation of GII fosters the co-ordination of activities within the GI production process, allowing cost savings and reducing redundancy, while modernising public administration and promoting the use of GI in political, economic, social and personal development.

From the end of the 80´s until the mid 90´s, the GII have evolved according to the availability of geo-spatial data and the data access policies existing in different countries. For example in the United States the Bureau of Census initiative to create the TIGER files (street addresses that can be linked to census track data), has led to an "explosion" of new markets. Professionals from fields different from the ones mentioned above, such as banks or insurance companies started to use this new digital GI. These new users were numbered by the thousands, as opposed to the dozens previously referred to using GI. The situation in Europe however, is very different, due to restricted data access policies.

Since the mid 90's, the GI industry started to offer software tools that could be remotely accessed, without the need for the user to have his own GIS. This is the door that has opened the possibility for citizens to explore GI, and National GII were challenged with the need to supply GI useful for citizens, that could now enter in the world of GI exploration, a world that before had been open only to professionals.

4.2 GII definitions

Several parallel attempts to provide a Geographical Information Infrastructure (GII) definition have been made. Quoting one of the first versions of the GI2000 document "a draft Communication of the European Commission to the Council of Ministers and to the European Parliament" from 1996:

"What is required is a policy framework to set up and maintain a stable, European-wide set of agreed rules, standards, procedures, guidelines and incentives for creating, collecting, updating, exchanging, accessing and using Geographical Information. This policy framework must create a favourable business environment for a competitive, plentiful, rich and differentiated supply of European Geographical Information that is easily identifiable and easily accessible".

At the 4th EC-GIS Workshop (Budapest 1998), Robin Waters suggested the following vision statement for the EGII (European Geographical Information Infrastructures): "GI Infrastructure for Europe should enable public and private sector users to access appropriate levels of up to date topographic and thematic spatial information in an interoperable environment at a reasonable cost within a single, easily understood legal framework covering copyright and confidentiality. The data collected from synoptic systems (remote sensing) may be centralised but the data collected in individual countries should be co-ordinated under the subsidiarity principle". This statement received general approval from the workshop participants and was considered suitable for submission for discussion in other arenas, such as the ongoing review of the DG III strategy document (Peckham 1999).

Another definition that intends to identify the GII building blocks is given by (Masser 1999). The main intentions are to ease access to and develop the market for GI.

The experience of the 1990s in countries that started the definition and implementation processes of national GII (or SDI - Spatial Data Infrastructure) shows that a political intention to create such infrastructure is necessary in addition to governmental resources and incentives.

There is a consensual agreement within the GI community that the main elements of a GII are:

- the legislation, rules and procedures needed to regulate the production, maintenance, exchange and access to Geographical Information;
- the development of metadata (information about data) services or clearinghouses for data exchange;
- the data including a referential on which value-adding content and services can be built and
- the people.

Much of the ongoing debate at the end of the last century related to GII was on the prioritisation of the different activities. Should resources be wholly concentrated on developing access to the existing content or should some of the available resources be spent on modernising the content?

4.3 Legal issues to be addressed in a National Geographical Information Infrastructure

The legal framework is one important aspect of an environment in which a Geographical Information Infrastructure can be established. It defines the rules, which guide the behaviour of the actors. These rules either facilitate the construction of a technical architecture or make it very difficult to find efficient solutions that satisfy the legal conditions. There is a strong connection between legal rules and technical architecture. The legal system is either dragged along behind technical and commercial developments or the rules restrict advances (Lessig 1999). A slow development to construct rules for commerce in the electronic age is underway in most countries.

The legal issues that must be addressed for a national geographic infrastructure are

- protection of intellectual property rights,
- protection of privacy, and
- free access to government documents.

The application of the established principles to the new electronic environment changes the game substantially and requires a rethinking of the goal of these rules and how these goals are best achieved today.

4.3.1 Protection of Intellectual Property Rights

Transferring data from a provider to a user does not imply that the user should be free to copy the data and distribute it further. The provider may want to retain control of his data and be able to sell it to other users. It is necessary to protect the Property Rights of the producer and owner of the data, even when physical ownership is not possible. Intellectual Property Rights are protected to make it attractive for people to invest in the collection of data, the elaboration of ideas etc. They define what can be the object of the commerce in data and information. The primary rules are:

- Copyright: the protection of an expression against copying. The owner of the copyright can act against anybody who makes unauthorised copies of the protected work (and is not covered by 'fair use' exceptions such as educational use).
- Contractual rules and Trade Secrets: Data can be kept secret and access provided only to persons or organisations having promised to keep the data secret. The owner of the data can act only against the partners with whom he has a contract.
- Unfair competition laws: Many countries have rules against the abuse of investments of one competitor by others acting in the same market.

4.3.2 Protection of Privacy

The freedom of the citizen protected in most democratic societies also includes a protection of the knowledge about the person. People have a right to privacy, i.e. to keep some facts about themselves and their lives secret; companies are hindered in collecting and integrating all of what is potentially known about a person and using it to construct a complete profile; administration is restricted to collecting and maintaining only the data that they directly need for their work. Exchange of data between organisations is often limited and strict regulatory agencies see to it that rules are observed. Most knowledge about people can be transformed into knowledge about locations and many jurisdictions consider data with address as 'personal' as data with names and therefore extend privacy protection to geographic data. A new question is the protection of the current location of a person: the mobile phone companies track, for technical reasons, the location of all mobile phones and therefore know where their clients most likely are and could construct profiles of locations visited, etc. It is assumed that such data must be protected as well.

4.3.3 Free Access to Government Data

Citizens can control their governments only if they have knowledge about its actions. Democratic societies therefore have legal provisions that allow citizens to acquire data about government activities, thus permitting effective control of government and administration. These rules typically give free access, or access against payment of copying costs. They conflict with the administrations' interest in selling data commercially.

EUROGI has developed studies that inventory the legal framework and correspondent bottlenecks in different European Countries (EUROGI 1996; EUROGI 1997) and are a good starting point for understanding what is at stake. At the European level many of these issues need further harmonisation since the member states have their own interpretation of issues involved.

4.4 National Geographical Information Infrastructures

In preparation for the 1998 Global Spatial Data Infrastructure (GSDI) conference, Prof. Harlan Onsrud (University of Maine, USA) surveyed existing and emerging National SDI (NSDI) initiatives (http://www.spatial.maine.edu/~onsrud/GSDI.htm) and Prof. Ian Masser wrote a paper on "The first generation of National Geographical Information Strategies".

The two studies demonstrated that in the beginning of the 90's a number of national GII initiatives started. Nearly all countries responding to Onsrud's survey indicated that they were preparing some initiative to achieve a NGII. They were generally under a single agency leadership although it implied the co-ordination of several agencies. The data reflect the availability of geographical data in digital format. Therefore GII initiatives included most often topographic or land ownership data. Metadata collections and the establishment of a data clearinghouse were usually planned. Often public agencies intended to co-operate with private businesses.

The following table (Table 3 by courtesy of Prof. Masser) indicates the starting dates of different initiatives and provides indication of the size, population and GNP of the countries; it shows that very different countries under different circumstances have started formal NGII initiatives and that a great variety of approaches have been tried (Masser 1999).

Country	Initiative	Start Date	Area '000 sq. km	Population (Millions)	GNP '000$ per capita 1990
Australia	ALIC/ASDI	1986	7686	18.1	14.5
USA	FGDC/NSDI	1990	9809	259.7	18.1
Qatar	NCGIS/NGIS	1990	11	0.5	16.6
Portugal	CNIG/SNIG	1990	92	9.9	7.5
Netherlands	Ravi/NGII	1992	40	15.4	13.0
Indonesia	Bakosutanal/NGIS	1993	1904	189.9	2.0
Malaysia	NaLIS study	1994	329	20.1	5.1
Korea	NGIS	1995	98	44.6	6.7
Japan	NSDI	1995	377	124.8	14.3
Canada	IACG/CCDI	1996	9970	29.6	17.1
UK	NGDF	1996	244	58.4	13.2

Table 3: Sources: Whitakers Almanac 1997 and National Bureau for Economic Research

The main findings of Prof. Masser's study were as follows:

Not all initiatives are formalised under the NGII flag. In some countries, such as France, GI co-ordinators prefer to work on a more political and organisational dimension (see "Le livre blanc" of AFIGEO at http://www.cnig.fr) with parallel activities on the technical elements: standards, metadata services, core data, etc. The movement towards GII in Western Europe is strong. The majority of Central European countries are defining their strategies. For example, Hungary, Poland and the Czech Republic are already in the process of designing and implementing parts of their infrastructures, sometimes with the help of international organisations (e.g. The World Bank).

In several countries, significant initiatives are undertaken at the regional level, which supplement existing national efforts. For example, in France the CRIGE (Comité regional de l'information géographique Provence Alpes Cote d'Azur) website (http://www.cerege.fr/) or the Urban Community of Lyon.

To better illustrate different implementations of NGII the American, Dutch, Finish and Hungarian examples are briefly described (for a detailed description of a NGII implementation process please refer to chapter 5, where the Portuguese NGII is described). These four initiatives together with the Portuguese are already implemented although they have followed different approaches. The experience of other countries such as Bulgaria, Czech Republic, Poland, Romania and Slovak Republic are also briefly presented since they include important components to implement a fully operational NGII (for complete description of these experiences please refer to the PANEL-GI Extended Package).

4.4.1 The US Example: The National Spatial Data Infrastructure (NSDI) http://www.fgdc.gov/

The concept

The USA was one of the first countries that started, at the beginning of the 1990s, the formalisation of a NGII. In 1994, considering that the major challenge over the next decade was to increase the use of spatially referenced data to support a wide variety of decisions at all levels of society, the Mapping Science Committee (MSC) conceptualised a National Spatial Data Infrastructure (NSDI). The proposed concept, illustrated in Figure 21, was: "the total ensemble of Geographical Information at our disposal that describes the arrangement and attributes of features and phenomena on the Earth, as well as the materials, technology and people necessary to acquire, process, store and distribute such information to meet a variety of needs".

In its broadest sense, the infrastructure also includes the cultural, environmental, economic, political, legal, and educational values and institutions that support, facilitate, and shape its character, including the form in which spatial data are represented and utilised through society.

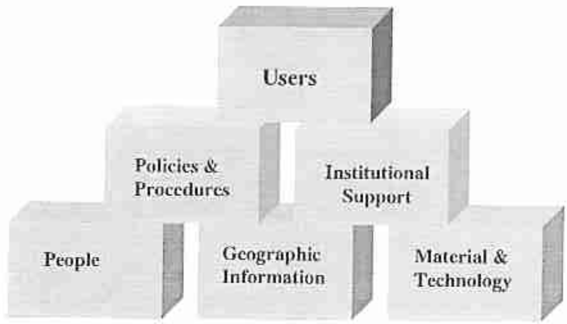

Figure 21: NSDI building blocks.

Goals and objectives of the NSDI strategy

The NSDI strategy is not limited to the Federal level: "If the NSDI is to be truly successful for the nation, it must be embraced by state and local government and the populace as a whole". (quoted from Wally Bowen of the Mountain Area Information Network), and its goals and objectives should be considered an invitation for every citizen who deals with geographical data to become part of the NSDI.

The NSDI goals and objectives are:

Goal	Objectives
1. Increase the awareness and understanding of the vision, concepts, and benefits of the NSDI through outreach and education.	Demonstrate the benefits to existing and prospective participants. Promote principles and practices through formal and informal training. Identify and promote the attitudes and actions helping development.
2. Develop common solutions for discovery, access, and use of GI in response to the needs of diverse communities.	A seamless National Geospatial Data Clearinghouse. Tools for easy exchange of applications, information, and results. Interoperable architectures and technologies that enable data sharing.
3. Use community-based approaches to develop and maintain collections of geospatial data for sound decision-making.	Continue to develop the National Geospatial Data Framework. Provide users with needed additional geospatial data. Promote classification systems, content standards, data and other common models to facilitate data development, sharing, and use. Provide mechanisms & incentives to incorporate multi-source data.
4. Build relationships among organisations to support the continuing development of the NSDI.	Develop a process that allows stakeholder groups to define logical and complementary roles in support of the NSDI. Build a network of organisations linked through commitment to common interests within the context of the NSDI. Remove regulatory & administrative barriers to form agreement. Find new resources for data production, integration, & maintenance. Identify and support the personal and institutional behaviors; legal frameworks, policies & technologies promoting NSDI development. Participate to develop a Global Spatial Data Infrastructure.

Table 4: NSDI goals and objectives.

Key elements for success

By 1999, the US NSDI initiative had reached an interesting stage of development in the standards and clearinghouse (metadata) activities but had less success in the framework data (GI content) and in liaison activities between Federal, State and local levels. A number of elements are recognised which facilitated the transformation from an idea to an implementation successful story:

Leadership: In 1994 President Clinton signed Executive Order 12906 entitled "Coordinating Geographical Data Acquisition and Access: The National Spatial Data Infrastructure".

A committee in charge: An inter-agency Federal Geographical Data Committee (FGDC) was set up in 1990 to coordinate "the development, use, sharing and dissemination of surveying, mapping and related spatial data". The FGDC is based in the National Mapping Division of the US Geological Survey and is chaired by the Secretary of Interior. In 1999 there were 16 staff members.

Cooperation and partnerships for spatial data activities among the Federal government, State and local governments and the private sector were seen as essential for the development of a robust NSDI.

A spatial data-sharing program was planned to be established to enrich national spatial data coverage, minimise redundant data collection at all levels, and create new opportunities for the use of spatial data.

Substantial governmental budgets were used to both manage the process and offer incentives to all interested parties. Money was given to regional consortia through three funding programs: the Cooperative Agreements Program, the Framework Demonstration Projects Program and the NSDI Benefits Program (for more information please refer to http://www.fgdc.gov/funding/urbanlogic_exsum.pdf).

4.4.2 The Dutch Example
http://www.ravi.nl

The concept

The Dutch GII has been defined as "a collection of policy data sets, agreements, standards, technology (hardware, software and electronic communication) and knowledge providing a user with the Geographical Information needed to carry out a task" (Ravi 1995). The creation of such infrastructure has been realised as a way to create new economic opportunities, since it will allow to improve existing services and products, as well as to create new ones that can be exportable. Moreover, the Dutch concept of NGII puts more emphasis on the process of creating the infrastructure as a way to serve the objectives of the interested parties than on the creation of products. The strong involvement that has been demonstrated by the main GI actors within the creation and development of the Dutch NSDI confirms this philosophy.

The development of the NGII is the responsibility of the Minister of Housing, Spatial Planning and the Environment (VROM) with the assistance of the Netherlands Council for Geographical Information (Ravi) - an independent non-profit organisation, whose main role is to support the Dutch government in matters of Geographical Information. Ravi was founded in 1984 as an advisory board of the Dutch Government and in 1993 was converted into a consultative body that comprises all public services and local authorities with an important role in the provision of real estate and GI.

Three key elements ensure a high political commitment to Ravi activities:

- The VROM minister is the Ravi political coordinator. This institutional arrangement promotes a strong relation between Ravi and the government. Moreover it is possible for Ravi to easily offer asked or unasked advice to the minister.
- Each of the participating authorities has a representative in the Ravi board of directors, which promotes the commitment of each institution within the NGII activities.
- Ravi is also a GI Business Platform on which representatives of private businesses have seats. This promotes cooperation between the public and private sector.

Moreover, the NGII is part of a government strategy for the information society, which is outlined in the BIOS Memorandum and the National Action Program for the implementation of the Electronic Highway (Ravi 1995).

Key elements for success

The Dutch NGII initiative counts on the active involvement of the main GI actors together with a high level of political commitment to its development. These two factors have been key elements to the success of the Dutch NGII development. Moreover, the Dutch NGII is an important element of national information society strategies and Ravi tries to contribute to the realization of the government policy.

The deep involvement of GI actors has allowed Ravi to promote a bottom up policy. For example, the metadata clearinghouse has been developed based on existing metadata services within different GI producers. The Dutch clearinghouse (http://www.geoplaza.nl/) is well developed and is maintained by a private company under the coordination of Ravi. Another strategy followed by Ravi to promote a bottom up approach is to create pilot projects to demonstrate potential benefits to organizations and promote its cooperation.

Additionally, Ravi promotes several projects that intend to promote awareness of the main issues within the GI sector as well as to promote communication among the GI actors. Examples of such projects are the creation of a standardization plan or the organization of workshops on GI accessibility.

Another key element for the success of the Dutch initiative has been the strong relationship that Ravi has promoted with universities and research centres. This relationship promotes awareness of the GI issues and allows creating innovative services and products.

4.4.3 The Finnish Example
http://www.nls.fi/index_e.html

The concept

The Finnish GII has its origin in the need to share GI within the public administration. In 1985, the Finnish Ministry of Agriculture started a Land Information System project that required shared use of GI among different sectors of the Finnish public administration. One of the objectives of the project was to find ways to facilitate data access and avoid duplication of data collection efforts. Therefore, two of the earliest outcomes of such project were: 1) a metadata directory to describe the existing data, and 2) a draft standard for geometric representation, positioning, positional accuracy and the use of EDIFACT (ISO 9735) data interchange protocol (Madame 1999).

As a follow-up of this project, a Consultative Committee for shared use of GI was launched under the umbrella of the Ministry of Agriculture. In 1995, this Committee has developed a strategic document: "The National Geographical Information Infrastructure of Finland: Starting Point and Future Objectives for the Information Society" (http://www.nls.fi/ptk/infrastructure/index.html). One of the main characteristics of the Finish SDI is that participation is always voluntary. Therefore, GI actors' involvement within the NSDI is based on their motivation.

Additionally, the National Land Survey of Finland (NLS) was made responsible by law to promote shared use of GI through Finland. Therefore, since 1988, NLS is responsible for developing and maintaining the metadata directory, aside from being in charge of producing the topographic and cadastre data, which is NLS's main mission.

As a result of its responsibility to promote shared use of data, NLS has invested greatly in the development of data access services through electronic communication networks. In 1999, three services were available online (Makinen 1999):

- Citizens MapSite - a free service for Finnish citizens. It provides access to seamless topographic maps for the whole country. The search can be done by address, place names or co-ordinates.
- Professional Mapsite - It provides the same service as the Citizen MapSite and in addition gives access to more detailed maps. Access to the more detailed maps is subject to charge. The charging scheme is based on charging a small amount (approximately USD 0.20) per image loaded.
- MapSite Ordering service - uses the citizen map site service to enable users to define the data and correspondent attributes that they wish to order.

Key elements for success

The Finish NGII is based on a long tradition of centralised data management common to other Nordic countries (Craglia and Evmorfopoulou 1999). Therefore, Finland has a wealth of detailed data that link socio-economic data to land registry data via their coordinates. This has allowed the NLS to provide data access services for different users based on their needs. Examples of such services are the Citizen Mapsite and the Professional Mapsite. The creation of services that intend to provide access to GI by citizen demonstrates the well-advanced stage of development of the Finnish GII.

Moreover, the Finnish NGII has a well-developed metadata directory, that allows for data discovery and search. The metadata catalogue is maintained by NLS, and it follows a centralised approach that allows for consistency checking.

The role of NLS as spatial data producer and its responsibility for the metadata directory have contributed significantly for the NGII development. However, three main aspects are slowing down the NGII development: 1) NLS' main mission is not to promote the development of GII, 2) it does not have the legal mandate to develop the NGII and 3) NLS does not have required funding to develop the NGII.

Another key element for the success of the Finnish GII are the well developed and wide spread sophisticated telecommunications infrastructure and remote access services, which have promoted the development of the NGII. Moreover, the Finnish information society strategy recognises GI as critical to the development of the society and has explicit links to the NGII strategy.

4.4.4 The Hungarian Example
http://www.fomi.hu/hunagi

The concept

The Hungarian NGII, although still in an early stage of development, intends to provide public information services with high quality data on spatial location, to support the development of the information society. The basic elements of the NGII have been approved in 1997 at the Inter-governmental Committee on Informatics level under the auspices of the Prime Minister's office. This Committee is also responsible for the formulation of a National Spatial Data Policy, which includes the development of the NGII as one important component. Demonstrating a high political commitment, in 1997 a Working group on Geographical Information was established also under the auspices of the Prime Minister's office. This Working Group has representatives from the interested ministries and several governmental agencies. The following subcommittees have been created to deal with the issues related to:

- National Strategy on GI
- Cadastral Programme
- Topographic Programme
- Aerial Survey Programme
- Harmonisation and geo-referencing of addresses
- Establishment of a Parcel-based Multipurpose Information System
- Establishment of the Administrative Boundaries Database
- Data dissemination: metadata service and clearinghouse concept

The implementation of these programmes is following different schedules according to the priorities established within each programme. For example, the project of setting up a Data Clearinghouse is still in the definition phase although, the inventory and documentation of existing data sets are in progress taking into account the different standards initiatives and the OGC recommendations. Additionally, two metadata servers have already been set up, METATÉR Server at the Geological Institute of Hungary, and FISH (http://fish.fomi.hu) with a server at the Institute of Geodesy, Cartography and Remote Sensing (FÖMI).

The key elements for establishing a NGII, such as technology, co-ordination and institutional framework, legislative and technical regulations, education and financial support are underway in Hungary, showing an interesting experience on building a NGII within a broader national policy for Geographical Information.

Key elements of success

The Hungarian experience counts on a high level of political commitment that has created a close interagency cooperation. The working group for Geographical Information has representatives from the major stakeholders within the GI sector, which include public administration GI producers but also representatives from the research and development community and from the GI users community (the working group is chaired by the president of HUNAGI - the umbrella organisation for GI). Besides having a strong political commitment this working group also benefits from a legislative framework that supports the establishment of the NGII. Moreover, European Phare, Tempus and research and development funding are also supporting the development of the NGII.

Additionally, there has been a strong emphasis on raising awareness of GI issues. Several conferences, symposia and workshops have been promoted since the early 90's, to collect and discuss the users' needs. The implementation of all high priority nation-wide programmes is based on an in-depth analysis of user requirements and feasibility studies.

4.4.5 Other Experiences

Although many Central and Eastern European Countries have not yet established a network that connects GI producers to GI users facilitating data access, they present very interesting experiences that are important for the implementation of NGII.

4.4.5.1 Bulgaria

In Bulgaria the use of GIS and GI in digital format has increased in the last decade, pushed by the development of the market economy and also by the research community. This increase in demand has led to several data collection and processing projects as well as the establishment of a legal framework for data access and pricing. Currently, the Ministry of Regional Development and Public Works regulates spatial data collection and a working group has been established at the national level to develop a uniform national model for Geographical Information.

4.4.5.2 Czech Republic

The Czech State Information Policy, a strategic document adopted by the government, acknowledges the need for a NGII and establishes in its action plan the need to develop a strategic plan for the NGII. This plan is being developed by the Association Nemoforum, a platform of public and private cooperation on land management and geoinformation, which includes public administration bodies, professional associations, chambers and universities. The NGII strategic plan includes an agreement on free access to geographical databases of public administration, a common metadata service, financial support for the improvement of basic datasets and the enlargement of geodata standards. For the metadata service, a pilot project that documents public geo-referenced datasets, is being developed by the Czech Association for Geoinformation (CAGI).

4.4.5.3 Poland

Poland has a long tradition in producing topographic maps and cadastral information according to a national uniform reference and geodetic system as well as national standards. These geodetic and cadastral systems have already well defined and coordinated updating and maintenance procedures that are carried out by the Geodetic and Documentation Centres according to an existing legal framework. Moreover, in this field Poland has a well-developed education network. This tradition can support some activities needed for the development of a digital information infrastructure.

4.4.5.4 Romania

In 1998, the Romanian Government approved the National Information Society Strategy and the Action Program regarding the development and large-scale use of information technologies in the country. These documents provide the background for public initiatives that intend to promote the use of information technologies within Romania. Within the field of GI, the sectors of cadastre, geodesy and cartography have also a recent legal framework that establishes their strategic objectives.

4.4.5.5 Slovak Republic

In the Slovak Republic several activities are being developed within the fields of geodesy and cartography. This sector counts on an updated legislation framework. The cadastre has been digitised and is used in digital form by the Cadastral Office. The high demand for digital data for GIS and the lack of resources led to a grouping of government initiatives and the private ones and to the development of a continuous vector map based on the base map of the Slovak republic. The map or its parts and several layers are available as licensed products, with available discounts for public institutions. The data is available online for viewing (http://mapa.arcgeo.sk) and can be licensed from both involved parties. However, to implement a NGII, problems of ownership and accessibility to the data should be solved, as well as the involvement of other GI sectors, such as agriculture, environment protection, mining, gas, water and electricity distribution companies, railways or demographic data producers.

4.4.6 Examples of Local Geographical Information Infrastructures

Some of the more significant local initiatives are initiated by the current move towards regionalisation in many European countries. Others are created for more radical political and cultural reasons.

For example, in France there is a movement towards regional GII initiated by stakeholders within the Regions. In 1999, several regional initiatives were already formalised. Similar initiatives are ongoing in other Member States of the European Union, in particular in Italy.

From the CRIGE (Comité regional de l'information géographique Provence Alpes Cote d'Azur) website (http://www.cerege.fr/crige/) it is clear that the intention is to work on the elements of a GII with a specific focus on sharing the maintenance and use of jointly purchased core data. An important characteristic or limitation is that the infrastructure is "closed", that is access is restricted to members.

Going deeper at the local level, other categories of initiatives creating "de facto GII" have been developed by groups such as the Urban Community of Lyon.

Other interesting local initiative examples in Europe include:

- SPIDI, the Spatial Information Directory (http://193.58.158.196/metadata) developed by the GIS-Flanders for the Flemish province of Belgium. It contains descriptions of some 200 data sets. This service was the first one based on a full implementation of the CEN/TC287 pre-standards (see chapter 6).
- NLIS is the National Land Information Service, a prototype land conveyancing service for England and Wales now in pilot form and involving data inputs from HM Land Registry, Ordnance Survey, local government and up to ten other sources.
- ScotLIS, the Scottish Land Information Service (http://www.bs.napier.ac.uk/rics/slis/slishome.htm) is a pilot project to establish an online service to connect professionals and to the public to a wealth of land and property information, from both the public and private sectors.

Local infrastructures focus on metadata service developments to unlock public service information. It seems that all of them intend to tackle the different elements of a GII. To facilitate interoperability between them, their interactions with national GII have to be developed.

4.5 Regional (Multi-Country) Geographical Information Infrastructures

There is a need to define and create GII in multi-country regions where there are political, military and/or commercial intentions or policies to federate within the same environment.

4.5.1 The European Geographical Information Infrastructure

At the beginning of the 1990's representatives of the European GI communities had the vision to create the European dimension for GI. In 1994 an umbrella GI organisation was created with a membership of national and pan-European GI organisations (EUROGI - http://www.eurogi.org). The main goal of this organisation has been to lobby the European Commission and Parliament to generate interest in GI issues and to propose that a political decision should be taken (the GI2000 communication initiative).

After five years, even if there is a better understanding of the GI situation in Europe and in the world, a growing awareness of GI benefits and better communication both within the GI community and with the European Commission, no formal decision to start implementing a European GI infrastructure has been taken yet.

4.5.2 The Spatial Data Infrastructure for Asia and the Pacific http://www.permcom.apgis.gov.au/

The 13th United Nations Regional Cartographic Conference for Asia and Pacific held in Beijing, China in 1994, adopted a resolution to create a regional Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP). By January 1999, the PCGIAP had 55 member nations. In 1998, only three years after its creation, members of the PCGIAP had agreed on a vision for a regional (multi-country) spatial data infrastructure that comprises fundamental data, standards, institutional arrangements and access mechanisms.

The PCGIAP's vision for the Asia-Pacific Spatial Data Infrastructure (APSDI) is a network of databases, located throughout the region, that together provide the fundamental data needed by the region for achieving its economic, social, human resources development and environmental objectives. Those distributed databases include geodetic, topographic, hydrographical, administrative and environmental data. They may, in the future, be linked electronically so that they appear, to the user, as a virtual database but in the meantime they will be linked through:

- an intra-regional institutional framework;
- the use of common technical standards;
- the adoption of common policies and inter-governmental agreements; and
- a comprehensive and freely accessible directory.

The PCGIAP has developed a SDI model that comprises four core components:

Core components of the SDI model	
Institutional Framework	Defines the policy and administrative arrangements for building, maintaining, accessing and applying the standards and data sets.
Technical Standards	Define the technical characteristics of the fundamental data sets and enable them to be integrated with other environmental, social and economic data sets.
Fundamental Data Sets	Are produced within the institutional framework and fully comply with the technical standards.
Access Network	Is the means by which the regional fundamental data sets are made accessible to the community, in accordance with policy determined within the institutional framework, and to the technical standards agreed.

Table 5: Core components of the SDI model.

The challenge of creating a multi-country GII involving more than 50 countries with different GI cultures would appear extremely difficult, mainly for institutional reasons. One advantage of this process is that a coherent grouping of organisations, i.e., the national survey and mapping organisations, is leading the activity with support from the UN. A disadvantage is that it may lead to a too narrow perspective oriented to the interests of those organisations, one of whose main interests is data production.

4.6 Global Spatial Data Infrastructure (http://www.gsdi.org/)

Starting in winter of 1995/96 a group of representatives of the GI community from North America and Europe envisaged the formalisation of the globalisation process for the Geographical Information sector. They identified the need to start sharing experiences between the different emerging NSDI communities and to start looking at the possibility of defining a common vision on how such infrastructures should be implemented to allow interoperability between them.

Since 1996 several conferences have been organised to promote awareness of the concept and the need to develop a GSDI. Moreover these conferences were also important in order to reach an agreement on a GSDI definition and strategies for its development. For instance, in the second GSDI conference the following definition was designed and accepted: The GSDI should comprise "the policies, organisational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives". Another important issue discussed in this meeting was the organizational model that should be followed in the development of the GSDI. It was recommended "that the model for the GSDI in the long term is the global umbrella organisation which brings together regional committees, national committees, and other relevant international institutions in the context of principles of flexibility, inclusivity, simplicity and subsidiarity."

GSDI development needs to found mechanisms to liaise and/or to learn from other ongoing global initiatives related to GI. Some thematic groups already have their own version of a GSDI, examples are:

- the marine industry (MARIS – Maritime Information Society, a G-8 Global Information Society Pilot Project),
- the environment (GELOS–Global Environmental Information Locator Service, another G-8 project),
- the petroleum industry,
- the International Geophysical Biophysical Programme (IGBP),
- the Military,
- UNEP-GRID (United Nations Environment Programme – Global Resource Information Database),
- the World Meteorology Organisation (WMO) and,
- the World Health Organisation (WHO).

As for all categories of GII, the GSDI development is essentially based on an active involvement of convinced individuals and interested groups. Their roles and tasks are even more important and critical in the global dimension as they have, at least at the beginning of the process, to be the initiators, the providers of leadership, the researchers and the implementers. Getting political leadership (one of the few possibilities is evidently the United Nations) and the appropriate financial resources (perhaps from the World Bank and international organisations dealing with global and continental developments) was seen at the end of the last decade as the main challenge for GSDI.

4.7 Conclusions

The implementation of GII at different scales (local, national, regional and global) is an irreversible movement since availability of geographical data has become a crucial component to improve social and economical development. However, the process of developing and implementing GII is difficult and slow since organisations have enormous staying power and resist change. The vision of a GII is an effort to translate the technical developments of twenty or thirty years into the corresponding change in the organisations.

Another issue that has held back the development of GII at different levels is the lack of a single and consensual definition of GII. More than a single definition, the GI community lacks a common vision of what a GII should be. If more GII processes were formalised and based on agreed definitions then GII would be more rapidly become operational and interoperable. However, there are some consensual principles that everyone can agree on:

- GII started to emerge due to the development of information technologies that allowed managing, manipulating, analysing and retrieving geo-referenced data, namely GIS and Interconnecting Networks.
- GII intend to facilitate access to geographical data in digital format connecting users with data producers. One of the key components to facilitate access to geographical data has been the development of metadata catalogues to document the characteristics of the data.
- The development of GII implies the co-ordination activities within the GI community to avoid duplication of efforts. This implies the development and promotion of standards and procedures to regulate the production, maintenance and exchange and access to GI.
- Geographical data and users are the GII main components.

The most important rule of thumb to develop GII is that each system should be implemented according to its specificities, for instance, if there is no data available in digital format no GII can be developed. Additionally, each technical decision on how to implement GII should also be based on the users needs and market characteristics. Moreover, local infrastructures have different needs than national infrastructures and they have different needs than the regional or global infrastructures. Their needs are different both in available digital data and technical expertise.

Worldwide there is a growing acceptance that global and regional GII should be based on NGII and local GII need a political, organisational and technical orientation provided by the NGII of that nation.

It is important to underline that major factors for GII success are the political decision and support, the governmental resources assigned to the GII development effort and the involvement of the public sector. As described above the most advanced processes of implementing GII have secured this political leadership. Moreover, important efforts have to be made to prepare the arguments to convince politicians of the need for GII.

Suggestions for further reading

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5. NATIONAL GII SOLUTIONS: THE PORTUGUESE EXPERIENCE (PROJECT SNIG)

Aims & objectives	• Describe in depth a successful, fully operational national GII solution.
Learning outcomes	• Particular factors playing a role in the success of SNIG. • The set-up of SNIG's structure.

Throughout the world, Geographical Information is being recognised as one of the most critical elements underpinning economic and social development as well as environmental management. This growing awareness has driven governments to assign resources to establish effective information infrastructures. Such infrastructures aim at encouraging spatial data sharing and integration among different organisations, simultaneously avoiding the costly duplication of datasets.

Within the European Union the Portuguese National Infrastructure for Geographical Information (SNIG) was the first to be created and implemented. SNIG was created by the Portuguese government in 1990 and launched on the Internet on May 3rd, 1995 (http://snig.cnig.pt). SNIG intends to remain the geographical data access portal in Portugal.

SNIG is the result of a co-ordination process that involves the main Geographical Information producers. It was designed and implemented as a fully distributed network where each node represents a spatial data producer. SNIG key components include a set of metadata catalogues, which describe the Geographical Information available in digital format, and applications to explore that information, such as database interfaces for the WWW.

This chapter describes the process of creating a NGII based on the Portuguese example. While chapter 4 presented an overview of different approaches to develop GII, this chapter describes in detail one example of a NGII implementation. This detailed description intends to contribute to the analysis of GII key elements and their impact on the development of national infrastructures. Following the introduction, sections 5.1 to 5.3 present the main components of SNIG: the institutional and legal framework, the network characteristics, the system structure and its users. To present the broader context of SNIG implementation, two other programmes supporting SNIG consolidation are outlined. To conclude some final remarks are presented.

5.1 Institutional and Legal Framework

To manage and co-ordinate SNIG, the government created, by the Decree-Law nº 53/90, the National Centre for Geographical Information (CNIG), as a governmental research agency, which is part of the central public administration. Although SNIG co-ordination is CNIG's main mission, CNIG participates in research and development projects carried out on a contract basis within the fields of Remote Sensing, GIS interfaces with alphanumeric databases, cartographic databases, mathematical modelling of spatially distributed phenomena using GIS and multimedia technologies.

Two major characteristics have influenced CNIG's role as a co-ordinator: 1) CNIG is not a GI producing agency and 2) it has a strong research and development component. Since CNIG does not have to spend its resources fulfilling basic needs of data production, it has always applied its resources to the infrastructure building process, namely helping each data producer to make the GI available through SNIG. Moreover, contacts with the GI producers are easier, as they recognised the role of CNIG as a supplementary one that would not compete with them.

Since its creation, CNIG's activities as the co-ordinating body of the GII have evolved according to the technological possibilities for SNIG development. In the early years, from 1990 to 1995, CNIG has been concerned mainly with the expansion of the GI market in the country (Gouveia *et al.* 1997). It has provided consultancy and has developed projects together with companies, public administration institutions and municipalities, within the GIS field. The technological developments, the Internet and its hypermedia interface, together with the expansion of the GI community, have enabled CNIG to focus on its main mission: the development of a distributed network that links Geographical Information producers to their users.

In 1999, SNIG included 117 Institutions, all of them GI producers. These are public administration institutions, at the National, Regional and Local level. The necessary condition for a public administration agency to become part of the infrastructure is to produce GI in digital format and make it available through the network. The GI data types and themes produced by these institutions are very diverse and they include classic datasets, such as land-use maps, census data and topographic maps, as well as less traditional datasets, such as the digital ortho-photographs.

It is important to underline that, in Portugal, each GI producer defines the way users can access their data. Within SNIG there are some examples of data that is available for free (e.g. Corine Land Cover - CNIG, Environmental Atlas - DGA) and other examples of data for which the user has to pay before it is made available to him. CNIG always tries to promote the access to GI as cheap as possible or even free of costs, but it always depends on the accessibility policy followed by each producer institution.

For the development of the distributed network that links GI producers and users, CNIG provided material and technical support to each node of the system. The equipment given to each institution willing to participate within SNIG was typically a communication and data server. The technical support is related to the type of digital geodata produced by the institutions. SNIG's team at CNIG might develop interfaces that allow users to access and retrieve data (or metadata) from databases or develop applications to explore cartographic information. The data are physically distributed in each institution and are stored in the data servers provided by CNIG.

Basically, the main obstacles that CNIG faced while trying to create the network, and stimulate the interchange of GI were:

- In the early days of SNIG implementation on the Internet, some institutions failed to see the advantage of distributing their spatial data through that new medium.
- Producers, with few exceptions (one of these exceptions, for instance, is the General Directorate of the Environment), usually charge for their data. Since accomplishing commercial trade through the Internet was considered not safe, producers' willingness to make information available was limited.
- Insufficient human resources available at each SNIG node.
- Confidentiality of information and liability problems.

14 staff members, with different levels of participation constitute CNIG's team, involved in the development of the infrastructure. This group has a multi-disciplinary background ranging from environmental engineers and computer scientists, to geographers and psychologists. The team is responsible for:

- Keeping each node motivated to provide information and help solving problems (helpdesk) of the connected institutions;
- Conceiving and creating interfaces to retrieve and access geo-referenced data produced by each node;
- Maintaining the digital Geographical Information catalogues;
- Researching and developing new functions.

CNIG's co-ordinating role is supported by three main institutions: FCCN - National Foundation for Scientific Computing, DECivil, the Department of Civil Engineering of the Instituto Superior Técnico-Technical University of Lisbon (IST), and the Environmental Spatial Analysis Group (GASA) from the Faculty of Sciences and Technology of the New University of Lisbon. FCCN, the organisation responsible for the electronic academic network, is the SNIG Internet Service Provider and has been responsible for configuring the equipment distributed to each node (since the end of 1998 this activity has been transferred to CNIG). On the other hand, DECivil and GASA collaborate in the research and development of tools and applications to disseminate and explore GI within SNIG.

Concerning the legal framework for data dissemination, in Portugal there is a lack of case law that gives clear ideas on what the legal status for Geographical Information (EUROGI 1996) is. The copyright act dates back to 1985, and has been revised since. It practically lists the same works eligible for protection as the Berne Convention, as Portugal has adhered to this

Convention. This includes geographical maps and illustrations and works related to geography or other sciences

If copyright does not give adequate protection, the law of unfair competition might provide protection in some circumstances. Acts that the industry of the Geographical Information sector holds to be contrary to acceptable behaviour, and that cause damage to a competitor by taking away clients, can be labelled as unfair competition.

A more recent law on the production of products of cartography states explicitly that copyright law applies to cartographic information. This law states that it is forbidden to use, supply to others, reproduce, divulge or commercialise cartographic products or the corresponding technical data without permission of the entity of which it is the property.

5.2 Network Characteristics

The equipment CNIG provides to each node includes a data server (typically a UNIX machine, SUN SPARC 5), a communication server (typically a 2503 router), and ISDN lines to connect each institution to the central node (CNIG), in an architecture that resembles a star.

This type of architecture, suitable for a small number of nodes located in the neighbourhood of the service provider, caused very high costs as soon as the number of nodes started to increase. In order to limit these costs, CNIG decentralised the architecture and installed lines with fixed costs in 4 regional coordinating commissions. The other regional institutions are now connected to the regional coordinating commission node in their neighbourhood.

5.3 SNIG's Structure

Since its creation, SNIG's structure has evolved according to the technological possibilities. Although SNIG was created in 1990 it was only "physically" implemented in 1995, when it was launched on the Internet (http://snig.cnig.pt). From 1990 until 1995 the actions towards the implementation of SNIG focused on developing experiences in linking different databases as well as pursuing contacts with the geospatial data producers to motivate them to participate in such a system. Additionally, efforts were made to promote the use of GIS and the production of GI in digital format.

Early in 1994 the emerging development of the Internet, particularly the World Wide Web (WWW), brought new possibilities for implementing a National Geographical Information infrastructure. SNIG was then officially launched on the Internet (http://snig.cnig.pt) in May 1995 and was implemented as a fully distributed system where each node represents a producer of geospatial data.

Additionally, the approval by the Portuguese Government and by the European Commission (at the end of 1994) of a Programme integrated in the Regional Development Plan 1994-1999, with a specific budget assigned to the support of the SNIG development (including conversions of existent geographical data into digital formats, development of computer applications to enable Internet access to existent data bases, purchase of satellite data and existent digital topographic data for Local GIS, implementation of Local GIS in Municipalities or groups of Municipalities and data and communications servers for the nodes of SNIG) was a major factor that helped the fast development of SNIG.

At the core of SNIG, there was a set of metadata catalogues that described the GI available in digital format and the direct connection to the producers' homepages. Initially, the metadata catalogues only described the alphanumeric and cartographic datasets. These catalogues have been expanded to include other data types, such as satellite images and orthophotos, and metadata on the GI service providers and GIS projects within the Portuguese context. The metadata catalogues were implemented in a Relational Database Management System with an HTML interface to allow any user to query the metadata and retrieve available datasets.

The metadata catalogues are the only information that is centralised in SNIG. This architecture allows for a rapid provision of information about the data available. Another reason to choose such architecture was the fact that metadata collection, by geodata producers in a consistent and organised way was, and still is, in an incipient phase. However, such a model has some drawbacks, namely the difficulty to keep the digital catalogues updated. To facilitate this task producers can register, through HTML forms, and insert or update information in the digital catalogues. This new information will be loaded in a temporary database to be verified by SNIG's team.

During the period from 1995 to 1998, additional efforts were made to develop applications that would be useful for GI users. An example of one such application is the access to files from a fixed GPS enabling mobile GPS users to perform differential correction. Additionally, it was also during this period that the Earth Observation Network was created and integrated within SNIG as the first thematic network available. The Earth Observation Network intends to disseminate information on remotely sensed data integrating satellite imagery users, suppliers and imagery value added services. It includes metadata on satellite images for earth observation, remote sensing projects, bibliographies and related events.

In summary, during this stage, SNIG's structure and design was mainly centred on the professional user, as shown by the type of applications and data formats available through the network. However, the expansion of the Internet and its users has increased the demand for other types of interfaces, information formats and applications, enabling any citizen to access and use the Geographical Information produced. Thus, during 1998, SNIG started to enter a new generation of Geographical Information infrastructures that favours the citizen. Therefore, SNIG is now structured according to two main gateways: one that targets GI professionals and the other, called GEOCID (http://geocid-snig.cnig.pt), that has been developed to facilitate access to GI by any citizen (Figure 22, Figure 23). These two interfaces are hyperlinked enabling any user to access both the technical and non-technical information.

Figure 22: SNIG's interface oriented for GI professionals.

The professional interface continues to be organised around the metadata catalogues. Several improvements have been made within the catalogues, namely the creation of new search options, which include graphical searches, and the adoption of the European standard CEN/TC287 (more details on the adoption of the standard to the SNIG data model can be found in chapter 6). Additionally, more applications have been developed that intend to facilitate GI access, the most significant being the application to allow commercial transactions of data through the SNIG network. The one currently available through SNIG uses the ATM system and safe communications to ensure the confidentiality of the transaction as well as the security of each node. The land-use map was used as a case study to implement such a mechanism. Another improvement within the SNIG structure was the integration of another thematic network - the Information Network for Emergency Situations (RISE).

The Geocid interface was created to be more appealing and information oriented, avoiding complex tasks and navigating routes to access to the data. Although Geocid is still in its early stage, the main service it provides is the direct access to databases and maps, already available through the SNIG network that is useful for the citizen.

Additionally, new applications based on the public preferences were developed. These applications are currently available through the professional version of SNIG and GEOCID. An example of such applications is the retrieval of aerial photographs from the 1995 aerial photograph coverage of the country, at a 1:40.000 scale and low resolution, property of CNIG, the General Directorate for Forests (DGF) and the Paper Companies Association (CELPA). Another example is an interactive presentation of the Municipal Master Plan maps and associated rules. An application to allow any user to produce thematic maps of Portugal was also developed.

Figure 23: GEOCID's interface: the citizen Gateway to SNIG information.

However, the most important application, launched in June 1999, is the access to the complete ortho-rectified aerial coverage of the country, one-meter resolution, from the 1995 flight. An application was developed that allows the user to navigate through Continental Portugal, select specific locations and download the part of the ortho-photo he is visualising on the screen. This later application has been the most used within SNIG and its number of users has increased exponentially (in the first two days online access was about 200.000 per day).

5.4 SNIG's users

The GI users community that can benefit from SNIG, can be classified in four main groups, each one with its own special interests:

- General public - this group is interested in highly informative, low resolution, low cost information;
- University and high-school students and teachers;
- GI producers and companies that handle Geographical Information;
- Central, regional and local public administration.

The number of SNIG users has increased since it's opening on the Internet. Moreover, the SNIG users' Internet domains have also become more diverse, reflecting the increasing use of the Internet. Analysing SNIG accesses since 1996, two events can be identified as having significantly contributed to this increase: the first occurred within the summer of 1998, when the

SNIG interface was redesigned to become more friendly based on usability tests. The second event took place in June 1999 with the citizen interface launching and more specifically with the possibility to browse through the orthophotos coverage at one-meter resolution for all of Portugal. These results show the importance of fulfilling the users needs both in terms of site usability and information.

5.5 SNIG Network Consolidation Programs

As a result of the SNIG development, CNIG became aware of the need for a specific and dedicated support to local governments considering that they were not only frequent users of Geographical Information, but also main producers of geo-referenced information and could not be treated as the typical data producer. Considering the conditions of most municipalities, CNIG created two initiatives: The Support Programme on Computer Management of Municipal Plans (PROGIP) and the Support Programme for the Creation of Local Nodes of SNIG (PROSIG).

These two programmes were established by the Portuguese government in February 1994 and funded by the Second Technical Assistance Programme integrated within the Regional Development Plan, sponsored by the Regional Funds of the European Commission in December of 1994.

The main objective of PROGIP is to build computer applications to support the management of the Master Plans, namely to facilitate the application of the plans' bylaws. This programme intends to enable a continuous assessment of land-use changes, according to the objectives and proposals specified in each Master Plan. The PROGIP has two main components: one is to digitise the Master Plans and the other is to provide the municipalities with a computer application that allows the management of the Master Plans.

The conversion to a digital process of the master plans became a more time consuming process than expected, since major insufficiencies were detected regarding geometric accuracy and coherency between the same contents published in different thematic maps. Furthermore, it was agreed between the Central Administration agencies and the Municipalities, to solve each of these problems on a case-by-case basis.

The computer application development has taken into account the fact that not all municipalities are able to create and maintain GIS applications in the short term. The alternative solution chosen consists in developing the appropriate GIS functions for municipal management in simpler CAD solutions. A survey of CAD solutions already existent in the Municipalities has been carried out and it was concluded that the application could be developed with the two most generalised solutions.

On the other hand, PROSIG intends to go further and support municipalities or associations of municipalities in creating GIS, which will be integrated in the SNIG network as local nodes of the system. However, the development of these nodes and the associated GIS applications require a set of demanding conditions that are difficult for every municipality to fulfil, namely the existence of digital cartography in the municipality and the qualified human resources with full time dedication to the GIS (Henriques 1996). These conditions have imposed some constraints on the PROSIG implementation, however a credible assessment of PROSIG can only be done later on, since the GIS implementation process is usually very slow.

5.6 Final Remarks

SNIG is the result of a co-ordination process that intends to link the main Geographical Information producers and their users through a distributed network. SNIG's future development is based on two strategies: (1) increase the GI producers' involvement within SNIG and (2) increase the number and types of users as well as their satisfaction with the system. To achieve such goals, SNIG's team at CNIG should organise initiatives to motivate and co-ordinate the GI producers. Examples of such initiatives already initiated are the Forum SNIG meeting and the publication of a magazine. Additionally, it should continue to support the development of applications aiming at facilitating access to the data owned by the different GI producers. SNIG's past experience has demonstrated that this is crucial to populate the system with useful data, such as the digital ortho-photographs.

On the other hand, SNIG's team at CNIG is also increasing the applications available at SNIG to manipulate the data. This refers to the development of applications that allow users to perform GIS operations without requiring them to have any specific software. The Master Plans presently available at SNIG are one example of such functions. Another example is the creation of an application to generate thematic maps from the users' own datasets. Other important initiatives that intend to increase the use of the National Geographical Information Infrastructure are the development of a NGII interface targeting the citizen (GEOCID) and the creation of thematic networks, devoted to specific areas and users. Two thematic networks are already available online: one is dedicated to the Earth Observation Network and the other is an information system for emergency situations. Two other thematic networks are currently under development: one example is the educational version of SNIG, which intends to take advantage of the current available information at SNIG, for educational purposes. Additionally, it intends to create applications to encourage students from high school to universities to get familiar with the characteristics of digital Geographical Information as well as to the potentialities of GIS to manipulate such data. A following module is foreseen, concerning the environmental field that intends to make available to the users, tools to explore environmental information, such as the interactive access to Environmental Impact Assessment (EIA) studies based on the spatial multimedia information involved.

To summarise, the key elements for SNIG's success have been an advantageous institutional and financial framework. CNIG, the agency responsible for SNIG's coordination was set up as a research agency with strong connections to the academic sector. This framework has allowed SNIG to evolve according to the recent technological developments. On the other hand, CNIG is not a GI producer, which facilitates the involvement of the GI producers within the NGII and allows CNIG to focus on its main mission, namely the development of the NGII. This is a model to be noted by other similar initiatives. Moreover, CNIG activities have been supported by a strong vision of what a NGII is and have also benefited from a continuity in the organisational leadership.

Financially, SNIG have benefited from an adequate funding programme. These funds, which were partially national and partially European, allowed to set up the network and also to develop applications to facilitate the access to metadata and GI. Moreover, these initiatives have helped CNIG to gain the initial support of data producers to the NGII concept. To conclude it is important to underline that SNIG's development is part of the information society policies defined by the Portuguese government. It contributes to accomplish some of the foreseen measures within the Green Paper on the Information Society (Mission for the Information Society, 1997), such as measure 2.8 that states "...to support the integration of digital Geographical Information into the National System for Geographical Information (SNIG), to serve as a support for urban and regional planning and environmental protection and management; these will be available to public and private bodies". The development of SNIG is also contributing to make information available to the citizen, not only through the integration of information that citizens may need during their daily activities, but also providing simple tools to allow its exploration and use.

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6. STANDARDISATION AND INTEROPERABILITY FROM A EUROPEAN PERSPECTIVE

Aims & objectives	• Introduce the reader to the "what, why and how" of standards and interoperability in the field of GI. • Explain the European point of view.
Learning outcomes	• The difference between standardisation and interoperability. • The different types of standards. • Bodies and organisations active in the standardisation process. • The benefits of standardisation and interoperability.

This chapter presents the current situation of the GI standard and specification making processes and in particular the CEN, ISO and OGC activities. Experiences in implementing new standards are commented, especially the CEN/TC287 Metadata standard implementation by CNIG Portugal, GIS Flanders Belgium and MEGRIN. The need to promote GI standards and to educate the GI community is expressed. The importance for GI market actors to participate in the standard and specification processes and to implement them is highlighted.

6.1 Introduction

As was the case for the development of Geographical Information Infrastructures described in chapter 4, the last decade has seen the movement from a national to a global dimension for the standardisation of Geographical Information (GI) and Geographical Information Systems (GIS). The last decade has also seen the emergence of greater interoperability requirements.

Standardisation in the GIS community was initially a standardisation of data exchange formats. The exchange of data between the proprietary GIS of the 80's and early 90's (closed GIS) was a permanent difficulty and users demanded standardised exchange formats, which all GIS could read and write.

In Europe, GI standardisation efforts that had been made by national standardisation bodies (such as AFNOR in France, BSI in the UK and DIN in Germany) were relayed from 1992 by a European effort made by the Comité Européen de Normalisation (CEN). Since 1994 the International Standardisation Organisation (ISO) has been working on similar topics.

From 1970 to 1990 GI sector activities resulted in the development of independent complex GIS based on proprietary data formats and the production of GI based on independently developed specifications. It was obvious at the beginning of the 1990s that the GI community had to tackle this non-interoperable schema to facilitate the work of the end users and to improve efficiency.

The movement towards a higher level of interoperability in the GI sector is led by:

- institutional standard makers who focus activities on the data part of the problem,
- industrial specification makers who focus activities on systems, and
- umbrella and co-ordinating organisations that focus activities on the institutional and organisational dimensions.

With the advent of widespread networking, users realised that data exchange was not sufficient. Downloading data from a provider resulted in having a copy of the data, which was not updated anymore. To have up-to-date data in the future it was necessary to download the data again and again. The better solution would be to access only the subset of data one needs for a single operation and not copy the full dataset. If an application program can automatically converse with a data provider and access the updated data on the provider's server ("life data") then the two programs are interoperable.

In parallel to these activities, a process of defining GI(S) specifications aimed at providing interoperability between GI systems was started in 1994 with an industry focus in the Open GIS Consortium (OGC).

Types of Standards

Four types of standard can be identified:

- Proprietary standards are those of a particular organisation, usually a product vendor.
- Ad hoc standards are standards for specific purposes or market segments and require an ad hoc adaptation or definition.
- De facto standards are when most of the users adopt them independently of the consortium that developed the standards.
- De jure standards are when they are developed by standards bodies established under national or international laws. (Self-evidently, de jure standards may be developed at the national level, for Europe as a whole and for the whole world).

Standardisation of data exchange formats	*Interoperability standards for GI*
Standards that fix the representation of geographical data so that they can be read by different GIS.	Standards that fix the operations and the interactivity patterns between a GI server and client (see chapter 2.3.3).
Useful to exchange large amounts of GI.	Useful to access specific GI of interest and exchange small amounts of GI.

Table 6: Purpose of geographical data exchange.

During the 1980s there were recognisable attempts to harmonise data structures, description and encoding. For the most part these efforts were national, although there were also some multi-national activities for narrow market sectors. The general target for a standard was to encapsulate in a single specification all those elements needed to move geographical data from one computer system to another independently of considerations of distributed computer platforms or data models. It is assumed that the main driver was the supply and demand of national topographic mapping, which also characterised the main market actors involved.

Several countries began to develop GIS standards strategies (Norway, Finland, Sweden and the UK) based on the generic information and communications technology standards that were available at the time. Since 1990 these have evolved and converged and become better modularised in themselves, for example Open Electronic Data Interchange (Open EDI) and Global Information Infrastructure proposals. However, it was the needs of a Europe-wide market that led to the development of a modular set of standards.

CEN and ISO each have a technical committee responsible for GI standards: CEN/TC 287 Geographical Information and ISO/TC 211 Geographical Information/Geomatics. There are also two committees for the major sector of transport informatics: CEN/TC 278 and ISO/TC 204.

6.2 The Standardisation Processes

Standardisation in the field of GI inherits concepts, models, practices, procedures and terminology from four main technological streams. Three belong to the general purpose Information Technology industry:

- Computer Aided Design (CAD/CAM) provides computer graphic tools such as the 'Standard for the Exchange of Product Model Data' (STEP) which may be useful for the geometric aspects of GI.
- Information System (IS) initiated the study of specific extensions to SQL in order to handle GI from an information system perspective.
- Electronic Data Interchange (EDI) addresses the exchange of GI for administrative purposes and thus has studied possible GI messages with the electronic document interchange (EDIFACT) context.

As far as GI standards are concerned, GI actors first grouped themselves either on a national or a professional basis. Thus national groups gave birth to a first generation of national 'de jure' standards such as National Transfer Format (NTF) in the UK, EDIGéO in France, Spatial Data Transfer Standard (SDTS) in the USA and Spatial Archive and Interchange Format (SAIF) in Canada. Professionals also organised themselves into international groups to create a first generation of 'de facto' standards such as: Digital Geographical Information Exchange Standard

(DIGEST) by the Digital Geographical Information Working Group (DGIWG) of NATO, Transfer standard for digital hydrographical data (DX-90/S57) of the International Hydrographic Organisation (IHO) and Geographical Data File (GDF) by the automotive industry.

With the increase of the GI market dimension a more comprehensive approach is needed and a new generation of GI standards is being produced. This will be documented in the following chapters.

6.2.1 National Standardisation Process

The usual situation in a country is that there is a national standardisation body with committees in charge of a specific sector (GI in our case). In addition, there is often a national GI organisation that in principal represents the interests of the whole sector, and may also have standardisation committees. In an ideal world, the standardisation committee of the national GI organisation would make proposals to the committee of the national standardisation body. This process has to be open to all concerned individuals who wish to participate. Generally speaking the standardisation mechanism should be as open as possible. It is a voluntary activity of the concerned sector. It is often said that a sector has the standards it deserves.

After having launched the standardisation process at the national level during the 1980s with a main focus on data transfer standards, national standardisation bodies are now mainly involved in the multi-country standardisation and global processes (CEN and ISO). Some national standardisation developments, such as the one by the American national body, the National Institute of Standards and Technology (NIST) - the successor of the American National Standards Institute (ANSI) - and their GI sector committee, the Federal Geographical Data Committee (FGDC) led the process before regional and international movements started. FGDC standards had a major impact in Europe and were seen as one of the possible solutions during the 1990s, certainly for the creation of metadata.

The current work plan of the Commission de Normalisation Information Géographique of AFNOR (the French official body for standards) is to identify standardisation needs, assure the maintenance of the EDIGéO standard (national transfer format now adopted as an AFNOR standard), analyse the consequences of the European Prestandards (ENVs) implementation and define the French positions on the International Standards projects. There is, for the time being, no intention in France to work on new national standards.

This is not the case in the UK where the AGI Standards Committee are involved in five-year update reviews of two widely used British standards: BS 7567:1992, a neutral transfer format and BS 7776 Part 4:1999, data description in the infrastructure and property sectors. Further standards are anticipated at the national level, primarily a standard for the 'UK Standard Geographical Base'.

It is clear that national standardisation bodies and their committees responsible for GI standardisation are in a difficult situation as they work to accompany international developments and to provide appropriate answers to users' urgent requirements.

Shall they continue to develop and maintain national standards? Shall they promote and educate users about CEN European Prestandards? Shall they advise users to wait for the ISO standards? It seems that different nations in Europe have different responses leading to a heterogeneous situation. But it is clear that national standardisation efforts in the field of Geographical Information must be merged within the European and international moves.

6.2.2 The European Standardisation Process

6.2.2.1 CEN/TC 287

CEN's (http://www.cenorm.be/default.htm) mission is to promote voluntary technical harmonisation in Europe in conjunction with worldwide bodies and its partners in Europe. Harmonisation diminishes trade barriers, promotes safety, allows interoperability of products, systems and services, and promotes common technical understanding.

CEN Technical Committees (TCs) gather the national delegations of experts convened by CEN National Members, which must make sure that such delegations convey a national point of view that takes account of all interests affected by the work. Technical Committees must take into account any relevant work (in ISO, for example) falling within its scope, as well as any data that may be supplied by CEN National Members and by other relevant European/international organisations. The results of this work can then be offered to ISO.

History

CEN TC/287 was set up in 1991 and AFNOR, the French National standardisation body (http://forum.afnor.fr/afnor/WORK/AFNOR/GPN2/Z13C/index.htm), was approved as the secretariat of the Technical Committee.

A total of about 60 meetings were necessary to review the technical work. Most of the technical work itself was undertaken by volunteered expertise. Some of the activities were fully funded by the European Commission.

Policy

There is more than one category of CEN standard. The original intention of CEN/TC 287 was to create a family of standards known as 'EN': Euro-Norme or European Standards. Members are obliged to implement 'EN' European Standards by giving them the status of national standard.

For a number of reasons, mostly relating to the later decision to set up an ISO technical committee, the members of CEN/TC 287 decided that the standards would be 'ENV': Euro-Norme Voluntaire or European Prestandards. ENVs are established as prospective standards for provisional application in technical fields where the innovation rate is high or where there is an urgent need for guidance. ENVs do not have to be adopted by the members (but they must be announced and made available).

A difference between the two is that European procurement law mandates that contracts above the various minimum limits shall adopt EN standards unless both parties mutually and amicably agree otherwise. The decision by CEN/TC 287 to produce ENVs means that adoption of its results is entirely a national decision.

Basis of family of standards

It has been mentioned that work prior to the creation of CEN/TC 287 pointed towards the need to modularise the typical data exchange transfer standard so that the resulting 'family of standards' would be more flexible. They would then be able to adapt to the evolution in information and communications technologies as well as to specific GI market needs. This was a significant change but the concept was little understood or appreciated by the community that it aimed to satisfy.

The conventional approach to modularising information technology standards is to construct a Reference Model: the CEN/TC 287 model shows how the standards may be used in the various contexts supported by it. Among these is a data provider/data procurer concept that relies on unspecified electronic commerce activities to be implemented.

The other characteristic of this family of standards is the use of a conceptual schema language, both graphical and lexical. The standardised language chosen by CEN/TC 287 is EXPRESS: this standard is referenced as 'ENV ISO 10303-11 Information automation systems - Product data representation and exchange - Part 11: Description methods'.

Details (including the EXPRESS schema of each standard) can be found at:

http://forum.afnor.fr/afnor/WORK/AFNOR/GPN2/Z13C/PUBLIC/WEB/ENGLISH/pren.htm

Achievements by 1999: List of the GI European Prestandards and CEN Reports

The full text of ENVs and Reports should be available for purchase at CEN National Members (who are the national standardisation bodies).

The life of the ENVs is limited to three years. After two years the CEN Central Secretariat (CEN/CS) will take action by requesting National Members to send their comments on the ENVs within six months.

Reference	Title
ENV 12009:1997	Geographical Information – Reference Model
ENV 12160:1997	Geographical Information – Data description – Spatial schema
ENV 12656:1998	Geographical Information – Data description – Quality
ENV 12657:1998	Geographical Information – Data description – Metadata
ENV 12658:1998	Geographical Information – Data description – Transfer
ENV 12661:1998	Geographical Information – Referencing systems - Geographical identifiers
ENV 12762:1998	Geographical Information – Referencing systems - Direct Position
ENV 13376:1999	Geographical Information – Rules for application schema
CR 12660	Geographical Information – Processing - Query and update: spatial aspects
CR 13425	Geographical Information – Overview
CR 13436	Geographical Information – Vocabulary
CR	Geographical Information – Conceptual schema language

Table 7: European Prestandards (ENV's).

Examples of implementation

First indications are that the favourite CEN/TC 287 European Prestandards are 'GI - Data description - Metadata' and 'GI - Data description - Quality'. Several implementations exist. In 1998 the Swedish organisation SIS prepared a questionnaire to assemble evidence of national implementations of CEN/TC 287 results prior to the review of the ENVs.

Two implementation success stories

1. SNIG's implementation of CEN/ TC 287 – a CNIG Portugal contribution

One of the main components of the Portuguese National Geographical Information Infrastructure (SNIG) is a set of metadata catalogues that describe the characteristics of the Geographical Information available in digital format (for a detailed description of SNIG and its metadata catalogues please refer to chapter 5). The main goal of these catalogues is to facilitate the access to available digital geo-referenced data sets.

The metadata catalogues have been part of SNIG since it was officially launched on the Internet in May 1995. Therefore, the first version of these catalogues was not based on any metadata standard. They were developed using a relational database management system in order to facilitate the management and update of the metadata as well as to allow different search options by the users. For example, the first version of SNIG metadata catalogues allowed users to discover which data sets were available querying the database by theme, by region or by information producer. Common sense, some guidelines provided by CORINE Catalogue of Data Sources project and the identification of the main GI data sources were the rules used to design the database of metadata included in SNIG at that time (Nicolau 1998).

In 1996, due to CNIG's participation in the European Spatial Metadata Infrastructure Project – ESMI, and to the need to provide more options to search the metadata catalogues, it was decided to modify SNIG's metadata structure. By the time it was decided to adopt the CEN/ TC 287 within SNIG, relational implementations were rare. The GDDD – Geographical Data Description Directory – data model, proposed by MEGRIN, was the only CEN/ TC 287 compliant relational model that was published. Therefore, the GDDD model was analysed to understand if it could be used as a model for SNIG metadata catalogues. However, it was soon realised that SNIG aims were not fulfilled with that model, since SNIG's metadata catalogues cover more information than just metadata about available data sets. For example, SNIG's metadata catalogues include metadata on remotely sensed data, such as satellite images, and describe the GI services providers and GIS projects within the Portuguese context. Moreover, the full list of attributes included in the CEN ENV 12657 needed to be interpreted and adapted to fulfil all of SNIG's requisites (Nicolau 1998).

The analysis of CEN/ TC 287 to build a relational model to fulfil SNIG's aims considered five main issues:

- The relational data model attributes should allow the description of all the data types already included in SNIG's metadata catalogues, i.e. maps, aerial photography, text files, databases and satellite imagery. Therefore, some attributes were added to the CEN/ TC 287 list. For example, SNIG's catalogues describe only digital data, thus some attributes were added to describe important characteristics of digital datasets such as the data model (e.g. raster or vector) and the map type (base or derived map).

- The CEN/ TC 287 compliant model should describe important relationships among different datasets or within subdivisions of the same attribute. For example, SNIG's data model makes an effort to reflect the hierarchy that occurs between a map series and its sheets. The adopted model intends to facilitate data management since the shared attributes of each map sheet and maps series do not need to be stored twice.
- The hierarchical relationships among geographical units and indirect positioning systems should be described so queries by geographical unit would be more efficient. In the model adopted, the geographical area covered by each dataset can be described using the highest indirect positioning system of the hierarchy, implying less data storage.
- The adopted model should support the development of a friendly and flexible interface. This interface should improve the search options presented to the user. For example, the thesaurus proposed by CEN/ TC 287 was adopted as a way to store keywords to classify datasets by theme.
- The metadata collection requirements should be, above all, pragmatic. Like other GI standards, CEN/ TC 287 proposes the storage of many attributes that are difficult to collect and are not used or even known by some GI producers (e.g. quality parameters or description of the objects relationships contained within each data set). The set of attributes that is currently defined as mandatory to describe a data set (CEN ENV 12657) is less ambitious and consequently more feasible than the one defined by the former draft version of the standard (prEN 287009 document).

The work developed by SNIG's team on metadata standards led to the development of a CEN/ TC 287 metadata profile and metadata extensions. Although these concepts are foreseen by other GI standards, CEN/ TC 287 does not mention this possibility. However, the achieved data model is CEN/ TC 287 compliant, facilitating information sharing and transfer. More information on the data model used by SNIG's metadata catalogues is available at http://snig.cnig.pt/metadados/modelo_snig.html. However, since CEN/ TC 287 does not provide instructions for its implementation and is not concerned with database design, the compatibility of different implementations for file transfer purposes has to be ensured by the adoption of additional mechanisms, such as a re-map software and the use of a common file transfer format.

In summary, the migration from the old data model to the CEN/ TC 287 compliant model created a structure that facilitates metadata sharing. However, it obliged the collection of additional metadata for the existing data sets and the development of a new interface. This later development improved significantly the user interaction with the metadata catalogues, since it increased the number of search options.

2. MEGRIN's implementation of CEN/ TC287 – a MEGRIN contribution

MEGRIN was created in 1993 on the initiative of CERCO (Comité Européen des Responsables de la Cartographie Officielle) with the aim of helping the National Mapping Agencies (NMAs) of Europe to meet the increasing demand for cross-border products and services. Knowledge and understanding of the geodata available at the European NMAs is one important prerequisite for MEGRIN (http://www.megrin.org/index.html) to accomplish its main mission.

In 1994 MEGRIN requested the NMAs to provide metadata describing their digital products. The model chosen was the current provisional version of the CEN TC/287 standard on metadata, the language is English. The metadata was initially provided on paper in response to questionnaires and loaded to a remotely accessible database. At this time the dial-up query interface was difficult for people to access.

The development of the use of the Internet made it far easier to share this information with all interested parties, and the GDDD v.2 was planned. The current service is constructed on a metadata database, to which all the previous data from v.1 has been transferred. The data is regularly updated and today covers some 23 European countries. Internet pages are automatically created at each update, and can be consulted freely on the Web. The GDDD counts some 10,000 hits a month.

Experience has shown that most users of the web site do not require all the elements composing the metadata standard resulting from the work of CEN TC/287, and that data providers may find it too demanding to produce and maintain the whole set of the standard metadata elements. The next version of the GDDD will be derived from these two findings. MEGRIN is working on the idea of a "core-metadata" structure (the first version of which was developed within the ESMI project), based on the CEN ENV 12657:1998, but reduced to some 40 elements that have been evaluated as being those necessary for the application purpose. In order to give the "core" its universal value that would ensure its wide use, and thus its success, MEGRIN collaborates for this initiative with several other organisations and projects, including GEIXS, the metadata service of the European Geological Surveys. It is expected that the "core" thus developed may be recognised as a "profile" in the ISO TC/211 metadata standard.

Issues

CEN policy includes the creation of standards and their dissemination by the National Standardisation bodies on a commercial approach (the intention is that the revenue from selling standards should cover the cost of the secretariats of the Technical Committees). CEN is not active in promotion and training activities related to its standards, this is the role of each of the national member bodies.

The visible situation is that some National Standardisation bodies limit their promotion activities to few pages on their websites providing, in the best cases, information on the existence of the GI ENVs and on how they can be purchased.

The situation is that relatively few standards experts, the majority of whom were involved in the standard writing process, are volunteering their expertise to help the GI community to implement the standards. As no official implementation guidelines exist, their visions on how to implement differ, resulting in different implementation schemas, although the aim of ENV 13376:1999 Rules for application schema intend to overcome that.

The future of CEN/TC 287

In November 1998, at the CEN/TC 287 Vienna meeting,

- all working groups were disbanded.
- The TC decided to continue its activity with the following objectives:
  - To provide a technical body for reaching consensus on revision of ENVs and Reports, and adoption of international standards when becoming available.
  - To review requirements for European standards leading possibly and eventually to the definition of a new work programme.
  - To provide a forum for discussion of issues of common concern.

At the time of writing the tendency is to leave CEN/TC 287 'dormant' until the end of the review period of the ENVs. The CEN/TC 287 will decide whether ISO 15046 or parts of it will be adopted by CEN as a replacement for the CEN/TC 287 ENVs and CEN Reports.

6.2.2.2 CEN/TC 278

http://www.nni.nl/cen278/

CEN/TC 278 Road Transport and Traffic Telematics was established in 1991. Its scope was then defined as follows: "Standardisation in the field of telematics to be applied to road traffic and transport, including those elements that need technical harmonisation for intermodal operation in the case of other means of transport. It shall support:

- vehicle, container, swap body and goods wagon identification;
- communication between vehicles and road infrastructure;
- communication between vehicles;
- in-vehicle human machines interfacing as far as telematics is concerned;
- traffic and parking management;
- user fee collection;
- public transport management;
- user information.

The work programme comprises over 50 work items classed either as application specific, databases, interfaces or basic concepts allocated to 14 Working Groups.

There is only one working group that activities relate to Geographical Information. Working Group 7 - 'Geographical Data Files' (GDF) is responsible for three work items of particular interest for the GI community:

Work Item	Title	Present Status	Present document
00278039	Geographical Data Files	Adopted	ENV ISO 14825:1996
00278041	Geographical road data - Location catalogues	Starting up	
00278044	Geographical road data - Maintenance rules	Starting up	

Table 8: Work items under responsibility of Working Group 7.

In an ideal world these three items should have been worked in close collaboration between CEN/TC 287 and CEN/TC 278 but unfortunately, that was not achieved. CEN/TC 278 works closely with ISO/TC 204 Traffic Information and Control Systems on more than 30 parallel work items.

6.2.2.3 CEN/ISSS frame

In 1997 CEN created a new process for standardisation to be used where the pace of technology development requires a consortium approach that will create consensus internally. Consensus building is achieved using electronic exchanges and workshops. This process, called Information Society Standardisation System (ISSS), is being used for electronic commerce, security and multimedia metadata (see also the CEN Workshop Agreement - Metadata for multimedia information, endorsing the Dublin Core as discovery metadata for a wide range of sectors in Europe:
http://www.cenorm.be/news/press_notices/metadata.htm). CEN/ISSS is the focus for CEN's information and communications technology activities. Individual organisations may join ISSS workshops for which a fee may be charged, at least to cover secretariat costs.

6.2.2.4 Is there a future for the European GI standardisation process?

By the end of 1998, CEN/TC 287 had completed its planned workload, CEN/TC 278 is continuing and the CEN/ISSS offers new possibilities.

A community of European GI standards makers exists and some of them are active in bringing their experience and knowledge to ISO and OGC activities. CEN/TC 287 ENVs are starting to be used, especially 'ENV 12657 – Geographical Information - Data description - Metadata', despite the fact that some consider these ENVs too complex resulting only in limited implementations. This provides the European GI community with the possibility of increasing their competence in the development of metadata services and clearinghouses. The contribution of the European GI standardisation community to the ISO and OGC activities is expected to influence their results.

From this situation a plan for future activities has to be prepared. Six months of opportunity for discussion identified several needs for continuing the work of CEN/TC 287 but no organisation or people willing to lead the technical committee. This discussion period ended in June 1999 without identifying a chairman and secretariat. In this case, CEN will close the TC.

With CEN/TC 287 foreseen as being dormant, it seems that the future for the European GI standardisation process is essentially to continue to influence the ISO developments using the channel of the national standardisation bodies and the participation of individuals, and then to validate and accept the ISO/TC 211 results. Two options are possible:

- CEN formally decides to accept ISO results making them 'mandatory' in the Member States;
- Each national standardisation body decides.

At the time of writing it is unclear which option will be taken. The next step will perhaps be to design 'regional profiles' of ISO standards.

6.2.3 The International Standardisation Process

6.2.3.1 'De jure' Standards – International Standard Organisation (ISO)

ISO TC 211

http://www.statkart.no/isotc211/

History

The Canadian member of ISO originally proposed ISO/TC 211 'Geographical Information/Geomatics' but an alternative nomination of the secretariat from the Norwegian member of ISO was adopted. The first plenary meeting was held in Oslo in November 1994, some 2½ years after the start-up of the CEN/TC 287.

Organisation and Policy

ISO/TC 211 established five working groups to cover more than 20 work items (see http://www.statkart.no/isotc211/pow.htm). These working groups normally hold meetings juxtaposed with the plenary sessions and mid-way between them if necessary. Occasionally, working groups call meetings to progress specific work items. As with CEN procedures, technical work is undertaken by specialist experts nominated by standards body members and liaisons. However, there is also the additional formality that each work item has an elected Project Leader and, possibly, a nominated Editor.

There is no equivalent in ISO for the direct funding of standards development by the European Commission as in the case of CEN. However it is conceivable that EC framework funding could be used to support a multi - Member State contribution to an ISO work programme.

ISO does not have compulsory standards because the concept of an ISO standard is that adoption should be entirely demand-driven. It has similar provisions for reports as CEN. Once adopted ISO standards are reviewed at five yearly intervals, as is the case with CEN's full standards (ENs).

Work programme fundamentals

The key milestones are transitions

- from Working Group draft to Committee Draft (CD),
- to Draft International Standard (DIS), and
- to International Standard (IS).

The scheduled time scale as a Committee Draft is six months and as a Draft International Standard nine months. Members (the national standards bodies) vote at each stage. At the Draft International Standard stage, a public consultation is organised by each member. The minimum time for standard development should be two years. In practice, it takes much longer, especially with a family of standards, because the cycles tend to be repeated.

Basis of family of standards

ISO/TC 211 is developing a more complete family of standards than those developed by CEN/TC 287: the family is said to be process oriented whereas the European work was concept oriented. The ISO/ TC 211 work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for Geographical Information, methods, tools and services for data management (including definition and description), acquiring, processing, analysing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. The work shall link to appropriate standards for information technology and data where possible, and provide a framework for the development of sector-specific applications using Geographical Information.

ISO/TC 211 Programme of Work

The following is the programme of work and can be found at: http://www.statkart.no/isotc211/pow.htm.

Project No.	Title
19101	GI - Part 1: Reference Model
19102	GI - Part 2: Overview
19103	GI - Part 3: Conceptual schema language
19104	GI - Part 4: Terminology
19105	GI - Part 5: Conformance and testing
19106	GI - Part 6: Profiles
19107	GI - Part 7: Spatial schema
19108	GI - Part 8: Temporal schema
19109	GI - Part 9: Rules for application schema
19110	GI - Part 10: Feature cataloguing methodology
19111	GI - Part 11: Spatial referencing by co-ordinates
19112	GI - Part 12: Spatial referencing by geographical identifiers
19113	GI - Part 13: Quality principles
19114	GI - Part 14: Quality evaluation procedures
19115	GI - Part 15: Metadata
19116	GI - Part 16: Positioning services
19117	GI - Part 17: Portrayal
19118	GI - Part 18: Encoding
19119	GI - Part 19: Services
19120	GI – Functional standards
19121	GI - Imagery and gridded data
19122	GI/Geomatics – Qualifications and Certification of Personnel
19123	GI - Schema for coverage geometry and functions
19124	GI - Imagery and gridded data components

Table 9: Programme of Work.

ISO/TC 211 future

One can expect that the full series of International Standards will be available by 2002.

ISO/TC 204

http://www.sae.org/TECHCMTE/204.htm

ISO/TC 204 - Transport Information and Control Systems (TICS), is the ISO equivalent of CEN/TC 278 covering the same themes. The two committees work closely together under the auspices of the Vienna agreement (see section 6.2.4.2 in this chapter) and some working groups are joint or linked.

There are 16 Working Groups. Working Group 3 - Geographical Referencing is responsible for five items of particular interest for the GI community.

Work item	Title	Target date
TR 14825	Geographical Data File	99/02
NP 14826	Physical storage for TICS database technology	99/09
NP 17267	Navigation system application program interface	99/11
PWI 3.1	Publishing update for geographical databases	98/08
PWI 3.2	Location referencing	99/03

Table 10: Items under responsibility of Working Group 3.

6.2.3.2 'De facto' standards – The Open GIS Consortium (OGC)

http://www.opengis.org/

History

The Open GIS Consortium Inc. (OGC), which has OpenGIS® as a registered trademark, was established in 1994. The operational structure of the consortium derives approaches to standardisation from a study of the successes and failures of past and current consortia.

Policy

OGC is designed to work closely with other consortia and the available 'de jure' processes. OGC is attractive to technology developers because the process is following strictly timed rules to be completed faster than CEN or ISO standardisation processes. Industry is directly represented and can undertake parallel development with reasonable confidence that their efforts will be rewarded by bringing compliant products rapidly to the market. OGC is particularly strong in this respect as major technology exploiters also support it, notably NIMA (National Imagery and Mapping Agency - US Defence). These are able to feed their requirements into the activities. The process involves only the minimum 'definition' work (Abstract Specification, Essential Models) needed to simplify the process of developing parallel interoperable implementation specifications.

OGC already has a high level of market acceptance and is able to devote resources to the growth of a global geospatial economy: it will ensure, eventually, the availability of plug and play components from many manufacturers and enable implementers to easily extend their use of technology.

OGC plays a key role in ensuring that the geospatial market is opened up through the provision of interoperable components and guaranteed access to all geospatial (data and software) resources. Moreover, it is a process that is open to all that can define their stake in the evolving geospatial market.

While much of the OpenGIS proceedings and documentation is proprietary to fee-paying members, the most useful documentation is available from the web site. Moreover, prospective members are always welcomed to at least one technical meeting: these take place six times annually, two of these being held in non-US locations.

Basis of family of specifications

The technology development activities of OGC have a single over-riding purpose that is to frame a new global market in which users buy and suppliers sell geo-processing technology and Geographical Information and services. This new market is vastly larger than the existing market for geo-spatial products and services for several reasons:

- the proposed capability to unlock the GI from its complex and proprietary data format that isolate it from main stream information systems;
- the imminent availability of geometrically controlled image-based geodata that needs new technology to be exploited economically; and
- the ability to geo-reference all kinds of data and data sets that have oblique references to location that will unlock this data to commercial exploitation.

The OGC vision is to

- develop Application Program Interfaces (APIs) to today's monolithic technology,
- open up development to add-on components,
- break the old monolithic technology down into components, and
- recycle the first generation component ware.

Liaisons

OGC has liaison relationships with Object Management Group (OMG), and ISO/TC 211 Geographical Information/Geomatics.

The OMG relationship is an important aspect of the development work. This is because OMG has spawned various offshoots such as 'Business Objects' (supported by the ESPRIT IT OBOE project) that are seen to be providing the basic trading components of future GIS, especially the 'brokerages' and on-line data providers.

ISO, CEN/TC 287 and OGC committees have resolved to co-operate (formal resolutions) and this includes providing access to each other's process. In practice, this is a formalisation and extension of the existing situation - many of the experts are the same. The resolution is supported by a shared business case that is designed to encourage further voluntary resource to be offered to both processes (and on which both depend).

Main achievements in 1999

Membership and organisational growth

As of June 2000, OGC has 200 members; 64 are European organisations and 2 of these are Principal Members. The OGC board of Directors now includes Canadian, European and Japanese members in addition to US members.

Specification Development

The key documents are the OpenGIS Abstract Specification and the OpenGIS Implementation Specifications.

The Abstract Specification is a living document comprising 16 topics subject to changes and addition at each OGC Technical Committee Meeting. Only members of OGC can formally propose changes and additions. OGC makes the current version (mid-1999: version 4) of the Abstract Specification public when an OGC Technical Committee Working Group issues a Request for Proposal (RFP) for engineering specifications that implement part of the Abstract Specification for particular distributed computing platforms. They may be down loaded from http://www.opengis.org/techno/specs.htm.

Topic No.	Topic Name	Topic No.	Topic Name
0	Overview		
1	Feature geometry	9	Accuracy
2	Spatial reference systems	10	Transfer technology
3	Locational geometry	11	Metadata
4	Stored functions and interpolation	12	The OpenGIS service architecture
5	The OpenGIS feature	13	Catalogue services
6	The coverage type	14	Semantics and information communities
7	Earth imagery	15	Image exploitation services
8	Relation between features	16	Image co-ordinate transformation services

Table 11: OGC's Abstract Specification.

The OpenGIS Implementation Specifications are the result of OGC's Technology Development Process. These are engineering specifications that implement part of the Abstract Specification for particular distributed computing platforms.

The completed specifications by mid-1999 are:

- OpenGIS Simple Features Specification for OLE/COM
- OpenGIS Simple Features Specification for CORBA
- OpenGIS Simple Features Specification for SQL

These are all at revision 1.1.

Conformance testing

The OpenGIS Testing Program was initiated and by mid-1999 successfully tested the Simple Features Specification for SQL in two products.

OGC future

It is obvious that OGC results will influence the Geographical Information market. It will provide standards for interoperable tools and services. OGC has chosen to focus on processes interoperability, not on the adequacy of the data in relation to the users needs.

The following project description of the OGC's Web Mapping Testbed (WMT) should demonstrate how OGC results are used in the Geographical Information market.

OGC's Web Mapping Testbed (WMT)
Rationale The main objective of WMT is to "rapid prototype" OpenGIS specifications for open, standard protocols to enable an ordinary web browser to access diverse web servers and display overlaid, georeferenced views of the diverse kinds of geodata served by those servers. This work builds on OGC's OpenGIS Simple Features Specification (for open access to basic vector GIS data processing), OpenGIS Coverages Specification (for open access to raster-based geoprocessing), and the OpenGIS Catalogue Specification (for metadata-based catalogues of online geodata and online geoprocessing resources).
Aims To provide a set of open interface protocols that serves a wide variety of web mapping needs.
Customers and Users Sponsors of the WMT were US Dept. of Defence National Imagery and Mapping Agency (NIMA), US Army Corps of Engineers Topographic Engineering Centre (TEC), the Federal Geographical Data Committee (FGDC), NASA, the US Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), and the Australian World Wide Web Mapping Consortium, a group of 24 Australian government and commercial organisations, led by the Australian Surveying and Land Information Group (AUSLIG). Users are initially the 200+ OGC members, who benefit from the results by getting privileged access to the underlying technology developed in the testbed. Eventually, after the technology has been made public, the entire GIS industry will benefit.
Application Description Approach and methods The Web Mapping Testbed is the first of OGC's planned Interoperability Initiatives, which involves sponsors and participants. Sponsors, government agencies or major corporations, provide funding and a set of objectives related to geoprocessing interoperability. In this case the objectives were based on user requirements in a hurricane response scenario. Participants, mainly vendors and integrators, are partially compensated for the contributions of time and technology they make during the fast-paced team effort to meet the sponsors' objectives. Data used Massachusetts Inst. of Technology, the city of Mobile, Alabama and other government agencies provided data and support for the testbed's hurricane disaster management scenario. Results Three protocols, GetMap, GetCapabilities, and GetFeatureInfo, were created and demonstrated to a group of 350 government officials. This was accomplished in approximately four months. Servers communicate automatically with a plain browser (Netscape Navigator or Internet Explorer, for example) with georeferenced overlays of multiple layers of vector and raster data of different kinds from various vendors' web servers. The servers ultimately deliver GIF images, but the protocols would also work with "real" data. A catalogue operates like a "spatial search engine" in which queries specifying regions and attribute types deliver a list of online data sources. Partners A group of about 30 IT companies (mainly from North America, Japan and Europe) is participating in this activity.
Web URL: http://www.opengis.org/wmt
Point of contact Kurt Buehler Email: kurt@opengis.org

Recommendations
OGC invites technology user organisations and technology providers to become involved in Interoperability Initiatives that will follow the Web Mapping Testbed. It is important that user organisations (such as national mapping agencies and major geodata-using corporations) pool their requirements so that specifications produced in this fast-track standardisation process meet the broadest possible set of needs. This is for the benefit of users but also for the benefit of providers: markets will be expanded most by specifications that meet the broadest possible set of needs.

6.2.4 Relationships national -> European -> Global

Co-operation between national standardisation bodies and CEN/TCs and ISO/TCs

This was explained in 6.2.1.

Co-operation between CEN/TC 287 and ISO/TC 211

The co-operation between these two committees is governed by a special umbrella agreement between CEN and ISO, known as the Vienna Agreement. This agreement establishes procedures for formal parallel development. In the case of these two committees it was possible to make formal agreements during the development work of CEN/TC 287 due to the timing aspects. The actual agreement is linked to a mutual exchange of progress reports and a recent resolution of the CEN/TC 287 committee to avoid locking European industry into its own standards development (by deciding to issue ENVs rather than ENs). Given that, for example, there are two metadata proposals with substantial evolutionary differences, it makes sense for the European industry to try to harmonise its interim implementation activities in order to achieve some level of interoperability in the short term.

Co-operation between ISO/ TC 211 and OGC

As a result of the OGC White Paper "Toward Implemented Geoprocessing Standards: Converging Standardisation Tracks for ISO/TC 211 and OGC", ISO/TC 211 issued Resolution 47.

ISO/TC 211 accordingly agrees to:

- establish a task force consisting of the chairman and the WG convenors to liaise with OGC;
- develop a business case to identify the benefits of this co-operation;
- seek establishment of a formal agreement with OGC for joint development of imagery and gridded data requirements;
- propose a joint project (case study) with OGC to demonstrate mutual co-operation and the feasibility of implementing the emerging ISO standard (ISO WD 15046-15 Geographical Information - Part 15: Metadata).

A draft business case for the harmonisation between the two organisations was presented at the June 1998 ISO Working Group meeting.

6.3 Interoperability Movements

To make "the ability of two or more systems or components to exchange information and to use information that has been exchanged" a reality in the GI world will take considerable time and effort, and will need many participants. These "interoperability movements" started almost a decade ago and yet end users are still facing non-interoperable situations. Different categories of actors are organised with the intention to solve interoperability issues. Some are solving some of the interoperability issues without knowing it.

For the last few years and in particular since the second "Geodata for all in Europe" EUROGI workshop (October 1996), there has been an emerging consensus that at least three levels of interoperability exist: systems, data and institutional.

6.3.1 At the System Level

The leading player for GIS is the Open GIS Consortium (see paragraph 6.2.3.2). It is expected that the GI industry will be able to offer to the GI user community a new generation of interoperable tools based on the OGC specifications.

Considering the broader context, other consortia are also organised to provide standards for interoperable solutions on which an interoperable GIS can be erected:

- The Object Management Group (OMG; www.omg.org) is mostly known as the consortium that established the CORBA middleware interface, which is not restricted to GI. OMG was founded in April 1989 by eleven companies; the consortium now includes about 800 members. The OMG is moving forward in establishing CORBA as the "Middleware that's Everywhere" through its worldwide standard specifications.
- The World Wide Web Consortium (W3C; www.w3.org) was created in October 1994 to lead the World Wide Web to its full potential by developing common protocols that promote its evolution and ensure its interoperability. W3C has more than 400 Member organizations from around the world and has earned international recognition for its contributions to the growth of the Web. W3C is financed primarily by its Members and to a lesser extent by public funds. W3C Membership is available to all organizations.
- INTERLIS is dedicated to 'Open and Documented GeoStandards' (www.gis.ethz.ch/interlis). This is a standard that has been especially created in order to fulfil the requirements of modelling and the integration of geodata into contemporary and future GIS.

Several technologies have merged and are emerging to facilitate interoperability. CORBA has already been mentioned above, some others are Java, XML/GML (Geographical Markup Language) and WAP (Wireless Application Protocol).

Developments in this field are moving extremely fast. For this reason, the Joint Research Centre of the European Commission has set up a so-called "Technology Watch", where all relevant technologies for interoperability are being monitored and summarised. This information is accessible under www.ec-gis.org/preanvil/.

6.3.2 At the Data Level

Interoperability as expected by the user is not only achieved by interoperable systems providing services, but requires also a common (interoperable) interpretation of the semantics of the data. Current production of data follows proprietary rules and in Europe, enormous efforts are being made by the public and private sectors to create pan-European geospatial data sets, for example MEGRIN, TeleAtlas and NavTech.

6.3.3 At the Institutional Level

The third level of interoperability relating to laws, regulations, agreements, people, etc. is of great importance. Having the technical interoperability between systems and data is not sufficient if users do not have the institutional rights and possibilities to exchange and use Geographical Information.

It is often the case that the political and organisational situation does not allow the exchange and use of GI. Movements toward this institutional interoperability started a decade ago at national and regional (multi-country) levels. These movements are described in more detail in chapter 4. In Europe, the Green Paper on "Public Sector Information in the Information Society" and the GI2000 Communication "Toward a European Policy Framework for Geographical Information" are initiatives aiming at providing a better level of institutional interoperability.

It is a long-term development and the process is extremely slow as political decisions will be necessary.

6.4 Conclusions

Standardisation of GI is vital for future development. Two major trends can be observed in this field. Firstly, there is the movement from standardisation at national levels to standardisation at the global level, with Geographic Data and GIS software becoming more and more worldwide products. Secondly, we see a movement from data exchange to direct access in distributed environments. This is reflected in the movement from standardised data formats to interoperability specifications.

There are four types of standards to be distinguished: Proprietary standards usually developed by a vendor, ad hoc standards designed for specific purposes or market segments, de facto standards developed by a consortium and adopted by large user communities, and finally de jure standards developed by official standardisation bodies.

National standardisation processes were predominant in the 1980s with a main focus in transfer standards. Nowadays, the focus is shifting to international processes. Several organisations are occupied with the development of supranational GI standards. On the European level, CEN has working groups TC287 and TC278 developing de jure standards. Internationally, this task is performed by ISO/TC211 and ISO/TC204. The Open GIS Consortium (OGC) develops global interoperability specifications. Although OGC develops de facto standards, close co-operation with ISO and CEN assures synchronisation of standards and avoids double work.

For users of GI and GIS, these standardisation processes are particularly important, because on the one hand they facilitate the use of GIS components from different vendors, rather than being limited to one product. On the other hand, on-line access to distributed geodata sources is being made possible, which is very important for the application, use and marketing of GI services over the Internet, through mobile phones and other wireless devices.

Suggestions for further reading

The field of standardisation in GI and GIS is a dynamic and fast moving one. Therefore, most literature tends to go out of date very quickly. For up to date information about standardisation developments, it is recommended to visit the respective web sites mentioned in the text of this chapter.

- A. Annoni and C. Luzet, Eds. (2000) *Spatial Reference Systems for Europe Workshop*, JRC-SAI, EUR 19575 EN.
- M. Konecny, Ed. (1998) *Geographic Information Systems: Information Infrastructures and Interoperability for the 21st Century Information Society* (Proc. of GIS Brno'98 Conference, 28 June - 1 July, 1998). Brno, Laboratory on Geoinformatics and Cartography, Masaryk University.
- C. Kottman (1998) *Progress Toward Interoperability and a Geospatial Infrastructure at the Open GIS Consortium.* 4th EC-GIS Workshop (24-26 June 1998), Budapest, European Commission DG III.
- O. Østensen (1996) ISO standardization in the field of geographic information: the global perspective. in: H. Moellering and R. Hogan (Eds.), *Spatial Database Transfer Standards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World.* Elsevier Science Oxford: 51-60.
- L. Rackman (1997) Convergence or Divergence? Recent European and International Developments in Standards for Geographic Information. in: *Lecture Material - Workshop G - JEC/GI 1997.* Vienna, 1997: G27-G38.
- F. Salge (1996) Standardization in the field of geographic information: the European efforts. in: H. Moellering and R. Hogan (Eds.) *Spatial Database Transfer Standards 2: Characteristics for Assessing Standards and Full Descriptions of the National and International Standards in the World.* Elsevier Science Oxford: 17-30.

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- *R. Nicolau (1998) Adoption of the Metadata Standards within SNIG, CNIG workshop: Challenges and Future Developments of GI Infrastructures - The Portuguese Experience. in:* GISPLANET'98, *Lisbon, Portugal.*

7. GIS APPLICATION DOMAINS

Aims & objectives	• Present domains in which GIS can be successfully applied. • Provide references (GI specialised magazines articles, books, web sites, conference papers etc.) for further reading. • Present examples corresponding some of the application domains (thematic field, implementation level, type of funding, geographical zone...).
Learning outcomes	• GIS is a widely applied technology (from local to global levels). • Internet is pushing for development of web-based services including GI layers. • Growth of the integration of different technologies and GIS (e.g. GPS).

The following chapter gives an overview of GIS application domains and some projects regarding different domains. It should also be noted a large part of GIS applications is in the field of defence and intelligence, i.e. outside the civilian thematic applications covered by this chapter.

The chapter is focused on the description of a wide spectrum of GIS application domains; GIS is a tool that is applicable in many fields. This inventory gives the reader an introduction to some of the possible uses of GIS. For some of the application domains, examples are provided, mainly chosen from the activities of the Joint Research Centre (European Commission), Ispra (Italy).

The presented projects deal with land use (mapping, monitoring, updating), forest (mapping, monitoring), soil (mapping, erosion and land degradation assessment), land registration and cadastre, integrated assessment, urban zones (mapping, monitoring, green management), and agriculture (crop yield forecasting, control of the implementation of the Common Agricultural Policy in the European Union, agricultural statistics). They cover a wide range of scale and information content.

It should also be noted that these GIS projects were selected for having a clear operational dimension. Research-oriented GIS projects were not taken into account, despite their obvious interest and usefulness in the future development of applications.

Homogeneity in the description has been attempted: for each detailed description of the selected GIS projects, information has been provided on background and rationale, aims and objective, customers, approach and methods, data used, results, partners, references, problems encountered and recommendations.

Other example of GIS applications can be found in the Extended Package (see the introduction of this book).

In the end, we would like to underline that a critical factor for the success of the development of a GIS application is the interaction among GIS experts and the operators (users) of the application domain. In recent years, initiatives have been taken to develop a common framework in which to promote knowledge sharing and then to exploit the development of applications in line with the user needs. Several such "Thematic Networks" have been set-up. A description of this approach and the resulting networks can be found in the Extended Package.

7.1 Agriculture

In the European Union, GIS techniques have been used in recent years for the production of agricultural statistics (acreage and yield for selected crops) and for the control of the implementation of the Common Agricultural Policy (CAP).

The activities related to the control of the CAP implementation have important financial consequences since they deal with control of the distribution of subsidies to farmers in 15 Member countries. The yearly subsidies to farmers are about 40.000 M€. More than 50% of the CAP subsidies are linked to geographical aspects (arable land and olive tree surfaces). The control with remote sensing covers 1% of all declarations. For example, in 1999, for CAP control with Remote Sensing, 20 contracts have been established with 50 companies, for a total of 21M€. This activity involves 10 European Commission officers, 50-100 National Administrations officers, 500 professionals in the private sector and 2000 professionals for ground survey verification using GIS and GPS technology. About 7.000.000 farmers prepare declarations using cartographic material. The new regulation n.1593/2000 makes the use of digital Land Parcel Identification System and GIS compulsory for the management and control of the area based subsidies. Total foreseen investments are estimated in 120M€, eligible to co-funding by the Commission.

GIS applications in the European Union and outside also include the preparation of a digital cadastre for permanent crops such as vineyards and olive trees. Some of the GIS applications, such as the CGMS - Crop Growth Monitoring System (developed within the MARS Project - Monitoring Agriculture with Remote Sensing) have been transferred to Central and Eastern European countries.

In the specific case of illicit narcotic crops, GIS technology is being used as a tool of assessment, monitoring and control at international or national levels.

Completely different are GIS applications in agriculture, at a more detailed level, for example for irrigation monitoring or precision farming. The combined use of GIS and GPS techniques may lead, especially in the case of large farms, to a more rational use of fertilisers, pesticides and insecticides and thus reduce the soil and water pollution induced by agriculture.

PROJECT DESCRIPTION: Crop Growth Monitoring System (CGMS)
Rationale The MARS (Monitoring Agriculture with Remote Sensing) Project from the Space Applications Institute of the Joint Research Centre (JRC) has been set up to provide the European Commission with objective, homogeneous and timely information on agricultural production of the European Union Member States. To achieve this goal, agricultural and meteorological modelling techniques have been combined into a Geographical Information System to provide agricultural yield estimates at the European level. The Crop Growth Monitoring System (CGMS) is driven by meteorological conditions, modified by other environmental factors such as soil characteristics and crop parameters. This mechanistic approach describes the crop life cycle from sowing to maturity on a daily time scale.
Aims To provide agricultural yield estimates at the European level and to monitor crop growth condition.
Customers: European Commission Directorate General Agriculture.
Users European Commission (DG Agriculture, Eurostat, JRC, etc.), National and Regional organisations, Research Institutes.
Application Description CGMS is made of 3 sub-systems, which are run sequentially: Level I: Weather monitoring. This module processes daily meteorological observations from weather stations to regular grid-cells of 50 km x 50 km with an interpolation procedure developed ad-hoc for the application. Level II: Crop growth monitoring. Simulations of crop growth are performed on a daily basis to provide quantitative indicators of crop growth (i.e. the Leaf Area Index LAI, the above ground biomass, the weight of the storage organ and the relative soil moisture) in combination with phenological development stage. The simulation is performed for each suitable Elementary Mapping Unit (EMU), consisting of a unique combination of the grid (weather parameter), the soil type polygon and the administrative region boundaries. The WOFOST model uses a combined energy balance/water balance module, which compares real transpiration with calculated potential transpiration. It describes the crop life cycle from sowing to maturity. Level III: Statistical yields forecasting. This module performs a regression analysis from historical statistical yield data and simulated crop growth indicators (above ground biomass and storage organ). The crop monitoring information produced by the CGMS is integrated into the MARS Bulletin and provided to the users, especially Eurostat and the European Commission Directorate General Agriculture. The MARS Bulletin is produced on a monthly basis during the crop-growing season and is available on the web (http://mars.aris.sai.jrc.it/stats/bulletin/).
Web URL: http://gi-gis.aris.sai.jrc.it/agro-meteo/

Point of contact
J. M. Terres, Joint Research Centre, SAI Email: jm.terres@jrc.it
Problems
The validation of the model has shown some weakness for regions of temperate climate (i.e. where trends over time are the main dependency for crop yield).
Recommendations
The modular structure of the system enables it to be transferred to different countries and modified for use at different scales. Furthermore, the CGMS system should be easy to adapt for research purposes in the field of agri-environment at regional scale. Candidate applications include phenological studies for crop suitability, agricultural potential production and regional hydrology. At local level, CGMS could support farming and environmental studies, for example, nitrate and pesticide leaching, ground water recharge or erosion.

Suggestions for further reading

- MARS project (http://mars.aris.sai.jrc.it/)
- Directorate General Agriculture (http://europa.eu.int/comm/dgs/agriculture/index_en.htm)
- Crop Growth Monitoring and yield forecasting at regional and national scale, C.A. van Diepen and T.van der Wal, pp.143-157, in Workshop for Central and Eastern Europe on Agrometeorological Models: Theory and Applications in the MARS Project, Office for Official Publications of the European Communities, EUR 16008 EN, 1996
- On the control of the implementation of the Common Agricultural policy, see Pascaud P.N., Baelz S., Fieldwork from on high, GIS Europe, 6/issue 3, March 1997 and Wagner M.J., Making crop sense with GPS, GEOEurope 8/issue 4, May 1999
- On the Agricultural Information System for South Africa (AGIS) (http://www.agis.agric.za)
- On the GIS of the International Maize and Wheat Improvement Center (CIMMYT), Natural Resources Group (http://www.cimmyt.mx/)
- On the Global Information and Early Warning System on Food and Agriculture (GIEWS), Food and Agriculture Organization of the United Nations, Rome (http://www.fao.org/giews/)

7.2 Land registration and cadastre

The use of GIS techniques is very important for the creation and management of digital cadastres in all the countries of the European Union and in Central and Eastern European Countries. These last countries have important ongoing land registration programmes, especially in light of the considered enlargement of the European Union.

Suggestions for further reading

- Niklasz L., Podolcsak A., Remetey- Fülöpp G., Baldwin R. The experience of Hungary in modernising a land registration system, Land Administration guidelines, Meeting of Officials on Land Administration (MOLA), Committee on Human Settlements, United Nations Economic Commission for Europe (see website: http://www.sigov.si/mola)
- Markus B., Building Web-based Land Information services in Hungary, AGILE Conference on Geographical Information Science, Rome, 1999.

7.3 Environment

At the local or regional level, GIS are frequently used for environmental impact assessment and planning. It should also be noted that GIS are increasingly used for the management of national or regional parks (fauna, flora, human activity), as well as for the monitoring of protected zones. Such examples are found within the framework of NATURA 2000 network covering around 10% of the surface area of the European Union. NATURA 2000 is a European network of areas, proposed under the Birds Directive and the Habitats Directive, where human activity must be compatible with the conservation of natural refuges. The use of GIS for integrated assessment is compulsory because apart from a few exceptions, NATURA 2000 sites are managed through productive activity.

GIS techniques, sometimes in combination with remote sensing, are also used in the tracking of wildlife or endangered species. This can be done by analysing location data provided by a satellite transmitter that can be attached on the animal of interest. GIS techniques can be used to assess the size and location of animal populations, to map supply-and-demand relationships to meet consumption requirements or to identify areas with a high food and habitat potential for given species.

GIS technology is also used for air quality monitoring by combining station measurements with topographic information and other types of input data, meteorological for example. GIS can be used at the global level for analysing and simulating the effect of an increase in the atmospheric carbon dioxide concentration on global warming and its possible consequences on present ecosystems.

It is also possible to combine GIS with spaceborne or airborne remote sensing data to monitor oilspill pollution.

Important GIS activities can also be mentioned in the field of water quality monitoring, in the case of groundwater and inland water (production of risk and vulnerability maps), as well as for coastal zones monitoring and management. GIS is a tool frequently used for watershed management and other applications such as hydrological modelling and groundwater flow modelling. The inter-disciplinary nature of GIS activities is an advantage for projects aiming at integrated management of watersheds. Catchment Information Systems are being designed and implemented at regional, national and international level. As an example, we can mention the development of a GIS for hydrological modelling of the River Rhine in which a water balance model has been developed in order to monitor the discharge of the Rhine and the resulting effects on such river functions as navigation and drinking water availability.

GIS techniques are used by institutions in charge of land management at the international level to improve their analysis and reporting capabilities. The CORINE (Co-ordinated Information on the European Environment) project is an example of a large-scale international project. This project was successfully extended to central and eastern Europe in the nineties within the framework of the PHARE Multi-Country Environment Programme. In the field of land management at international level, UNEP (United Nations Environmental Programme) has also implemented a GIS Project to map, analyse and monitor desertification around the world. Another example at the international level is the use of the MEDALUS georeferenced database (parameters measured at eight field locations on atmosphere, vegetation and land use, soil and surface) for land degradation monitoring and land use change analysis in the European Mediterranean.

PROJECT DESCRIPTION: The CORINE Programme - Co-ordination of Information on the Environment

Rationale

From 1985 to 1990, the European Commission has realised the CORINE Programme. The results are essentially of three types:

- An Information System on the state of the environment in the European Community has been created (the CORINE system) to be used in the orientation and application of the Community's environment policy, as well as for other Community policies.
- Nomenclatures and methodologies were developed and are now used as the reference in the areas concerned at the Community level. This approach has also gained use in Non-Member States (e.g. Air and Land Cover methods and nomenclatures in countries of Central and Eastern Europe).
- A systematic effort was made to concert activities with all the bodies involved in the production of environmental information especially at the international level. In 1990, a regulation, which establishes the European Environment Agency (EEA) was adopted. In the meantime a Task Force has been created within the Commission of the European Community's Directorate General for the Environment, in charge of the technical aspects of the preparation of the setting up of the EEA, including maintenance and use of the CORINE Information System. In 1991, it was decided to extend three main CORINE inventories (Biotopes, Air and Land Cover) to the Central and Eastern European Countries. One of the major tasks undertaken in the framework of the CORINE Programme was the establishment of a computerised inventory on the land cover (CORINE Land Cover project).

Aims
To prepare a land cover database for the twelve EC countries (2,36M Km2), at an original scale of 1:100,000, using the 44 classes of the CORINE nomenclature in order to provide those responsible for and interested in the European policy on the environment with quantitative data on land cover, consistent and comparable across the Community.

Customers: European Commission, National Ministries of Environment

Users
Regional Authorities, Environmental Agencies, Spatial Planners etc.

Application Description
Approach and methods
The analysis made in the definition phase of the project showed that, contrary to the situation met by the other CORINE projects, it was not possible to rely on available data to realise a Community-wide inventory on land cover. Existing inventories were either too specific (e.g. agricultural) or the areas covered were too small. These conditions largely determined the characteristics of the Land Cover Project (i.e. nomenclature and scale). The methodology consists of the computer-assisted photo interpretation of Earth Observation satellite images, with the simultaneous consultation of ancillary data, into the categories of the CORINE Land Cover nomenclature. The nomenclature distinguishes 44 classes, which are grouped in a 3-level hierarchy.
Data used
Satellite images, ancillary data (aerial photos, thematic maps, statistics etc.).
Results
CORINE Land Cover database
Partners
- Co-ordination: EEA-Task Force CEC, Brussels, together with Member States administration.
- Realisation: Land Cover teams in the Member States and regions, co-ordinated by the Project Leader assistance on technical problems (CORINE Land Cover technical team).

References
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- Perdigao, V. and A. Annoni, 1997. Technical and Methodological Guide for Updating CORINE Land Cover Database, Brussels-Luxembourg, EUR 17288 EN.

Web URL: http://etc.satellus.se/

Point of contact
C. Steenmans, European Environment Agency
Email: chris.steenmans@EEA.eu.int

Problems
- Difficulty to adopt a unique nomenclature,
- Harmonisation of data originally produced in different National Geographical Projections,
- Differences in the date of satellite data acquisition and in ancillary data availability.

Recommendations
- A good preparatory work reduces the number of problems to be encountered if:
- The vector data (and images) are delivered in the National geographical projection used.
- The information on all ancillary data used is collected.
- Common rules to maintain comparable data quality (i.e. screen scale of work) are established.

Suggestions for further reading

- European Environment Agency (http://www.eea.dk)
- M. De Cort, G. Dubois, Sh. D. Fridman, M. G. Germenchuk, Yu. A. Izrael, A. Janssens, A. R. Jones, G. N. Kelly, E. V. Kvasnikova, I. I. Matveenko, I. M. Nazarov, Yu. M. Pokumeiko, V. A. Sitak, E. D. Stukin, L. Ya. Tabachnyi, Yu. S. Tsaturov and S. I. Avdyushin, "Atlas of Caesium Deposition on Europe after the Chernobyl Accident", EUR report 16733, EC, Office for Official Publications of the European Communities, Luxembourg, 1998
- On surface water pollution monitoring, see Buttner G., Maucha G., Purging the past, GIS Europe, 7/issue 6, June 1998
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- Environmental Information Systems in Sub-Saharan Africa: from innovation to management, EIS News October 1997, Program on Environmental Information Systems, CSIR-Environmentek, Pretoria
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- M.de Wit, Nutrient fluxes in the Rhine and Elbe Basins, ISBN 90-6809-282-0, Netherlands Geographical Studies, Utrecht, 1999
- National Geographical Society MapMachine, http://www.nationalgeographical.com/mapmachine
- GIS solutions in Natural Resource Management (Editor Morain S.), Adams Business Media, Cambridge.
- Raimondi L., Secondini P., Tondelli S., Urban mobility, air quality and GIS: Integration experiences in the Bologna Province, AGILE Conference on Geographical Information Science, Rome, 1999.
- Painho M., Cabral P., Environmental Information System for the Environmental Regional Directorate of Alentejo-Evora (Portugal), AGILE Conference on Geographical Information Science, Rome, 1999.

7.4 Forestry

GIS systems are used for forest monitoring purposes at national or continental level. An example is the TFIS (Tropical Forestry Information System) within the TREES (Tropical Ecosystem Environment Observation by Satellite) Project of the Joint Research Centre. It provides information on deforestation rates in tropical ecosystems. In addition, GIS are also used in forestry at the local level for such purposes as forest resources assessment, harvest scheduling, treatment programs planning and modelling the spread of forest fires. GIS is also used in order to produce interactive digital atlases of forest fire history for given regions.

Suggestions for further reading

- Ireland P., Sorting the wood from the trees, GIS Europe Vol. 5 N.8, August 1996
- Hocevar M., Kovac M., Kobler A., Taming the wilderness, 7/issue 4, GIS Europe April 1998
- On the Tropical Forest Information System (TFIS), Tropical Ecosystem Environment Observation by Satellite (TREES) Project of the JRC, (http://www.trees.gvm.sai.jrc.it/)

7.5 Soils

GIS techniques are used for the management of soil digital databases at the regional, national or continental level (as in the case of the activities of the European Soil Bureau of the Joint Research Centre). GIS systems are used to combine information that is generally related to type of soil and erodibility class, land use and quality of soil protection, topography, or climate aggressivity as in the case for example of soil erosion risk mapping and monitoring. These data are generally combined and after qualitative or quantitative modelling result in the delineation of erodibility classes, expressed as soil losses in tons per hectare. The advantage of the use of GIS in this case is the possibility to update the map information periodically but also to allow new simulations by changing the model parameters or definition. At a later stage, GIS may be used for watershed rehabilitation purposes.

In 1990, the UN FAO performed a study on the use of high-resolution satellite data and GIS for soil erosion mapping. The study was performed in the State of Parana (Southern Brazil) particularly affected by severe soil erosion (sheet, rill and gully) due to a high deforestation rate followed by intense agricultural mechanisation. In a first approximation, the cost of one ton of soil was estimated at US $ 2. It was considered that the average soil loss is around 20tons/hectare/year, which represents a cost of US $ 40/hectare/year. For Parana State (199.060 km^2), surface erosion costs approximately US $ 40 x 6 million hectares of annual cropland = US $ 240 million per year (reference 1984). This analysis would be cost effective for mapping and monitoring purposes. Even if the cost-benefit analyses have to be performed specifically for each region or country, it is nevertheless clear that the costs associated with GIS - erosion monitoring are limited compared to the damage provoked by soil erosion and the budgets necessary for soil conservation programmes.

PROJECT DESCRIPTION: European Soil Information System (EURSIS)

Rationale

Soil information is now urgently needed in Europe for addressing a number of environmental problems and questions. These include: leaching of agrochemicals, deposition of heavy metals, disposal of waste (agricultural, domestic and industrial), degradation of soil structure (through loss of organic matter, salinisation and subsoil compaction), risk of erosion (by water and wind), immobilisation of radio nuclides, supply of water at catchment level, assessing the suitability (and sustainability) for traditional and alternative crops, and estimation of soil stability. To satisfy these needs, the European Soil Bureau (ESB) has been developing a European Soil Database, comprising a geographical data set, a semantic data set, a soil profile analytical data set, a soil pedotransfer rules data set and a data set of hydraulic parameters. It represents a first step in the development of a fully integrated European Soil Information System (EURSIS) that will ultimately be scale independent.

Aims

The main aim is to establish a fully harmonised soil database at continental scale to plan the sustainable use of the soil resources in Europe.

Customers: European Commission (DG Agriculture, Environment, Regional Policy in relation to the European Spatial Planning Perspective (ESDP), and DG External Relations and DG Development in relation to soil information in non-European Union countries). European Environment Agency (EEA). European Commission (DG Agriculture, Environment, Regional Policy in relation to the European Spatial Planning Perspective (ESDP), and DG External Relations and DG Development in relation to soil information in non-European Union countries). European Environment Agency (EEA).

Users

European Commission, Member State Governments, Regional Authorities, Environmental Agencies, Spatial Planners, Research Organisations (EU and Member States).

Application Description

Approach and methods

EURSIS consists of two major component workpackages:

- 1:1.000.000 scale soil geographical database and associated data sets: (a) geographical extension to TACIS and MEDA countries; revision of existing coverage, particularly border harmonisation and Former Yugoslavia; (b) thematic extension including applications
- 1:250,000 scale Georeferenced Database of Europe: development of a manual of procedures for use at European level: (a) testing the procedures in the Mediterranean (Italy), The Alps, Western Europe (France); (b) revision of the manual in the light of experience.

Data used

Soil data from European Union Member States, Accession Countries, EFTA States, PHARE countries (in total 28)

Results

The European Soil Database (available on CD ROM) incorporates the following data sets:

- Soil Geographical Database of Europe at 1:1,000,000 scale – geometrical and attribute data.
- Soil Profile Analytical Database of Europe (SPADE).
- Hydraulic Properties of European Soils (HYPRES) database.
- Pedotransfer Rules (PTR) database, for environmental interpretations.

Later versions will follow annually or biannually.

Partners

Members of the ESB Scientific Committee, – comprising technical experts from the European Union and neighbouring countries – for implementing the necessary activities. The Advisory Committee of the ESB – with representatives of the European Union Member States and the European Commission Inter-Directorate General Co-ordination Group on Soil Information.

References

European Soil Bureau (1998). Georeferenced Soil Database for Europe, Manual of Procedures Version 1. ESB, Scientific Committee. EUR 18092 EN, Luxembourg.

Web URL: http://esb.aris.sai.jrc.it/

Point of contact

L. Montanarella, Joint Research Centre, SAI
Email: luca.montanarella@jrc.it

Problems
The problems encountered are related to the extent of a project that covers 28 European countries. Diversity of the sources of data, complexity of the data collection process, ownership of the data.
Recommendations
Future success of the project depends on maintaining and nurturing the ESB network. Largely comprising the European Soil Bureau Scientific Committee, this network has been augmented by a number of other experts who have contributed through the European Soil Bureau's Working Groups. These groups need to be supported and encouraged as well. Developing a soil database appropriate for geographical representation at a 1:250.000 scale will require a significant increase in the level of support currently provided by the European Union.

Suggestions for further reading

- European Soil Bureau, (http://esb.aris.sai.jrc.it/)
- European Soil Bureau, Georeferenced Soil Database for Europe, Manual of Procedures, Version 1, ESB Scientific Committee, EUR 18092 EN, Luxembourg
- Kozak J., Nimecek J., Vacek O., Development of the Soil Information System for the Czech Republic, International Workshop on Land Information Systems, Developments for planning the sustainable use of land resources, Office for Official Publications of the European Communities, Luxembourg, EUR 17729, 1998
- Munteanu I., Grigoras C., Sorina Dumitru, Simota C., Dobrin E., Mocanu V., Iordachescu C., ROMSOTER-200: a Digital Soils and Terrain Database for Romania, International Workshop on Land Information Systems, Developments for planning the sustainable use of land resources, Office for Official Publications of the European Communities, Luxembourg, EUR 17729, 1998
- Dufour M.J.D., Hallett S.H., Jones R.J.A., Gibbons J.W., Spatial Information Systems for Environmental Impact Assessment in the UK, International Workshop on Land Information Systems, Developments for planning the sustainable use of land resources, Office for Official Publications of the European Communities, Luxembourg, EUR 17729, 1998
- Magagna B., Folly A., Honninger K., Muhar A., Quinton J., Sancho F., Strauss P., The SPIES Model: Data flow and GIS linkage between a soil erosion and a soil productivity model, Proceedings of the Fifth EC-GIS Workshop, Stresa, EUR 19018 EN, 2000
- Lantieri D., Dallemand J.F., Biscaia R., Sohn S., Potter R.O., Use of high resolution satellite data and Geographical Information System for soil erosion mapping, Pilot study in Brazil, Food and Agriculture Organization of the United Nations, RSC Series No 56, Rome, 1990.

7.6 Natural hazards

At the local or regional level, GIS is frequently used for environmental risk assessment. The need to integrate data from different sources and to introduce the spatial component in risk assessment are the basic requirements that justify the use of a GIS to perform these analyses. The typical activities linking to natural disasters are: risk assessment, simulation, assessment of damages, support monitoring and control during the crisis phase.

The GIS belonging to this category generally deal with forest fires, floods, landslides, avalanche, hurricane and drought. The users are generally civil protection agencies and emergency services and the systems usually rely on spaceborne or airborne remote sensing information. In the case of floods, if the contribution of remote sensing (Airborne radar for example) is mainly related to assessing the extent of the flood, the use of GIS opens possibilities of analysis/modelling/simulation prior to and after the event, thus allowing land management recommendations.

Regarding forest fires and considering only Southern Europe (Portugal to Greece in this case), the mean burnt area is estimated at 0.5 Million hectares per year. The economic damage (defined in this case as the soil protection work after the fire plus the possible afforestation) corresponds to 3.000 € per hectare and thus approximately to 1.500 M€ for the zone considered, without taking into account the en*vironmental and social damages.*

Suggestions for further reading

- Oder LISFLOOD Project, European Commission contribution to the International Commission on the Protection of the Oder River (IKSO) (http://natural-hazards.aris.sai.jrc.it/floods/)
- Kallidromitou D., Papachristou P., Bonazountas M., Caballero D., Forest Fire Management & Fire Prevention System, Proceedings of the Fifth EC-GIS Workshop, Stresa, EUR 19018 EN, 2000
- Barredo J.I., Hervas J., Lomoschitz A., Benavides A., van Westen C., Landslide hazard assessment using GIS and multicriteria evaluation techniques in the Tirajana Basin, Gran Canaria Island, Proceedings of the Fifth EC-GIS Workshop, Stresa, EUR 19018 EN, 2000
- Final Report of the SERGISAI Project (Seismic Risk Evaluation through integrated use of Geographical Information Systems and Artificial Intelligence techniques) (http://ade.irrs.mi.cnr.it/SERGISAI/)
- Pratt T., Dealing with disasters, Geoworld Vol.13 No7, July 2000
- Scholten H.J., Bonn B., Fighting the deluge with data, GIS Europe 6/issue 10, October 1997
- Forest Fire Risk Mapping activities of the Joint Research Centre, (http://natural-hazards.aris.sai.jrc.it/fires/)

7.7 Geology, geophysics and geotechnical applications

Mineral exploration is traditionally one of the first application domains for GIS. GIS has been used to analyse geological data in order to identify areas for new mineral explorations. In addition to mineral exploration, GIS have been used for simulation purposes in order to analyse the consequences of an earthquake on the response delay of fire and rescue squads. In countries with significant seismic activity, several teams work on the use of GIS for volcanic risk assessment for crisis prevention purposes.

Suggestions for further reading

- On the selection of radioactive waste disposal facilities in Hungary, see Turczi G., Szeiler R., Tullner T., Between a rock and a hard place, GIS Europe Volume 6, issue 5, May 1997
- Schofield A., A seismic shift for soil mechanics, GIS Europe, 7/issue 2, February 1998
- Delgado Martinez L., Perez Cerdan F., Jackson I., GEIX, A harmonised Geological Information System for Europe, Proceedings of the Fourth EC-GIS Workshop, Budapest, Joint Research Centre, European Commission, EUR 18667 EN, 1999.

7.8 Spatial planning

Spatial planning is a traditional domain where GIS tools are used by decision makers at all levels. Because spatial planning is more and more directly linked to the policies of the European Union a new initiative is started at the European Union level, the so-called European Spatial Development Perspective. It has three fundamental goals: economic and social cohesion, sustainable development and balanced competitiveness of the European territory. It should help integrating the environmental policy within other policies of the EU.

A number of EU instruments exist, affecting how land can be used or requiring that a certain type of land use should be respected within territorial development. These instruments include the Nitrates and Urban Water Directives, the agri-environmental Regulation, the Birds and Habitats directives and the Environmental Impact assessment Directive and the future proposal for the Integrated Coastal Zone Management - ICZM. In pure financial terms, two policies have a major impact on land use changes in the European Union: the Common Agricultural Policy and the Structural Funds.

At the regional level, a number of initiatives have been taken or are being finalised in the fields of urban development (Sustainable cities, Urban Initiative), wetlands management (1995 Commission Communication) and integrated management of coastal zones. These initiatives enhance the importance of spatial planning for the sustainable development of sensitive areas. GIS is thus a useful tool for producing the spatial information necessary to the follow-up of the European Union policies, at European or regional levels. Some projects such as LACOAST (coastal zones monitoring) and MURBANDY (urban areas monitoring) are contributing to spatial planning at the European level.

GIS techniques are also used for aquaculture development, for example identification of suitable sites for the construction of fishponds, taking into account the soil suitability and the temperature regime.

PROJECT DESCRIPTION: Digital Map Project of the Genoa Municipality
Rationale The Municipality of Genova spans over 24.000 hectares (about one third densely urbanised). The morphology of the area under its jurisdiction is very complex, due to its mountain/sea nature, characterised by deep valleys and abrupt land changes from densely urbanised areas to non-urbanised areas. In the last few years the Municipality of Genova has implemented a GIS, developing environmental and planning applications: nevertheless a more detailed base map was necessary to integrate those data with huge administrative databases.
Aims The Genoa Municipality is facing problems such as the restoration of environmentally unsuitable industrial sites, the flooding risk and the ageing of transportation structures (both rail and vehicular). To set up a proper tool to support analysis and solution of these problems the Municipality has decided to build a new large scale digital cartography (fully structured and topologically organised), 1: 1000 (urban areas) and 1: 2000 (non-urban areas).
Customers and Users The Municipality of Genova needs to create the city spatial data infrastructure for its own purposes and to exchange data on a common base with the other Administrations, Authorities, Agencies and Companies working with the geodata of the urban environment.
Application Description Approach and methods The implementation of the cartographic database is carried over by an external Data Provider and by the Municipality. Every phase of the Data Provider's work is verified: the strictly "cartographic" part is verified by sampling; the digital data is numerically controlled on the whole. In the ground control phase (carried out by GPS positioning) the co-ordinates of vertex points are calculated relative to the Cadastral Network. Data used The area was already covered by the 1: 5000 Regione Liguria Digital Cartography (graphic data files, without attribute data). The new cartography however comes completely from aerial photographs. Results The main features of the 1:1000 Municipal Digital Map are: 1. Base produced by digital image processing of aerial photograms; 2. Every map point defined as 3D (East, North, Height); 3. Planimetric co-ordinates mapped in the National Geodetic System (Gauss-Boaga); 4. Same frame of reference as the Regione Liguria 1: 5000 Digital Map; 5. Use of both Gauss-Boaga and UTM grid systems; 6. Feature attributes keys implemented as database keys to other Municipal databases; 7. "Neutral" ASCII format for transfer files. Partners Genoa Municipality, AMGA, DeFerrari-Galliera and Nicolay Acqueducts, ENEL, Genova Port Authority, AMT, AMIU, IACP, Societa' Autostrade and TELECOM-Italia. References S. Farruggia e R.E. Russo, A Geographical Information System for the Renewal of Genoa's City Centre, 21st Urban Data Management Symposium, Venezia 21-23 April 1999.
Web URL: Sit@mail.comune.genova.it
Point of contact Sergio Farruggia, Municipality of Genova, "Sistemi Informativi Territoriali" Department Email: sfarruggia@comune.genova.it
Present and future scenarios The most important issue is to perform address matching for different Departments' non-graphical databases. Occasional updates (both of Municipal and non-Municipal provenience) will be checked. The spatial database will permit detailed planning (and smaller scale planning) in public utilities, road planning and recovery, or emergency dispatching. The Municipal Digital Map will allow further services (some directed to the public): • Thematic data processing to help planning in the Municipal Departments. • On-demand GIS data processing. • Plain graphical digital data supply.

PROJECT DESCRIPTION: Monitoring Urban Dynamics (MURBANDY)

Rationale
Quality of life in the urban areas is high on the agenda of city planners and developers as well as the European Environment Agency (EEA) and European Commission. Current studies are addressing planning issues using socio-economic as well as physical datasets. Yet, such studies are seldom carried out at the continental level to provide a synopsis of the situation of urban landscape in Europe. The Space Applications Institute of the Joint Research Centre has launched several projects that use Earth Observation to support sound and sustainable development of Europe's landscapes, an issue that is addressed by the European Commission in a number of documents including the European Spatial Development Program (ESDP). One of the initiatives in this direction is the project "Monitoring Urban Dynamics" (MURBANDY).

Aims
Provide synoptic view of spatial extent of European cities, document and monitor their growth in the last 50 years, and develop scenarios of urban evolution. These objectives are subdivided into three tasks. First, implement an Earth Observation (EO) based procedure for monitoring cover changes in urban and suburban areas using very-high resolution imagery. Second, compute static and dynamic EO based urban indicators as well as EO/non-space data environmental indicators to help understand urban and sub-urban landscapes. Third, develop scenarios for sustainable urban development using a combination of EO and non-space data. Integration of space and non-space data is best accomplished by using the Geographical Information Technology that is used in this project.

Customers European Commission Directorate Generals involved in the European Spatial Development Perspective and European Environment Agency

Users
Regional Authorities, Environmental Agencies, Spatial Planners etc.

Application Description
Approach and methods

The project foresees three interrelated tasks:

- Change detection: Measuring changes in the spatial extent of urban areas and in urban structure in 25 urbanised areas in Europe. A period of approximately 40 years is considered.
- Understanding: Identifying a number of environmental indicators to be used to measure the "sustainability of urban and peri-urban areas". These indices could include the theoretical "ecological footprint" for the cities and the potential "carrying capacity" of urban and rural area supporting it. The two indicators above will allow the "sustainable development potential" of an area to be derived – i.e. urban landscape with surrounding agricultural and forested areas.
- Development of scenarios (Forecast). Develop "urban growth" scenarios for the 5 cities (initially) selected, using state of the cellular automata techniques.

Data used

IRS-C panchromatic satellite imagery, ancillary data in form of maps and aerial photographs.

Results

Four land use databases. (1) for 1997-98, (2) for early 80's, (3) for 70's, (4) for mid 50's. Indicators for urban sustainable development. Model outputs (scenarios)

Partners

National Mapping Agencies, EEA, EUROSTAT, National enterprises.

References

Ehrlich, D., Lavalle, C., Schillinger S. 1999. Monitoring the evolution of Europe's urban landscapes. IGARSS'99, Hamburg.

Web URL: http://murbandy.sai.jrc.it

Point of contact
C. Lavalle, Joint Research Centre, SAI
Email: carlo.lavalle@jrc.it

Problems
Definition and application of a harmonised legend for all 25 areas, accounting for specific issues in each area. Merging of statistical data sets and spatially geo-referenced data.
Recommendations
A good preparatory work reduces the number of problems to be encountered if: Ground Control Points are stored and used for (any) data georeferencing Land use databases are checked by people with knowledge of each city Calibration and tuning of the model is accurately performed

Suggestions for further reading

- Rachev B., Todorov V., Sirekov A., Racheva E., Nikolov N., Velkova D., ECOURBAN, An Ecological GIS for the City of Bourgas, Bulgaria, Proceedings of the Fifth EC-GIS Workshop, Stresa, EUR 19018 EN, 2000
- Von Rimscha S., Building the new Berlin, GIS Europe 6/issue 9, September 1997
- Ehrlich D., Lavalle C., Schillinger S., Monitoring the evolution of Europe's urban landscapes, Proceedings of the IEEE 1999 International Geoscience and Remote Sensing Symposium (IGARSS), Hamburg, 1999
- MURBANDY (Monitoring Urban Dynamics) Project (http://murbandy.sai.jrc.it)
- Boehner C., Haastrup P., Esposito M.A., A case study of Florence on the use of Geographical Information Systems and Remote Sensing for Urban Environmental Management, 1996, Report EUR 16386 EN, Office of Official Publications of the European Communities, Luxembourg, CL-NA-16386-EN-C, 1996
- National Wetlands Inventory Center, U.S. Fish & Wildlife Service (http://www.nwi.fws.gov/).

7.9 Transport

The use of GIS for transportation network management is growing. At national or international levels, GIS are used for infrastructure planning, safety assessment, environmental impact assessment, construction preparation, land use planning and emergency management. By combining information on geology, soils, water infiltration, topography, or land use, GIS are an efficient tool used in the process of road design.

At the local level, with the development of the access to digital cartography and the growing use of GPS systems, new applications appear that allow to improve or optimise the use of fleets of vehicles used for public transport or private companies distribution networks. One example would be in-car navigation systems. The possibility to monitor in real time the displacement of groups of vehicles allows better decisions and thus leads to cost savings for logistic decisions. Based on the use of GIS and GPS, management systems for freeway incidents or car crashes are also set-up.

Suggestions for further reading

- On public transport buses management, see Horbury A., There'll be one along in a minute, GIS Europe 7/issue 6, June 1998
- On planning of rapid train line, see Von Rimscha S., Towards a frictionless future, GIS Europe, 7/issue 9, September 1998
- Kux H.J., Penido L.R., de Mattos J.T., GIS techniques applied to highway planning: the Sao Paulo Metropolitan Ring Road (RODOANEL), Brazil, Proceedings of the IEEE 1999 International Geoscience and Remote Sensing Symposium (IGARSS), Volume V, Hamburg, 1999
- Wagner M.J., Geofocus: Emergency services, GEOEurope, 8/issue 6, June 1999
- On car navigation, see http://www.teleatlas.com

7.10 Tourism

GIS information is more and more used in the framework of tourist activities, especially for the planning of trips by travellers through searches on the World Wide Web. Many regions or cities have now developed databases that combine basic cartography with essential information for the traveller (hotels, places of interest etc.). This information can be easily accessed on the web through specialised searches and queries. GIS technology is also increasingly used in real estate transactions.

Suggestions for further reading

- Information Service of the City of Vienna: http://service.magwien.gv.at/wien-grafik/wo.html
- Hernandez A., Larrayoz P., Clerigué R., Saving the Canary that laid the golden egg, GIS Europe, 6/issue 8, August 1997
- Example of a web based Tourist Information System, see Kruger Park web site, http://www.ecoafrica.com/krugerpark/

7.11 Health, social policy and humanitarian aid

The usefulness of GIS in this field is related to the possibility of spatial monitoring of given diseases. This is achieved by integration of health parameters, for example, with demography, social or ecological parameters. Simulation possibilities of public health evolution in the case of respect/non respect of threshold conditions, such as atmospheric pollution, are very relevant. As an example, the World Health Organisation studied the use of GIS technology to improve the control of tropical diseases. At a detailed level, GIS technology has been used to study lead poisoning at city level.

There is also an ongoing development of the use of GIS techniques for humanitarian purposes, either as a tool for demining purposes or as a tool for reconstruction planning after a conflict.

Suggestions for further reading

- Women and heart disease: An Atlas of racial and ethnic disparities in mortality, Center for Disease Control and Prevention (CDC), West Virginia University (WVU), see web sites: http://oseahr.hsc.wvu.edu and http://www.cdc.gov/nccdphp/cvd/womensatlas
- Gatrell A., Loytonen M. (Editors), GISDATA 6: GIS and Health, 200pp., Adams Business Media, Cambridge
- Forcen E., Salazar A., GIS: An effective tool for disease monitoring, 9/issue 2, GEOEurope February 2000
- Bajic M., Fiedler T., Gorseta D., GIS for Demining activities in Croatia, GIS for Mine Infected Areas, Proceedings of the International Workshop on Demining Technologies, 29 September-1 October 1998, Joint Research Centre of Ispra, EUR 18682 EN, 1998
- Bouchardy J.Y., Winning the peace in Kosovo, GeoEurope 9/issue 7, July 2000
- D. Ehrlich, P. Reinartz, C. Hansen, C. Louvrier, N. Hubbard, H. Mehl, T. Richards, Satellite imagery and Geographical Information Systems in support to the reconstruction of Kosovo, Geo-Information Systems, In Press, (see web site: http://gmes.sai.jrc.it)

7.12 Telecommunications

In this field, the development in the use of mobile telephones presently creates new activities, since the definition of new networks must take into account detailed topographic information. The necessary Digital Terrain Models are produced or updated for the area of interest, in some cases using spaceborne imagery.

In the European Union, the objective of the trans-European telecommunications network policy is to contribute to the creation of a European Information Society, through the development of information and communication technology (ICT). The potential spatial impact of ICT is significant since there are still wide variations in the level of ICT provision and in the cost and reliability of services both between countries as well as within countries.

Suggestions for further reading

- On the Applications of the Synergy of Satellite Telecommunications, Earth Observation and Navigation (ASTRON Project), http://www.sai.jrc.it/astron.

7.13 Public sector - local and regional administration

The GIS are created by many local or regional authorities all over the world in order to manage an integrated database allowing localisation of the objects of interests (streets, buildings, water pipes, sewage network, electricity network, fire stations etc.), support of the routine network management and also performance of analysis or simulation. Generally based on topographic information, these systems can in some cases also integrate cadastral information. In the case of cities, the information content corresponds to a scale of approximately 1:500 or 1:1 000. Such systems can be useful for the territorial management at city level and the definition and monitoring of development plans.

The difficulties European content firms encounter in accessing, using and exploiting public sector information constitute another main barrier to their growth potential. Extended commercial use of this information could substantially expand the supply side of the market, providing added value services for the consumers. At the same time, much of the public sector information is commercially attractive and has the potential to be exploited in the market. New GIS technologies facilitate the collection, storage, processing and retrieval of information. Not only do they allow governments to improve their information management, strengthening the relation with citizens and businesses, but they also allow the exploitation of data collections commercially, and turning them into added value digital products and services.

Suggestions for further reading

- Friedmannova L., Large scale urban plans digital processing for local authorities, Proceedings of the Third EC-GIS Workshop, Leuven, Joint Research Centre, European Commission, EUR 17715 EN, 1997
- Kubicek P., GIS diffusion in district governments in the Czech Republic, Proceedings of the Third EC-GIS Workshop, Leuven, Joint Research Centre, European Commission, EUR 17715 EN, 1997
- S.Farruggia, R.E.Russo, A Geographical Information System for the renewal of Genoa's City Centre, 21st Urban Data Management Symposium, Venice, 21-23 April 1999
- Contini S., Bellezza F., The role of GIS in industrial risk studies, Proceedings of the Fifth EC-GIS Workshop, Stresa, EUR 19018 EN, 2000
- On a district Urban Information System, seeLand and freedom, GIS Europe, 6/issue 3 March 1997
- Vernez Mouden A., Hubner M., Monitoring Land Supply with Geographical Information Systems, Theory, Practice and parcel-based approaches, 416 pp., Adams Business Media, Cambridge.

7.14 Utilities management

GIS in this field are mainly used for the management of water, electricity and gas networks. The networks are represented in the GIS and combined with data about users. The GIS is mainly used in the case of connections to the network, network maintenance, interventions planning, network analysis and simulation. In the case of water management, it is not only used for water distribution purposes but also to optimise wastewater treatment and sewer operation.

Suggestions for further reading

- On gas network management, see Sdrallis M., Rogakos V., Mourtzinou N., A new flame, GIS Europe 6/issue 7, July 1997
- Vaynchtok A., Gitis V., Andrienko G., Ermakov B., Erkhov V., RESOURCE: knowledge based GIS for oil and gas resource monitoring, Proceedings of the Fourth EC-GIS Workshop, Budapest, Joint Research Centre, European Commission, EUR 18667 EN, 1999
- On planning of the location of electricity pylons and high-voltage power lines, seeHebert M.P., Argence J., Virtual pylons into geographical reality, GIS Europe, Volume 5 Number 8, August 1996.
- Bernhardt U., Von Rimscha S., The short-circuit route to systems analysis, GIS Europe 6/issue 7, July 1997

7.15 Socio-economy

A large part of the statistical data collected by the Statistical Offices has a spatial component. These statistical data relate for example to populations and activities (agriculture, industry, tourism), which vary geographically and temporally. The management, processing and use of statistical data are thus to a large extent a spatial process. The statistical data are collected for territorial units of different size and ranking that in the case of the European Union are called NUTS ("Nomenclature des Unités Territoriales Statistiques"). Even if the territorial framework for data collection is generally satisfactory, it is far from ideal for many applications. For example, especially in the case of environment, many data are collected through point measurements (meteorological data, air quality data etc.) or through natural units (habitats, watersheds etc.). This leads to a need of use GIS tools for spatial transformation of statistical data in order to improve the visualisation of the data, to aggregate or disaggregate data to different scales, to combine or compare data collected in different spatial units and to extrapolate in the case of missing measurements of extrapolation.

In the field of socio-economy, an example of use of GIS techniques is given by projects aiming at the mapping of population densities at municipality level, by disaggregating population data and imputing different densities to different land use/land cover categories (urban areas, agricultural land, natural vegetation areas etc.).

Suggestions for further reading

- Martin D., Towards an integrated national socio-economic GIS: the geography of the 2001 census in England and Wales, Proceedings of the Third AGILE Conference on Geographical Information Science, Helsinki, 2000.
- Benenson I., Omer I., Studies of the GIS of the Israeli population census: high-resolution urban patterns and individual residential segregation, Proceedings of the Third AGILE Conference on Geographical Information Science, Helsinki, 2000.

7.16 Geo-marketing

With an ever-increasing number of users, electronic commerce is growing rapidly, sometimes using GIS applications and rapidly meeting new problems, at juridical level for example.

The Geo-marketing or Geo-Business activity is growing thanks to the ongoing development, by public postal services or limited companies, of georeferenced postal address databases. The use of GIS in geodemographic analysis and targeting allows companies to improve their marketing by better selecting their target audience or types of consumers.

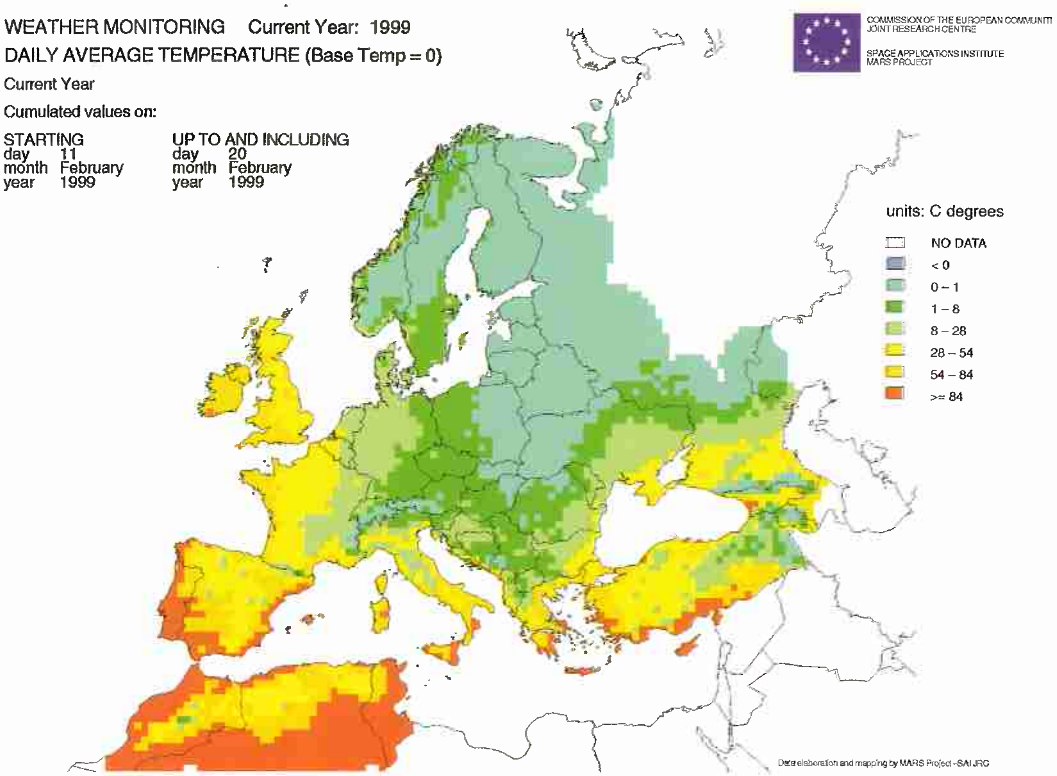
GIS is also used in logistics for distribution planning (allowing to minimise the products distribution costs).

Suggestions for further reading

- R. Waters (1999) *GIS for the retail market: combining town plans and geodemographics*, Proceedings of the Fourth EC-GIS Workshop, Budapest, Joint Research Centre, European Commission, EUR 18667 EN.
- P. Longley and G. Clarke (1995) *GIS for business and service planning*. Adams Business Media, Cambridge.

As a complement to chapter 7 and related to some of the application domains, and examples provided therein, some pictures are added to further illustrate the outlined GIS applications. They show projects at different levels (from the European to the Municipality scale), also with Remote Sensing imagery, demonstrating the wide range of GIS applications for territorial analysis and the link between GIS and techniques such as Remote Sensing.

AGRICULTURE



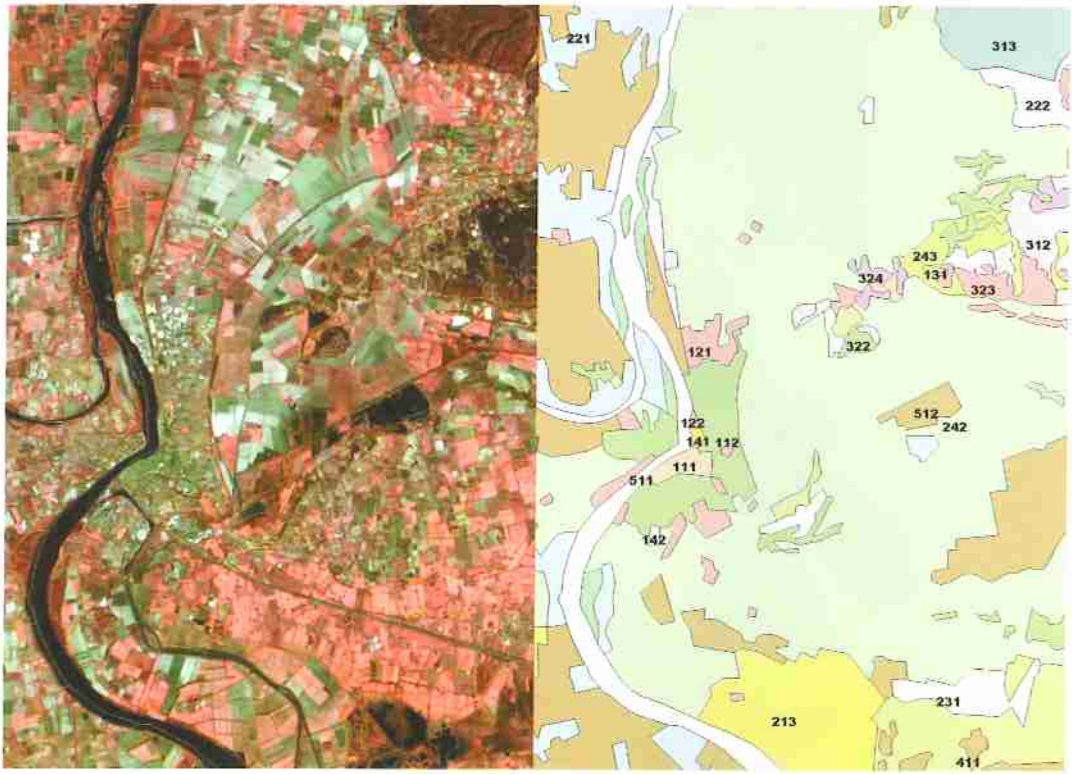
Example of output of the Joint Research Centre Crop Growth Monitoring System (CGMS), see project description at page 102.

AGRICULTURE

Remote sensing imagery for land use/land cover mapping and agriculture monitoring. Example of a Landsat 7 satellite image of the North-East of France (15 meters resolution Panchromatic and 30 meters Multispectral merged). Colours are associated to different crops or ploughed fields. An airport, railway and the road network can also be seen.

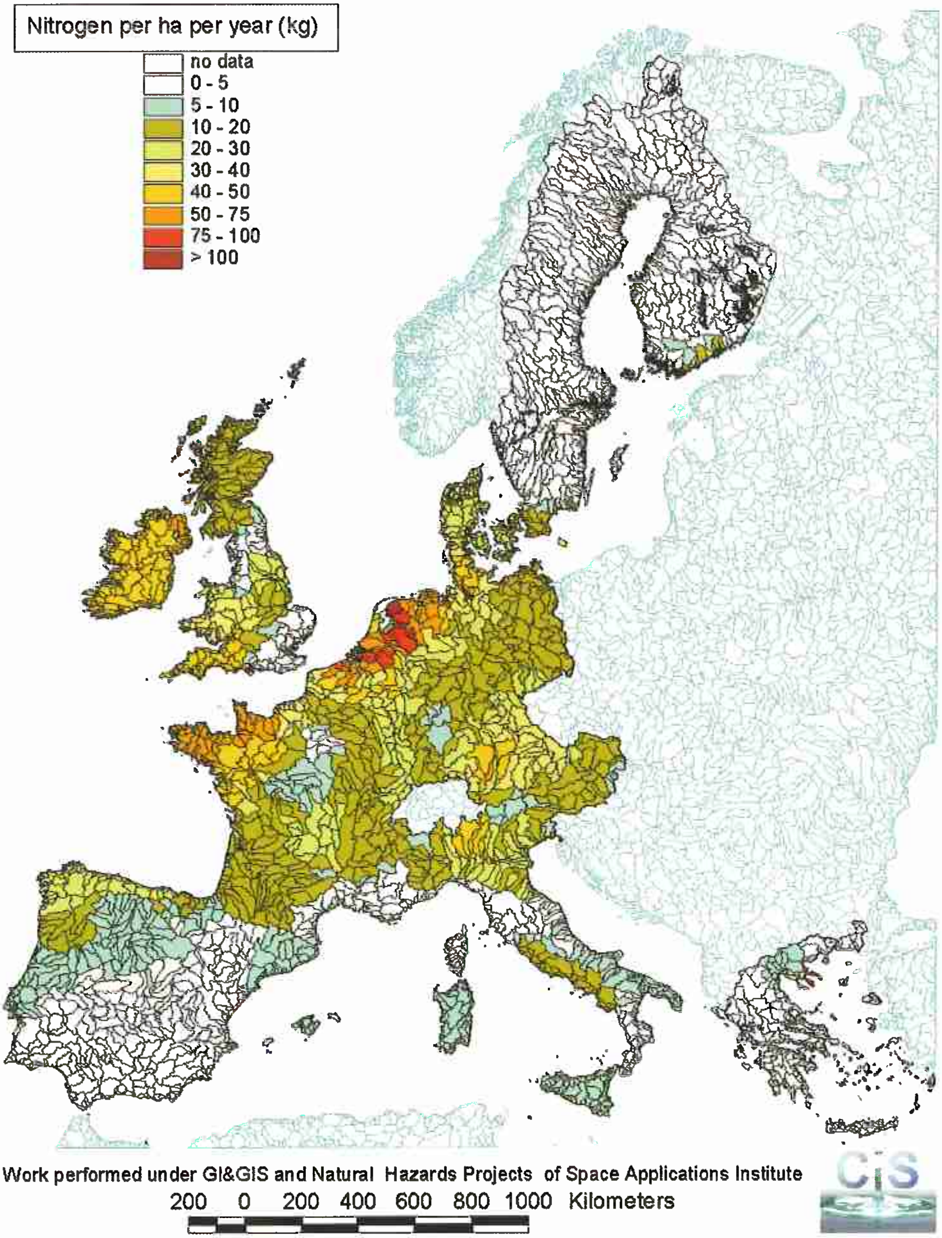
(by courtesy of ESA/distributed and elaborated by Eurimage)

ENVIRONMENT



CORINE Land Cover Mapping Project, example from Provence (France).
Left: Landsat Thematic Mapper satellite image.
Right: Corresponding interpretation result and CORINE nomenclature codes.
See also page 104.

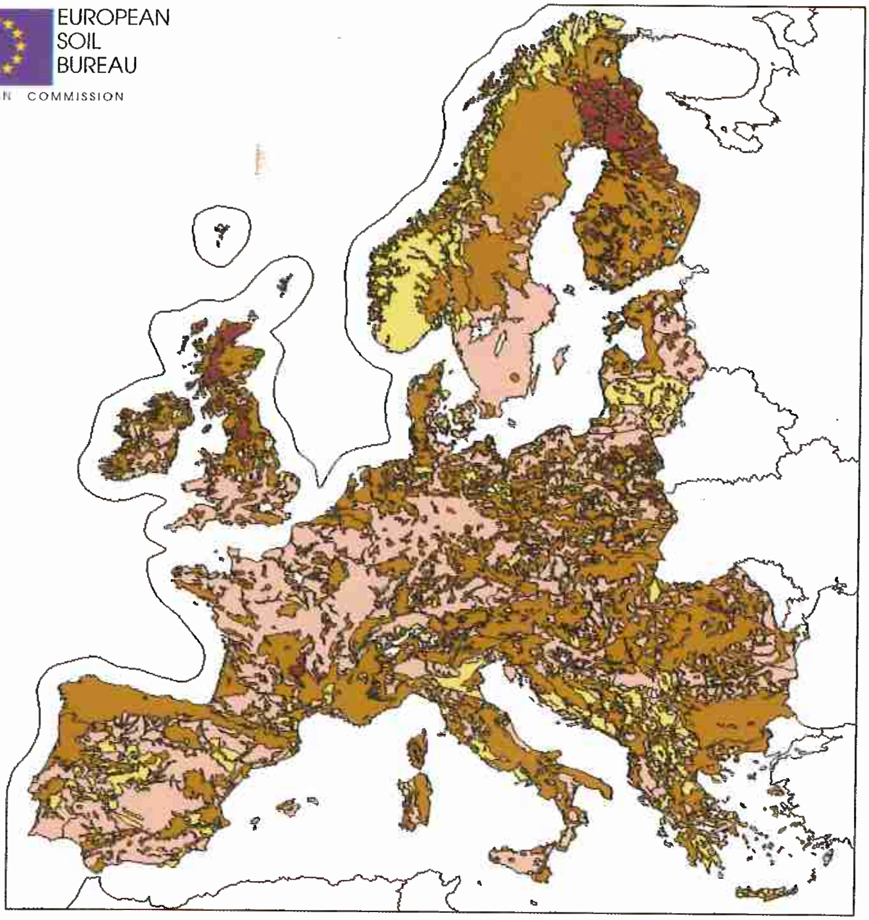
ENVIRONMENT



Nitrogen from Manure, Bovine Animals, European Union, 1994
Data Sources: Livestock Number: Eurostat Regio Database
Catchments: JRC-SAI, Natural Hazards
N-Equivalent Manure: Directorate General Environment.D.1
Realization: Catchment-based Information System
Projection: GISCO (Lambert Azimuthal Equal Area)

SOILS

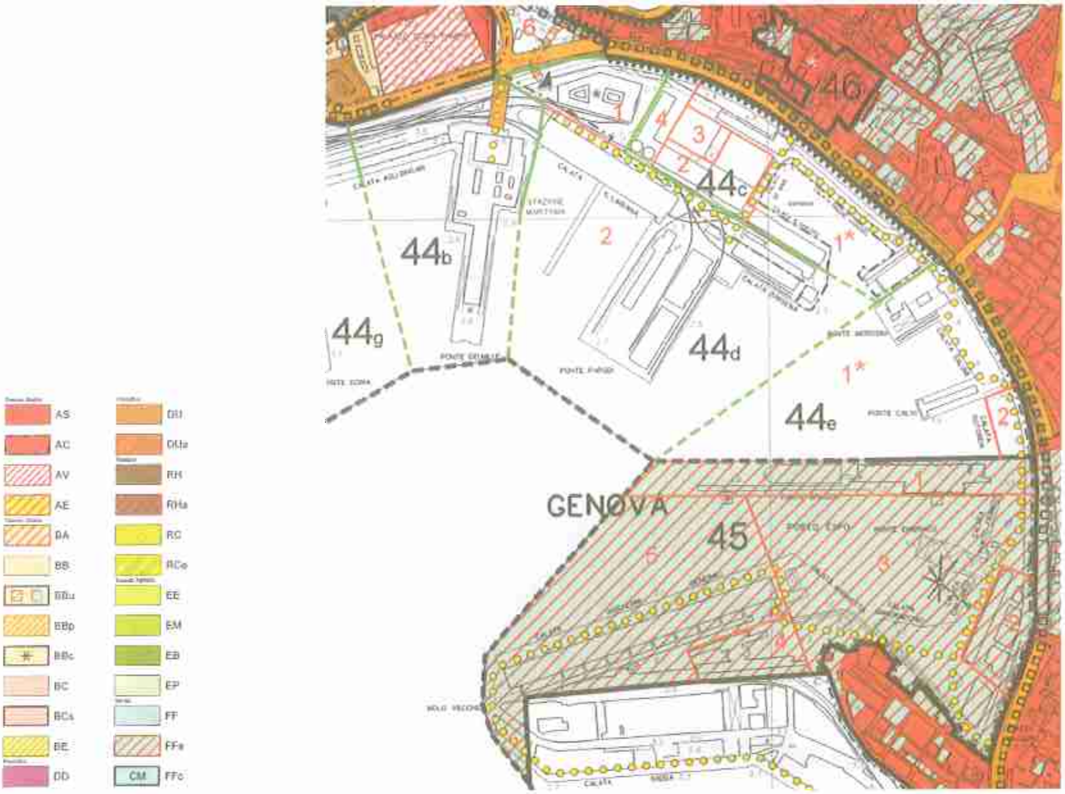
EUROPEAN
SOIL
BUREAU
EUROPEAN COMMISSION



Topsoil organic carbon content of the European soils
Map derived from pedo-transfer rules of the European Soil Database at scale 1:1.000.000

(by courtesy of European Soil Bureau)

SPATIAL PLANNING



Digital Map Project of the Genoa Municipality (see Genoa Municipality project description at page 110)
The picture shows an area of the PUC (Municipal Master Plan) zoning in Genoa, as approved on March 10th, 2000. In particular, it is possible to see:

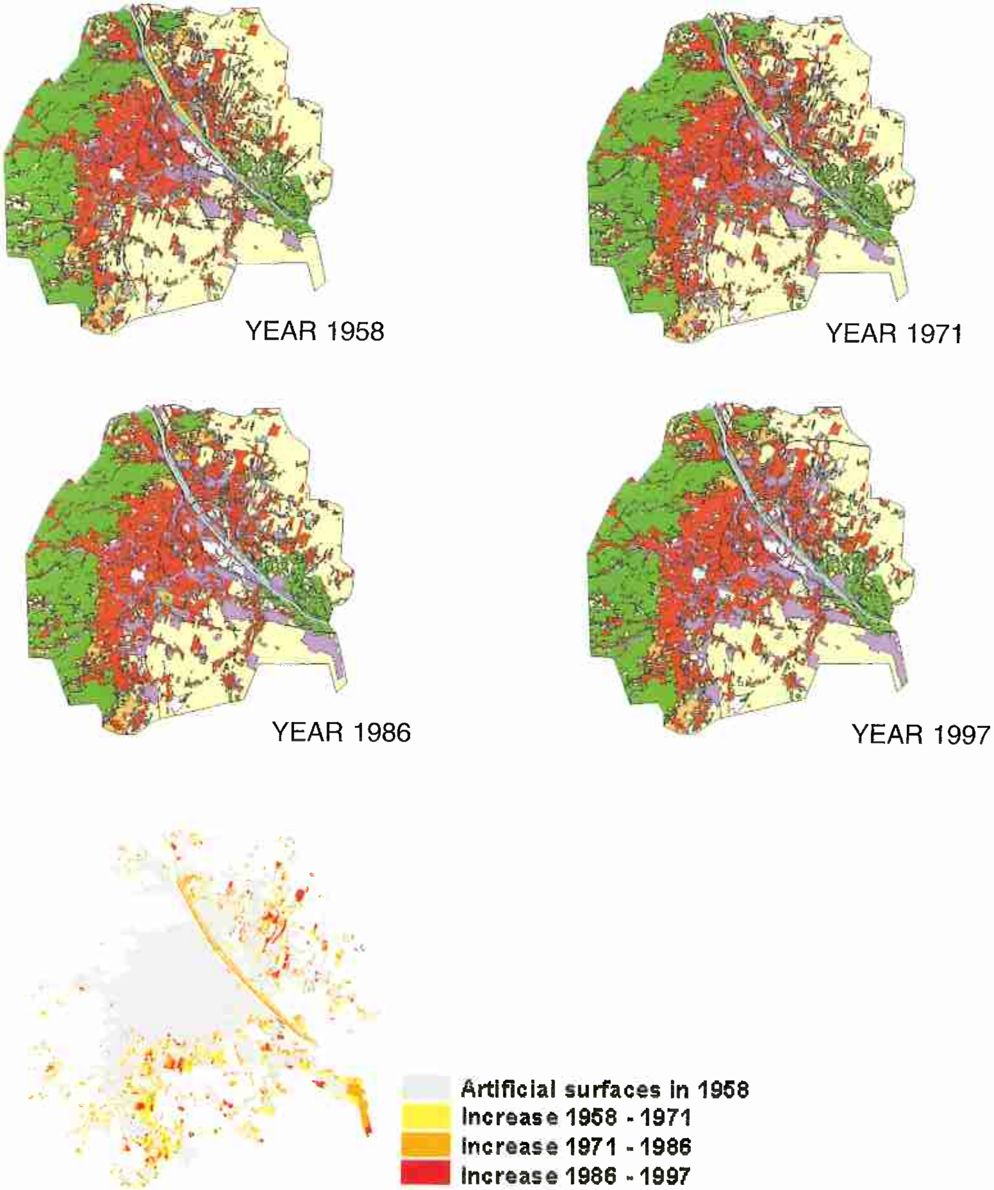
· an area in the city historic centre (AC)

· an area for services (Ffa), in the Old Port, which includes the "Columbus Expo'92" district.

The base map used in the background is from the Regional Technical Map, produced by the Liguria region at the scale 1:5000.

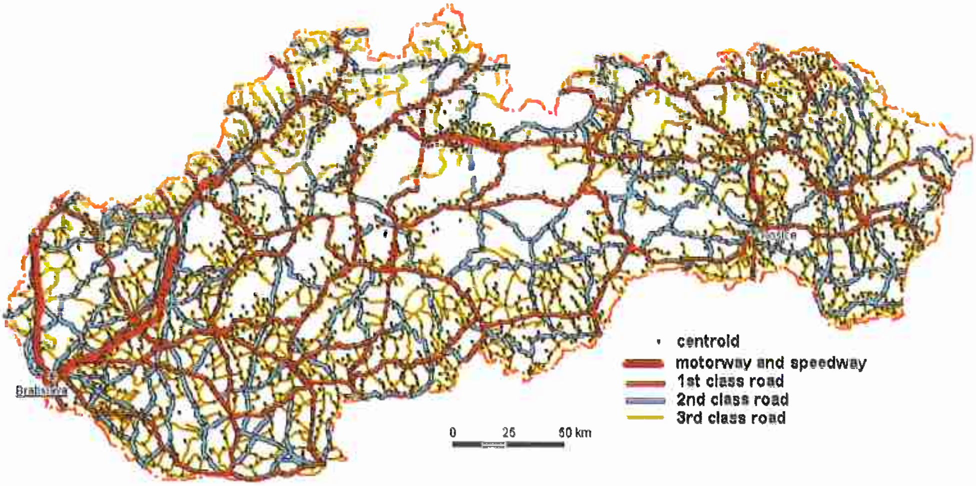
(by courtesy of Genova Municipality)

SPATIAL PLANNING

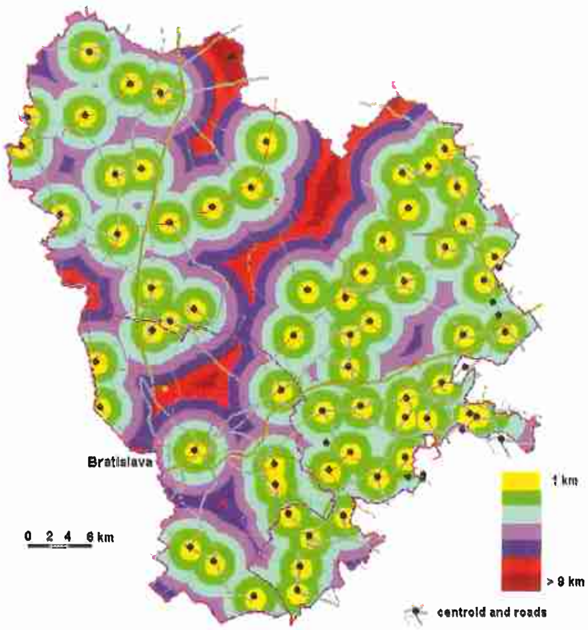


MURBANDY project: Land use maps for the City of Vienna and increase in built-up area from 1958 to 1997.
See also project description at page 111.

TRANSPORT



Map of the road communication and centroids of the settlements in the Slovak Republic



Map of isochronic road connections of settlements in the region of Bratislava.

(by courtesy of Dr. Dagmar Kusendova, Comenius University, Bratislava, SK)

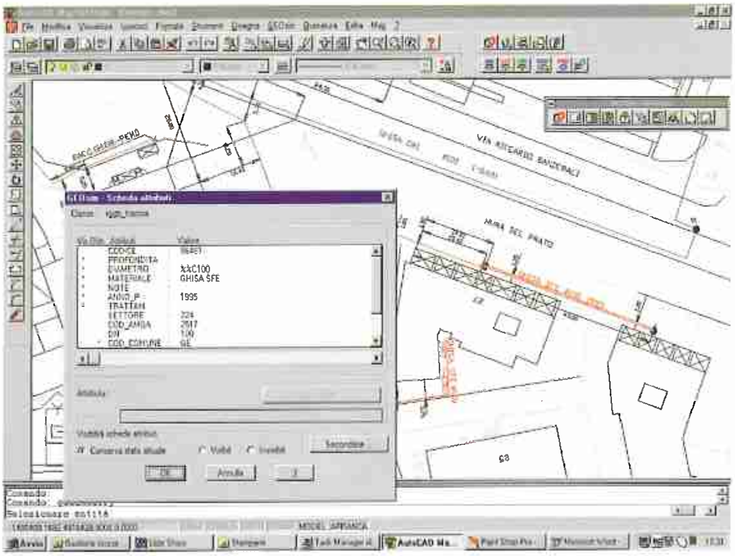
PUBLIC SECTOR - LOCAL AND REGIONAL ADMINISTRATION

Remote sensing imagery for urban area studies.
Example of a Landsat 7 satellite image of the region of Rome (15 meters resolution Panchromatic and 30 meters Multispectral merged). Tevere River, Fiumicino Airport and a burnt area can also be seen.

(by courtesy of ESA/distributed and elaborated by Eurimage)

UTILITIES MANAGEMENT

Some of the characteristics presented by GIS addressing utilities management are:
a database able of giving full information about the network elements, a clear graphic display to schematize the geometrical and technical features and a fast and easy update from non IT-skilled personnel



GIS for Water Network Management (by courtesy of AMGA SpA, Italy).

8. TRENDS

Aims & objectives	• Show in which direction GIS technology and spatial information applications are developing.
Learning outcomes	• There is a trend from "Big GIS" to "Small GIS". • Transportation and mobile technologies become increasingly important. • The GIS business is becoming more user-oriented and market-driven. • There will be more and more integration of GIS into mainstream IT.

Geographical Data is crucial for the economic development of a country, it is central to the protection of the environment and it contributes to a democratic society. Most geographical data are acquired by people living in their environment and used daily without thinking about it. Technology constantly changes our world, two changes affect the way we handle geographical data in particular:

- Transportation technology, especially cars, but also air transportation – has increased people's mobility. We find ourselves more often in places we do not know and depend on the availability of Geographical Information to find our way to the hotel, to the station etc. The adaptation of cities to individual transportation with cars has reduced our abilities to find our way using simple concepts and increased our reliance on outside providers of explicit Geographical Information.
- Information technology makes it possible to collect, process and deliver information in ways not previously possible. Information is valuable to improve decisions and decision makers in public and private request more information. As many decisions are related to space, Geographical Information is needed.

8.1 From Batch processing to Interactive and Network computing

GI today has evolved through two phases to reach the current situation. It is useful to understand this succession to plan evolutions.

8.1.1 Isolated systems

Most countries have National Mapping Agencies and other similar agencies that collect geographical data systematically and make them available in map form. Originally, maps were produced manually and paper maps printed to distribute the data to the users. Mainframe computers have been used to assist with map production methods since the early 1970's and we can see a first phase of GIS as a tool to produce maps, which are then distributed in paper form. This applies equally to National Mapping Agencies producing topographic maps, cadastral offices producing real estate maps and public utilities maintaining paper maps of their pipes and cables.

At about the same time, regional and town administration used computers to map their localities, but also discovered the use of computers for spatial modelling and analysis. All their queries were provided by invisible computers and only the products (paper maps mostly) communicated to the users.

8.1.2 Interactivity

Interactive, multi-user computers with small networks of directly connected terminals provided the technology to produce Geographical Information on demand: instead of producing Geographical Information as a map and to distributing it to all potential users who consult the map when they have a need for Geographical Information, users were directly connected to the database and could pose their questions as they come up and get immediate answer in form of a cartographic sketch.

8.1.3 Integration

The advent of the Internet and mobile communication technology, where essentially every user is connected to every computer in the world opens the path for the delivery of Geographical Information to whoever needs it, exactly when it is needed and in the form most effective for the decision to be made.

8.2 Technology Push versus User Demand

To understand the trends in GIS, which are opened by technology changes one has to compare the possibilities the technology opens with the demands of the users. A wide variety of users in many different situations could use very different forms of Geographical Information.

The value of Geographical Information is the improvement of the decision to which it contributes. The cost of acquiring the information reduces its value and must not be larger than the value of the information; otherwise the user is better off making the decision without Geographical Information. The cost of acquiring the Geographical Information consists of the payment to the owner of the information. It also includes all the time invested, learning and the equipment that the user must have to access the geographical data. Unless Geographical Information is very simple to get, it will usually not be used.

The early GIS and especially the early adapters of GIS in the 1970s and 80s were mostly fascinated by the technology and used GIS because it was possible to make maps with computers. The benefits of the GIS were often described summarily and cost-benefit assessments often were not carefully made, in consequence many early projects were not completed technically. On the other hand, some were technical successes but failed to find users and a substantial number had difficulties maintaining organisational support and appropriation of resources, because benefits to the organisation could not be demonstrated.

8.3 GIS based on Cost-Benefit Assessment

GIS projects today must be based on a careful assessment of the benefits the GIS will bring the organisation. The information the GIS produces, what we call the 'Geographical Information product', must be assessed for its value to the business. The overall contribution Geographical Information makes to the business goals must be evaluated. GIS that do not substantially contribute to the strategic goals of the organisation and are not cost effective should not be started, because they will eventually fail (This does not include projects that are done for demonstration and experimentation. In these, the value is in the experience gained and this must be compared to the cost).

This approach fits completely with the concept of 'business re-engineering', where quality of decisions, quality of responses to users and timeliness of information and decisions are all appropriately valued. GIS can improve services to users: for instance public utilities can respond more quickly to new clients who ask to be connected for services, can schedule preventive maintenance and respond more quickly to interruptions in services etc. if their network database can connect with their clients database.

For many companies, GIS is a strategic investment, which is crucial for the business to survive in today's competitive situation. This is especially true for all public utilities, which move from a public (protected) non-competitive environment in market competition. Timely, up-to-date information about the network improves services and reduces cost. The investment is not so much in GIS technology, but in up-to-date, accurate data collections. The substantial cost of data transfer from analogue to digital is not so much the cost of the translation per se as the cost of correcting all the mistakes, omissions etc. which are found once the data can be systematically analysed. It is payment for past oversight and an investment for future business.

8.4 Distributed GIS

GIS are connected to the web and can be distributed: servers provide data that is used by many clients. In this sub-section we discuss aspects that relate to 'close user group' (or intra-net) solutions: data are collected and used by a small number of organisations. Contractual arrangements for protection of data, compensation, liability etc. are set up initially and cover a multitude of interactions.

Today, providing GIS data to a large and initially unknown group of users is possible. In such cases, contractual arrangements are set-up for each use. We treat this case in a later subsection under the heading of 'e-Commerce'.

8.4.1 Technology

Today's web technology permits the connection of a user with any computer on the web. This is of great benefit to GIS, as it permits integration and the use of data combined from different sources. The promise of spatial integration of data from different sources according to location can be fulfilled without the physical centralisation of data in a single location. Today's technology does not justify physical centralisation. Technically it is sufficient to connect the different data holdings logically using a distributed database system.

The design of new GIS applications must always consider the Internet as a means to distribute the data storage and thus resolve organisational problems of data ownership, and a means to deliver the results to a larger number of potential users.

8.4.2 Logical connections between data bases

The logical connection between databases permits us to treat the data found in multiple data collections as if they were a single logical data base and ask questions about the compound holding. This requires the construction of an integrated database schema, which indicates how the different data are brought to a common interpretation on which the query processor can operate (Devogele *et al.* 1998).

No fully automated approach for schema integration is known today and often no complete integration is necessary. It is typically sufficient to identify the data which should be shared and describe the common semantics. This is best done in face-to-face discussions of the people responsible for data collection and data use.

8.4.3 Organisational aspects of distributed GIS

The potential of connecting the data holdings of different organisations and using them jointly, overcomes the reluctance of independent organisations to give up their ownership of data and bring them into a central pool. Organisations often believe (mistakenly) that having the data gives them power and do not understand that in today's competitive but co-operative world, sharing of information benefits both sharing partners. Technical means today permit to resolve all questions of data sharing – if a clear policy is agreed upon, the technical solution can be constructed, usually from standard components (Onsrud and Rushton 1995).

Data that is maintained by one organisation but made available to others can be protected such that only the first organisation can update it but all others can read it. A recent EU project developed an automated mechanism, which permits the co-operating organisations to propose updates to the data and send them for validation and integration to the 'keeper of the original' (Frank 1999).

8.4.4 Compensation for data use

Questions of compensations between users of data and the providers are difficult to address. Traditionally the discussion is defined by the effort and the cost invested in the initial collection of the data and the cost of maintenance. It is recommended that the value of the data to the user is also considered.

8.5 Metadata and Open GIS

Investigations in the potential for re-use of geographical data have shown that most users who would need geographical data do not know that others have already collected them. Advertising the availability of data is an important first step to realise re-use. The information that describes the data available is called meta-data, data that describes the data.

Standardised formats for metadata have been established (see chapter 6). They help providers of data collect necessary data in a uniform format, which can be inserted in a database and queried automatically. Unfortunately, the current metadata standards usually have a data producer perspective. They describe in detail how the data was collected and treated. They do not respond to the user's questions about what the data could be used for (Timpf *et al.* 1996). The potential user must have extensive and detailed knowledge about data collection technology to deduce which data is usable for his application. Metadata are very important for knowledgeable users, but they are not the answer to a widespread use of GIS.

Once data is localised, the transfer of the data and the conversion from the format the data is stored in to the format in which it could be used is necessary. Widely used commercial data formats and standardised transfer formats are requirements for use of off-the-shelf data translators.

The Open GIS concept (see section 6.2.3.2) brings interoperability into the area of the web: instead of transferring complete data sets as files from computer to computer, the user can access the particular data she is interested in. The advantage is that the data accessed is the current, up-to-date version, not the version that was acquired and transferred a few months ago. To allow this, the client software on the computer of the user and the server software on the computer of the organisation maintaining the data collection must communicate the users' precise need for data and respond with the data required in the formats agreed upon.

Open GIS makes cooperation of GIS software from different vendors possible. It is not important that the same vendor provides all the software under which the data are collected and stored. Different systems can be used and be accessed from software from various vendors. From the user's perspective this avoids the trap of having the data in a proprietary format of one vendor and not being able to use software from other vendors. High cost is not incured, when changing from one vendor to another one (Varian 1996).

The Open GIS consortium is an industry group, which sets the standards required for this interaction. It follows a layered approach. The same Open GIS standard can be implemented on various Internet interoperability standards and corresponds to the spatial extension of SQL. A recent demonstration (the "Web Mapping Testbed", described in 6.2.3.2) has shown how different data sets maintained under different GIS products can be integrated and used to solve complex problems.

8.6 Small, Business-Oriented GI

GIS in the past decades was mostly built for public administration, to help them with the collection and management of spatial data for complex planning and administration purposes. A single organisation managed the data and used them. IT, especially the web, has opened new opportunities: the use of GI in business.

New opportunities to start a business are created: Companies can collect and maintain data or assemble data from other sources into useful packages and make the data available for others. This makes a GI business possible, where a single user cannot cover the cost of collecting the data for the occasional use she/he has – but a multitude of users together create a viable business.

For example, Business geography – the use of spatial demographic data for business, in particular marketing – is a very rapidly growing field. Large companies acquire data sets and software for their marketing divisions to plan publicity campaigns, to identify regions where there is potential for increased sales etc. Small companies do not use geographical data often enough to warrant acquisition of the data set. In a current EU project Small and Medium Enterprises are given access to the same geodemographic data and application software on a 'pay per use' concept[1].

These new opportunities to provide various business processes with the necessary Geographical Information in a cost-effective manner are very large: they are given in real-estate marketing, tourism, travel, road navigation, etc. One can assume that the volume of these businesses is in total much larger than the current GIS business, which mostly addresses the

1 For examples of geomarketing see: www.gismo.nl or www.wigeogis.at

needs of large, public organisations. In this 'small GI' business, each transaction is small, the amount of GI provided is small and the value is limited, but the number of transactions is very large. Consider, for example, a business to provide the nearest taxicab for each request a small fee – once set up, a fully automated money-maker!

8.7 e-Commerce

Widespread use of GI by many users is only viable if the complete transaction can be completed over the Internet and no human intervention on the provider side is necessary. The user electronically requests the data – probably using an Internet enabled web browser, which follows the Open GIS standard, completes electronically the arrangements for payment and gets the requested data delivered.

To fulfil this dream, e-Commerce software, which manages the business relations between a provider and its users, and the Open GIS software must be integrated (Wenzl 2000).

8.8 GI and Telecommunication

The past few years have seen a change in the telecommunication industry: the wire-based telephone system has changed to a wireless telephone and, correspondingly, the wireless broadcast radio and TV move quickly to a cable-based system. The potential for every person to reach and to be reached at any place by phone is very attractive. Diffusion of the GSM technology for telephones is extremely quick and the next generation of UMTS communication systems is planned as we write this. In some European countries, 70% of the population has GSM phones and the numbers are growing everywhere.

The ability to communicate person-to-person by voice telephones and between computerized systems is a major new factor for GIS. GIS is built on the promise to produce and deliver Geographical Information where it is needed and replaces the previous paper-based maps, where Geographical Information had to be produced ahead of times and distributed to all potential users who then had to extract the information they needed – reading a dense topographic map and drawing the right conclusions is quite difficult! With GMS or UMTS a person in need of the Geographical Information can connect to the GIS and get the exact information needed at this moment. This is further simplified by the fact that the position of a GSM phone is known and can be used to select the information of interest for the user. Most obvious are examples from transportation, where a user can ask "which street at this crossing leads to Hotel X", or applied to users of public transportation "which bus will take me most quickly to Hotel X?" and "where is the bus stop?"

The current technology is GSM for communication between two phones, and WAP (Wireless Application Protocol) for communication between a phone and the Internet. The current technology is far from perfect but it shows clearly what services are possible and how they can be organised. It is too limited in bandwidth to be used in more than special cases or for demonstrations, but the UMTS with ten or more times the bandwidth will allow easy-to- use services for many different classes of users.

Technical development occurs not only for processor speed, disk capacity etc., which is widely advertised by the computer manufacturers, but also in the *form factor.* IT devices become smaller and therefore portable. Communication technology does away with cables and allows wireless communication. This makes it possible to carry around computers and communication devices with GPS receivers. Manufacturers are working on integrating these – there is a palmtop cum GSM phone combination on the market and prototypes of GSM phones with GPS antennas are shown. Researchers discuss "wearable computers" (see MIT Media Lab - http://www.media.mit.edu/wearables/). There are technical difficulties with batteries and foremost with usability. Constructing user interfaces for very small and powerful devices with many functions is a major challenge. Most users of GSM phones restrict themselves to a small percentage of the total functionality offered (very similar to VCRs) (Norman 1988).

This breakthrough in technology (communication, portability and integration of devices) relevant for Geographical Information opens the door for new services and therefore for new business opportunities. It is most likely that these services will be offered by independent private companies and it is, in the current political climate, not expected that governmental agencies will enter this market. Services could be:

- emergency services for road side assistance, as well for persons travelling in cities by foot or using public transportation,
- information about the best mode of travel to a destination and then continuous information along the path (http://gi13.geoinfo.tuwien.ac.at/users/winter/ss00/MobileNav.html),
- information about services, from nearby restaurants, hotels and museums to general information based on 'yellow pages' helping people to find any business, or
- information for tourists about sights (e.g., information about special events and locations).

In each case, a potential provider has to evaluate carefully what the value of his service is to the customer and how many customers he may find to assess the economic viability of a business idea. Clearly, all these ideas require the availability of the base geographical data, e.g. topographic data, street network etc. and investments today in improving the quality of this data and the access to the data will pay off in the future fostering such new GI businesses.

8.9 General Integration of GI into Mainstream Computing

The separation of GIS from other software packages in the 80s and 90s must be overcome. Very little is special about spatial, but these special aspects must be covered by interoperability standards. In most aspects, GI is similar to other data and must follow the general standards. Users demand that the result of geographical analysis can be integrated in reports – for example when they write Environmental Assessment Reports. New businesses are possible if for example:

- GI can be combined with e-Commerce; we can sell Geographical Information to tourists.
- A routing algorithm can be combined with regular order processing,
- Geographical Information can be used to give people ordering supplies using the web: an accurate prediction when it will be delivered is possible.

This integration of GIS into mainstream computing is best documented with the introduction of the MapPoint GIS viewer into the Office suite of Microsoft. This shows the recognition that a large number of business users of Office have a need to use geographical data in one form or another.

8.10 Easily and cheaply available data is the fuel for GI business take-off

The availability of the few core data sets that are most often used in an easily usable format and attractive business conditions are the primary conditions to have a viable GI business take off. This is clearly visible when one compares the European situation and the situation in the USA. In the USA geographical data have long been freely available to the public. GI businesses have been able to flourish using these basic data. In Europe the situation is much more difficult, as public institutions sell their data, usually at high cost.

References

- *T. Devogele, C. Parent, and S. Spaccapietra (1998) On spatial database integration.* IJGIS *12(4 - Special Issue): 335-352.*
- *A. Frank; Raubal, Martin; Van der Vlugt, Maurits, Ed. (1999)* Multi-Agency Databases to Manage Geographic Information. *GeoInfo Series 16. Dept. of Geoinformation, TU Vienna, Vienna.*
- *D. A. Norman (1988)* The Psychology of Everyday Things. *Basic Books, New York, NY.*
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- *H. R. Varian (1996) Differential Pricing and Efficiency. First Monday.*
- *P. G. Wenzl (2000)* A Technical Concept for Pay-per-Use in Geomarketing Services. *Dept. of Geoinformation, TU Vienna, Vienna.*

CONCLUSIONS

This book describes how Geographical Information is used and produced with today's Information Technology. It attempts to give an overview of the situation in Europe. We have seen the contributions provided by the technology to change the way Geographical Information is collected, managed and distributed. We witness a transformation of the Geographical Information industry from cartography to GI business. The transformation is gradual and follows the potential provided by the technology with a delay of several years, because the industry consists not only of the technology – which could be changed quickly – but also of organisations and institutions, which are much slower to change.

When the first cars were designed, they appeared as "horse drawn carriages without horses", but had the same form, the same basic parts as horse drawn carriages. It took more than fifty years to develop a "car" structure that was emancipated from the horse carriage. Similarly, when information technology was initially applied to cartography, the product was still a map and distributed as a printed paper map. Slowly, we find new, more suitable solutions where information is produced and communicated on demand in small units – just what is needed.

We hope to have shown the availability of the technology to improve the methods used for collecting, managing and distributing Geographical Information. The technology is here. We have also provided a glimpse at the thousands of useful applications, where Geographical Information can help people, citizens, companies, organisations and governments to make better decisions and thus help us to make better use of the limited resources of the world and to improve citizen wealth and the environment at the same time. The demand is here.

Many of these applications need relatively simple, often used geographical data, topographic map data, demographic data as collected by the national statistical offices, which is all stored on some computers. The computers are linked together and technically the bits can be transferred from the source to the place where they are needed. There are challenges in providing the organisational structure to make this happen.

The world is not only technology and not everything that is technically feasible should be done. The unlimited collection of information about people and their communication would change the way we interact socially and is potentially dangerous for human society. It is necessary to carefully assess the dangers and the benefits and to establish rules that preserve important values of society (e.g. personal freedom, privacy etc.). These values are not the same for every society and therefore the rules must be adapted to the particulars of different countries.

The organisations that are involved today with Geographical Information, National Mapping agencies in particular have an important role to play in the future Information Society. Geographical Information is widely used and it has been proposed to consider it as an "infrastructure" which a country must provide as it provides roads, police or education. The role of agencies for Geographical Information Infrastructures is different from the role of today's National Mapping Agencies – not less important, but very different. Every organisation involved with Geographical Information today is facing the challenge to find the new role it plays in the future Geographical Information Infrastructure.

The future for Geographical Information is bright: there is a strong demand that is increasing rapidly. New technology makes the production and distribution of Geographical Information much more feasible. Geographical Information Systems move from systems designed by specialists for specialists and having few users within closed organisations to systems designed for use by the population at large. The market will truly explode if we can provide the services requested.

To make this happen, the technology must be made simpler to use through standardisation: unnecessary complications that result from proprietary solutions have no place in the Information Society of the twenty-first century. Organisations must adapt to the Information Technology – which is not a problem specific to Geographical Information as the general discussion of copyright etc. testifies. The spatially aware professionals, that is surveyors, geographers, environmentalists, and all the other professionals working with spatial data can jointly contribute to allow progression at the turn of the millennium.

ANNEX 1: LINKS

This annex will contain links (URL's) and keywords to EU-related sites and big initiatives such as European commission, joint research Centre GIS page, Centre for Earth Observation, Agenda 2000, agenda 21, GNSS etc. this list of links can also be found at the PANEL-GI website http://www.gisig.it/panel-gi/.

European Commission	
Europa, European Union web server	http://www.europa.eu.int/
European Commission Community Research and Development Information Service (Cordis)	http://www.cordis.lu/
European Commission Information Dissemination on GI and GIS	http://ams.egeo.sai.jrc.it/
Joint Research Centre (JRC)	http://www.jrc.org/
JRC Space Applications Institute (SAI)	http://www.sai.jrc.it/
Information Society Technologies Programme	http://www.cordis.lu/ist/
Information Society Promotion Office (ISPO)	http://www.ispo.cec.be/
GI and GIS Project (JRC)	http://gi-gis.aris.sai.jrc.it/
European Commission Directorate General Enterprise and the Information Society	http://europa.eu.int/comm/dgs/information_society/index_en.htm
GISCO (Eurostat)	http://europa.eu.int/comm/eurostat/
Centre for Earth Observation (CEO)	http://www.ceo.org/
Agenda 2000	http://europa.eu.int/comm/agenda2000/
National/International links	
European Environment Agency (EEA)	http://www.eea.dk
Multipurpose European Ground Related Information Network (MEGRIN)	http://www.megrin.org/
Association Française pour l'Information Géographique (AFIGEO)	http://www.cnig.fr
The Association for Geographical Information Laboratories in Europe (AGILE)	http://www.uniroma1.it
Association for Geographical Information (AGI) (UK)	http://www.agi.org.uk/
Portuguese National Infrastructure for Geographical Information (SNIG) (Portugal)	http://snig.cnig.pt
The Citizen component of the SNIG (GEOCID) (Portugal)	http://geocid-snig.cnig.pt/
National Land Survey of Finland (NLS)	http://www.nls.fi
The National Mapping Agencies of Europe (CERCO)	http://www.cerco.org/
National Centre for Geographical Information and Analysis (NCGIA) (USA)	http://www.ncgia.ucsb.edu/
The Association of the Geological Surveys of the European Union	http://www.eurogeosurveys.org/
Geocommunity	http://www.geocomm.com/links/education/

ESRI	http://www.esri.com/
INTERGRAPH	http://www.intergraph.com/
LASERSCAN	http://www.laserscan.com/
SICAD Geomatics	http://www.sicad.com/
PCI Geomatics	http://www.pcigeomatics.com/
Data and Metadata	
European Spatial Metadata Infrastructure (ESMI)	http://esmi.geodan.nl/
National Geospatial Data Clearinghouse (NSDI) (USA)	http://nsdi.usgs.gov/
MEGRIN's Geographical Data Description Directory (GDDD)	http://www.megrin.org/gddd/
National Spatial data Infrastructure (NSDI) (USA)	http://www.fgdc.gov/
Global Spatial Data Infrastructure (GSDI)	http://www.gsdi.org/
Interoperability	
GIS Interoperability Stimulating the Industry in Europe (GIPSIE)	http://gipsie.uni-muenster.de/
Open GIS Consortium (OGC)	http://www.opengis.org/
PANEL GI Project partners	
Geographical Information Systems International Group GISIG (Italy)	http://www.gisig.it
CNIG (Portugal)	http://snig.cnig.pt
European Umbrella Organisation for Geographical Information (EUROGI)	http://www.eurogi.org/
Technical University of Vienna (Austria)	http://www.geoinfo.tuwien.ac.at/
National Institute for Research and Development in Informatics, ICI (Romania)	http://td1.ici.ro/
National Land Information Systems Users Association (GISPOL, Poland)	http://www.gispol.org.pl
Masaryck University (Czech Republic)	http://www.geogr.muni.cz/
FOMI (Hungary)	http://www.fomi.hu/
HUNAGI (Hungary)	http://www.fomi.hu/hunagi/index.htm
Technical University Sofia (Bulgaria)	http://www.vmei.acad.bg/
University of Zilina (Slovakia)	http://www.utc.sk/
Examples of GIS Applications Projects	
DISGIS	http://www.disgis.com
Tele Atlas	http://www.teleatlas.com/
Web Mapping testbed	http://www.opengis.org/
Geobusiness	http://www.geomarketing.net http://www.gismo.nl http://www.wigeogis.at

Crop Growth Monitoring System (CGMS)	http://gi-gis.aris.sai.jrc.it/agro-meteo/
City Council of Genova	http://www.comune.genova.it/
City Council of Vienna	http://service.magwien.gv.at/wien-grafik/wo.html
EURSIS	http://gi-gis.aris.sai.jrc.it/soils/esb.html
CORINE	http://etc.satellus.se
TREES (Tropical deforestation monitoring)	http://www.gvm.sai.jrc.it
Cadastre	http://www.bev.gv.at
Radioactivity Environmental Monitoring	http://java.ei.jrc.it/
MURBANDY (Monitoring urban dynamics)	http://murbandy.sai.jrc.it

ANNEX 2: PANEL-GI GLOSSARY

The table below is a subset[1] of entries kindly made available from:

- the AGI dictionary (http://www.agi.org.uk/pag-es/dict-ion/dict-agi.htm),
- the ESRI Glossary[2] (http://www.esri.com/library/glossary/glossary.html) and
- the glossary from OGC's "OpenGIS guide" (http://www.opengis.org/techno/guide.htm).

One of the interesting aspects of GIS is that many people are still struggling with its definition. Plenty of definitions exist, each with a (slightly) different focus. Some are limited to the technological aspect; others include the scientific or even organisational side. As an illustration, here are five different definitions. For the main glossary, we have selected the AGI definition, mentioned here first.

GIS is:

1. A computer system for capturing, storing, checking, integrating, manipulating, analysing and displaying data related to positions on the Earth's surface. Typically, a Geographical Information System (or Spatial Information System) is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image of a map. (AGI)
2. A set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes. (Burrough, 1998)
3. An organized collection of computer hardware, software, geographical data, and personnel designed to efficiently-capture, store, update, manipulate, analyse, and display all forms of geographically referenced information. (ESRI)
4. A database system in which most of the data are spatially indexed, and upon which a set of procedures are operated in order to answer queries about spatial entities in the database. (Smith, 1987)
5. A special-purpose digital database in which a common spatial coordinate system is the primary means of reference. GISs contain subsystems for: 1) data input; 2) data storage, retrieval, and representation; 3) data management, transformation, and analysis; and 4) data reporting and product generation. It is useful to view GIS as a process rather than a thing. A GIS supports data collection, analysis, and decision-making and is far more than a software or hardware product. Other terms for GIS and special-purpose GISs include: Land-Base Information System, Land Record System, Land Information System, Land Management System, Multipurpose Cadastre, and AM/FM (automated mapping and facilities management) system. (OGC)

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[1] The criteria for an entry to be included in the Panel-GI glossary are:

- The entry appears in the text of the package, or
- the entry is part of basic, essential GIS jargon, and
- the entry is not part of common sense general language.

Where duplicates occur, preference has been given to use entries from the AGI dictionary, as this is European and non-proprietary.

[2] Selected terms and definitions reprinted courtesy of Environmental Systems Research Institute, Inc. www.ESRI.com.

Acceptance Test	A series of tasks performed by either hardware or software to assess performance. Test data is used as input and the response is analysed regarding suitability for operational use. Usually conducted under the control of the procurer of the product, rather than the vendor, to determine whether a product lives up to the claims of the vendor and whether it is fit for purpose.
Accessibility	An aggregate measure of how reachable locations are from a given location.
Accuracy	The closeness of observations, computations or estimates to the true value as accepted as being true. Accuracy relates to the exactness of the result, and is distinguished from precision that relates to the exactness of the operation by which the result was obtained.
Address Matching	A mechanism for relating two files using address as the relate item. Geographical coordinates and attributes can be transferred from one address to the other. For example, a data file containing student addresses can be matched to a street coverage that contains addresses creating a point coverage of where the students live.
Aggregation	The grouping together of a selected set of like entities to form a single entity. For example, grouping sets of adjacent areal units to form larger units, such as grouping UK electoral wards to form districts. Any associated attribute data is also aggregated into a single group.
AI	Artificial Intelligence. A term that applies to that branch of computer science, which aims to imitate the thought, processes of the human brain. There are a number of different methods of achieving this, these include creating a computer with a similar although greatly simpler structure), as the human brain through the use of neural networks, or alternatively, to simply imitate the thought processes through the use of software. The latter approach is perhaps the most common and has resulted in the development of expert or knowledge based systems
Algorithm	A finite ordered set of well-defined rules for the solution of a problem.
AM/FM	Automated Mapping and Facilities Management. Geographical Information System designed for the optimal processing of information about utilities and infrastructures such a pipes, cables networks and power lines. These systems combine digital mapping functionality with systems for managing spatial and non-spatial databases.
ANSI	American National Standards Institute. A US institute which co-ordinates standards relating to many different aspects of computing. It has strong links with ISO, the International Standards Organisation; consequently many ANSI standards are ISO approved.
API	See Application Program Interface
Application	A process that uses data or performs some function on a computer system.
Application Program Interface	An API is a set of system calls or routines for application programs to access services from operating systems or other programs. An API allows your program to work with other programs, possibly on other computers. API is fundamental to client-server computing.
Arc	An ordered string of vertices (x,y coordinate pairs) that begin at one location and end at another. Connecting the arc's vertices creates a line. The vertices at each endpoint of an arc are called nodes.
Architecture	Internal structure of a computer system, including the organisation of the major components, memory storage, I/O operations and the user interface. Often displayed as a schematic diagram.
Archive	A store of information on permanent storage media, usually off-line
Area	A bounded continuous two-dimensional object usually defined in terms of an external polygon or in terms of a continuous set of grid cells.
ASCII	American Standard Code for Information Interchange. A set of codes for representing alphanumeric information. For example, the letter 'A' is stored as the value 65, and 'B' as 66 and so on until the letter 'Z' which is 90.

Attribute	1. A trait, quality or property describing a geographical feature. 2. A fact describing an entity in a relational data model, equivalent to the column in a relational table.
Back-up	A copy of a file, a set of files, or whole disk for safekeeping in case the original is lost or damaged.
Bandwidth	A measure of the volume of data that can flow through a communications link.
Base Map	A map containing geographical features used for locational reference. Roads, for example, are commonly found on base maps.
Benchmark	A standard test devised to enable comparisons to be made between computer systems.
Benchmark Testing	A variety of tests undertaken on computer software or hardware to ensure products meet all user requirements and conform to the claims made by vendors regarding product performance. Typically these tests involve data and operations most likely to be encountered in the workplace.
Binary	A number system of base 2. Numbers are represented simply as a series of 0's or 1's in contrast to base 10 number systems that represent numbers using the characters 0-9.
Bit	Short for binary digit. A bit can take one of two possible binary values, 0 or 1. It is the smallest unit of storage and information within a computer. The values 1 and 0 can represent on/off, yes/no or true/false.
Bitmap	The representation of an image on a computer screen whereby each pixel corresponds to one or more bits.
Buffer	A zone of a specified distance around coverage features. Both constant- and variable-width buffers can be generated for a set of coverage features based on each feature's attribute values. The resulting buffer zones form polygons-areas that are either inside or outside the specified buffer distance from each feature. Buffers are useful for proximity analysis (e.g., find all stream segments within 300 feet of a proposed logging area).
Byte	A unit of computer storage of binary data usually comprising 8 bits, equivalent to a character. Hence Megabyte one million bytes, and Gigabyte, one thousand million bytes.
CAD	See Computer Aided Design.
Cadastre	A public register or survey that defines or re-establishes boundaries of public and/or private land for purposes of ownership and taxation.
Calibration	In spatial analysis, calibration is the process of choosing attribute values and computational parameters so that a model properly represents the real-world situation being analysed. For example, in pathfinding and allocation, calibration generally refers to assigning or calculating appropriate values to be entered in impedance and demand items.
CAM	See Computer Aided Mapping
Cartesian Coordinate System	A two-dimensional, planar coordinate system in which x measures horizontal distance and y measures vertical distance. Each point on the plane is defined by an x,y coordinate. Relative measures of distance, area, and direction are constant throughout the Cartesian coordinate plane.
Cartography	The organisation and communication of geographically related information in either graphic or digital form. It can include all stages from data acquisition to presentation and use.
CD-ROM	A read only optical disk similar to a commercial audio compact disk. The storage capacity of CD-ROM's is approximately 650 Megabytes.
CEN	Comitée Européen de Normalisation. The regional standards group for Europe. It is not a recognised standards development organisation, and so cannot contribute directly to ISO. It functions broadly as a European equivalent of ISO and its key goal is to harmonise standards produced by the standards bodies of its member countries. Membership is open to EC and EFTA countries.
Central Processing Unit	That part of a computer where essential arithmetic and logical operations are performed, often considered as the heart of a computer.

CERCO	Comitée Européen des Responsables de la Cartographie Officielle. The European Committee of Representatives of Official Cartography, under the auspices of the Council of Europe.
Class	Group of entities that share given attribute values.
Classification	A method of generalisation. In the process of classification, an attempt is made to group data into classes according to some common characteristics thereby reducing the number of data elements. Classification tends to be based upon the attributes or characteristics of data rather than their geometry. In digital image processing, images are usually classified according to the spectral properties of the pixels composing the image. In spatial analysis, a map can be classified according to any attribute value, for example, soil types, population density, unemployment etc. The result of performing classification is a thematic derived map.
Client	A computer system or process that requests a service of another computer system or process (a server). For example, a GIS workstation requesting data from a database server is a client of the database server.
Client-Server	A software partitioning paradigm in which a distributed system is split between one or more server tasks which accept requests, according to some protocol, from (distributed) client tasks, asking for information or some action. There may be either one centralised server or several distributed ones. This model allows clients and servers to be placed independently on nodes in a network. GIS are usually based upon client-server architecture. The database may exist upon a central server, however the graphics subsystem exists upon a local workstation, and the two communicate via a local area network.
COM	Component Object Model. Microsoft's underlying object architecture for allowing objects written by different companies in different programming languages to interact.
Computer Aided Design	1. The design activities, including drafting and illustrating, in which information processing systems are used to carry out functions such as designing or improving a part or a product. 2. Software packages designed for high quality graphical output regarding the design of products.
Computer Aided Mapping	Software packages designed for graphical output in the form of maps. These packages usually contain no analytical or manipulative qualities as the data has no topological links.
Conceptual Model	A database modelling technique that defines the types of entities or objects which are of immediate interest and the relationships between them without being specific to any particular database semantics. Thus a conceptual model can theoretically be implemented in any type of database management system.
Configuration	The particular arrangement of computer hardware and software for use within specific applications.
Continuous Data	A surface for which each location has a specified or derivable value. Typically represented by a tin or lattice (e.g., surface elevation).
Contour	A line connecting points of equal surface value.
Control Point	A system of points with established horizontal and vertical positions which are used as fixed references in positioning and relating map features, aerial photographs or remotely sensed images.
Coordinate System	A reference system used to measure horizontal and vertical distances on a planimetric map. A coordinate system is usually defined by a map projection, a spheroid of reference, a datum, one or more standard parallels, a central meridian, and possible shifts in the x- and y-directions to locate x,y positions of point, line, and area features.
CORBA	Common Object Request Broker Architecture. The basic distributed object scheme developed by the Object Management Group (OMG), a consortium similar to OGC but focused on object technology instead of distributed geoprocessing. Object Request Brokers (ORBs) help clients find servers.

CPU	See Central Processing Unit.
Currency	The level to which data is kept up to date.
Data Conversion	The translation of data from one format to another.
Data Dictionary	A repository of information in a database in which information is stored on all the objects within the database and their relationships.
Data Model	An abstraction of the real world which incorporates only those properties thought to be relevant to the application at hand. The data model would normally define specific groups of entities, and their attributes and the relationships between these entities. A data model is independent of a computer system and its associated data structures. A map is one example of an analogue data model.
Data Quality	Indications of the degree to which data satisfies stated or implied needs. This includes information about lineage, completeness, currency, logical consistency and accuracy of the data.
Data Set	A named collection of logically related data items arranged in a prescribed manner.
Data Type	The characteristic of columns and variables that defines what types of data values they can store. Examples include character, floating point and integer.
Database	A logical collection of interrelated information, managed and stored as a unit, usually on some form of mass-storage system such as magnetic tape or disk. A GIS database includes data about the spatial location and shape of geographical features recorded as points, lines, areas, pixels, grid cells, or tins, as well as their attributes.
Database Design	Formally, database design can be regarded as the third stage in the development of a database. It is where the conceptual model, developed during the data modelling or second stage, is applied to a specific database management system.
Database Management System	A collection of software for organising the information in a database. Typically a DBMS contains routines for data input, verification, storage, retrieval and combination.
Datum	A set of parameters and control points used to accurately define the three-dimensional shape of the Earth (e.g., as a spheroid). The datum is the basis for a planar coordinate system. For example, the North American Datum for 1983 (NAD83) is the datum for map projections and coordinates within the United States and throughout North America.
DBMS	See Database Management System.
De Facto Standard	A standard that has been informally adopted, often because a particular vendor was first to market with a product that became widely adopted. MS-DOS and Microsoft Windows are examples.
De Jure Standard	An official standard created in a formal "juried" process, such as the International Organization for Standards Technical Committee 211 (ISO TC/211).
DIGEST	The Digital Geographical Information Exchange Standard is produced under authority of NATO's Digital Geographical Information Working Group. DIGEST is a standard for digital Geographical Information which will enable interoperability and compatibility among national and multinational systems and users.
Digital Elevation Model	A digital representation of a continuous variable over a two- dimensional surface by a regular array of z values referenced to a common datum. Digital elevation models are typically used to represent terrain relief. Also referred to as 'digital terrain model' (DTM).
Digital Map	The representation of data in graphical form, whereby the data are divided into discrete quantified units.
Digital Terrain Model	See digital elevation model.
Discrete Data	Geographical features containing boundaries: point, line or area boundaries.
Distributed Database	A database for which different components are located on different nodes in a computer network. This network can be a simple LAN with a small number of users, to a database that is connected via a WAN such as the Internet with possibly thousands of users.

Distributed System	A complex computer system where the workload is spread between two or more computers linked together by a communications network.
DOS	Disk Operating System. Originally created by Microsoft for the IBM PC as one of the first operating systems. Operations are carried out through command line, rather than menu-driven instructions. Has become a de-facto standard within the industry.
DTM	Digital terrain model. See digital elevation model.
DXF	Data Exchange Format. A format for storing vector data in ASCII or binary files. Used by CAD software for data interchange.
EDI	See Electronic Data Interchange
EDIFACT	Electronic Data Interchange For Administration, Commerce and Transport. A set of syntax rules for the preparation of messages to be interchanged.
Electronic Data Interchange	The interchange of processable data between computers electronically.
Encoding	The assignment of a unique code to each unit of information, such as encoding of English using the ASCII character set.
Entity	A collection of objects (persons, places, things) described by the same attributes. Entities are identified during the conceptual design phase of database and application design.
Entity Relationship Diagram	A graphical representation of the entities and the relationships between them. Entity relationship diagrams are a useful medium to achieve a common understanding of data among users and application developers.
Entity-Relationship Model	A logical way of describing entities and their relationships within relational databases. An entity-relationship model is often used in the conceptual design phase of creating a relational database and is usually expressed as a diagram showing the entities and the linkages that exist between them.
Eurostat	The European Community statistical agency.
Expert System	A computer system that provides for solving problems in a particular application area by drawing inferences from a knowledge base acquired by human expertise, it is a form of artificial intelligence. Knowledge based systems, or more commonly, expert systems have been used for purposes of automated map generalisation. This is an area that they have particular application within the field of Geographical Information Systems.
Feature	A set of points, lines or polygons in a spatial database that represent a real-world entity. The terms feature and object are often used synonymously.
Federal Geographical Data Committee	A US organisation composed of representatives of several federal agencies and GIS vendors, the FGDC has the lead role in defining spatial metadata standards.
FGDC	See Federal Geographical Data Committee
Field	A set of one or more alphanumeric characters comprising a unit of information.
Format	The pattern into which data are systematically arranged for use on a computer. A file format is the specific design of how information is organized in the file.
Generalisation	Simplification of map information, so that information remains clear and uncluttered when map scale is reduced. Usually involves a reduction in detail, a resampling to larger spacing, or a reduction in the number of points in a line. Traditionally this has been done manually by a cartographer, but increasingly semi-automated and even automated methods have been used, particularly in conjunction with a GIS.
Geodata	Information that identifies the geographical location and characteristics of natural or man-made features and boundaries of the Earth. Geodata represent abstractions of real-world entities, such as roads, buildings, vehicles, lakes, forests and countries.
Geographical Analysis	See Spatial Analysis
Geographical Data	Data that record the shape and location of a feature as well as associated characteristics, which define and describe the feature.

Geographical Information	Information about objects or phenomena that are associated with a location relative to the surface of the Earth. A special case of spatial information.
Geographical Information System	A computer system for capturing, storing, checking, integrating, manipulating, analysing and displaying data related to positions on the Earth's surface. Typically, a Geographical Information System (or Spatial Information System) is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image of a map.
Geometry	The shape of the represented entity or entities, in terms of its stored co-ordinates and the lines connecting those co-ordinates.
GI	See Geographical Information
GIS	See Geographical Information System
Global Positioning System	A satellite based navigational system allowing the determination of any point on the earth's surface with a high degree of accuracy given a suitable GPS receiver.
GPS	See Global Positioning System
Graphical User Interface	The use of pictures rather than just words to represent the input and output of a computer program.
Grid	A geographical data model representing information as an array of equally sized square cells arranged in rows and columns. Each grid cell is referenced by its geographical x,y location. See also raster.
Ground Control Point	Any point which is recognisable on both remotely sensed images, maps and aerial photographs and which can be accurately located on each of these. This can then be used as a means of reference between maps or, more commonly, between maps and digital images. Often used in the geometric correction of remotely sensed images and surveying.
GUI	See Graphical User Interface.
Hardware	All or part of the physical components of an information processing system. For example, hardware might include the monitor, printer/plotter, network, digitising tables, scanners as well as the computers themselves.
I/O	Input/Output. Refers to the ability to input data for processing or display purposes, through peripheral devices, and subsequently produce either hard or soft copy output from these processes. Peripheral devices which can be used to input data are digitising stations, photogrammetric workstations, alphanumeric workstations and scanners. Output devices include plotters and printers.
IEC	International Electrotechnical Committee. This organisation has the same status as ISO, but focuses on electrical and electrotechnical issues, especially electricity measurement, testing, use and safety.
IEEE	Institute of Electrical and Electronics Engineering Inc. A major international professional body and an accredited standards setting organisation.
Interface	For communication, a hardware and/or a software link that connects two computer systems, or a computer and its peripherals, or between a computer and its user.
Interoperability	The ability of different software systems to exchange information and requests, using methods, through an object request broker in accordance with OMG standards. It allows different applications from different vendors to work together seamlessly.
Interpolation	The estimation of z values of a surface at an unsampled point based on the known z values of surrounding points.
ISDN	Integrated Services Digital Network. Provides combined transmission of analogue and digital services. It is a set of communications standards allowing a single wire or optical fibre to carry voice, digital network services and video.

ISO	International Standards Organisation. A world-wide federation of national standards bodies that develops international standards. A Technical Committee (ISO/TC211) is developing international Geographical Information standards. Among many other computing standards, ISO also maintains an SQL standard and is developing an extended version, SQL3, which will support queries on geographical data sets.
Java	Java is an object oriented application development language written by Sun Microsystems. It is an interpreted object oriented programming language similar to C, but has been designed to run with minimum resources. It is entirely platform independent and is intended to be used to create Java applet (small application) objects which can be stored on public servers and downloaded to PCs or other network devices when needed.
Knowledge Based System	A computer system that provides for solving problems in a particular application area by drawing inferences from a knowledge base acquired by human expertise, it is a form of artificial intelligence. Knowledge based systems, or more commonly, expert systems have been used for purposes of automated map generalisation. This is an area that they have particular application within the field of Geographical Information Systems.
LAN	See Local Area Network
Land Information System	A system for capturing, storing, checking, integrating, manipulating, analysing and displaying data about land and its use, ownership and development.
Lineage	The ancestry of a dataset describing its origin and the processes by which it was derived from that origin. Lineage is synonymous with provenance, but is more than just the original source or author.
LIS	See Land Information System
Local Area Network	Computer data communications technology that connects computers at the same site. Computers and terminals on a LAN can freely share data and peripheral devices, such as printers and plotters. LANs are composed of cabling and special data communications hardware and software.
Macro	A text file containing a sequence of commands that can be executed as one command. Macros can be built to perform frequently used, as well as complex, operations.
Map Projection	A mathematical model that transforms the locations of features on the Earth's surface to locations on a two-dimensional surface. Because the Earth is three-dimensional, some method must be used to depict a map in two dimensions. Some projections preserve shape; others preserve accuracy of area, distance, or direction. See also coordinate system. Map projections project the Earth's surface onto a flat plane. However, any such representation distorts some parameter of the Earth's surface be it distance, area, shape, or direction.
Metadata	Data about data and usage aspects of it.
Middleware	Software that enables applications to access data and computing resources distributed across networked computers, regardless of incompatible operating systems and networks.
Model	A simplified representation of reality used to simulate a process, understand a situation, predict an outcome, or analyse a problem. A model can be viewed as a selective approximation which, by elimination of incidental detail, allows some fundamental aspects of the real world to appear or be tested.
Multimedia	A combination of a variety of user interfaces and communication elements such as still and moving pictures, sound, graphics and text.
National Institute of Standards and Technology	National Institute of Standards and Technology is the agency that produces the Federal Information Processing Standards (FIPS) for all US government agencies except the Department of Defence.

National Land Information Service	The National Land Information Service is an ongoing project with the aim of providing easier access to all land and property data in Britain. It is a direct result of the Citizen's Charter of 1992. Based upon BS7666, the NLIS is a hub-based network with access to data held by HMLR, The Valuation Office, OS and local government. The NLIS is a precursor to the development of a National Geospatial Database.
National Spatial Data Infrastructure	Established as a result of an Executive Order from the United States government, this is an attempt to promote the sharing of Geographical Information and increase its use in policy formation. The aim of this initiative is to enhance the United States economy and maintain a competitive edge.
Network	1. An interconnected set of arcs representing possible paths for the movement of resources from one location to another. 2. A digital map representing linear features containing arcs or a route-system. 3. When referring to computer hardware systems, a local area network (LAN) or a wide area network (WAN).
NIST	See National Institute of Standards and Technology
NLIS	See National Land Information Service
Node	The beginning and ending locations of an arc. A node is topologically linked to all arcs that meet at the node.
Normalisation	A data modelling method first devised as a database design tool for relational databases, but has since been found a useful tool for conceptual modelling. Normalisation is a bottom-up approach to data modelling.
NSDI	See National Spatial Data Infrastructure
NTF	National Transfer Format. British Standard BS7567, used for the transfer of geographical data, administered by AGI.
Object	A set of points, lines or polygons in a spatial database that represent a real-world entity. The terms feature and object are often used synonymously.
Object Management Group	The Object Management Group, founded in 1989, is a computing industry collaboration to promote object-oriented interoperability among heterogeneous computing environments. They continue to develop specifications which address the many aspects of this problem, the most popular of which is the Common Object Request Broker Architecture (CORBA). Members include all the main hardware and software vendors, as well as leading users of object technology. Further details can be found at http://www.omg.org.
OGC	See Open GIS Consortium
OLE	Object Linking and Embedding. Microsoft's specification for object technology, which it is using throughout its operating systems, development tools and applications. Based upon the underlying Component Object Model (COM), OLE is the foundation for component software to interact and co-operate. OLE also makes it easy to create compound documents consisting of multiple sources of information from different applications, for example, embedding a MS Excel spreadsheet into a MS Word document.
OMG	See Object Management Group
Open GIS Consortium	The Open GIS Consortium is a voluntary, non-governmental, non-profit organisation dedicated to the development of an open systems approach to geoprocessing.
Open System	An information processing system that complies with the requirements of open systems interconnection (OSI) standards in communication with other such systems.
Operating System	The low-level software which schedules tasks, allocates storage, handles the interface to peripheral hardware and presents a default interface to the user when no application program is running.
Oracle	A relational database management system.

OSI	Open systems interconnection. This defines the accepted international standard by which open systems should communicate with each other. It takes the form of a seven-layer model of network architecture, with each layer performing a different function.
Picture Element	See Pixel
Pixel	Square shaped cell comprising the smallest unit that makes up a computer image. Pixel size determines resolution of an image and the quality of graphical output. Pixels can be assigned a number of attribute values.
Plotter	Peripheral device used in the making of hard copy maps or graphical output.
Polygon	A feature used to represent areas. A polygon is defined by the lines that make up its boundary and a point inside its boundary for identification. Polygons have attributes that describe the geographical feature they represent.
Precision	The exactness with which a value is expressed, whether the value be right or wrong.
Projection	See map projection.
Protocol	Protocols are a fixed set of rules used to specify the format of an exchange of data.
Quadtree	The expression of a two dimensional object, such as a digital image, as a tree structure of quadrants which are formed by recursively subdividing each non-homogeneous quadrant until all quadrants are homogeneous with respect to a selected property, or until a predetermined cut-off 'depth' is reached.
Query	A statement expressing a set of conditions that forms the basis for the retrieval of information from a database. Queries are often written in a standardised language such as SQL.
Query Language	Method of communicating data manipulation and definition commands to a database. Command driven interface rather than menu-based. Commands are typed by the user and then analysed by the query compiler which subsequently passes them to the processor. The de facto standard in use is the Standard Query Language (SQL). Query languages allow data to be inserted, modified and retrieved. Query languages are more highly structured than earlier command-based systems, approaching English in syntax.
Raster	A method for the storage, processing and display of spatial data. Each given area is divided into rows and columns, which form a regular grid structure. Each cell must be rectangular in shape, although not necessarily square. Each cell within this matrix contains an attribute value as well as location co-ordinates. The spatial location of each cell is implicitly contained within the ordering of the matrix, unlike a vector structure which stores topology explicitly. Areas containing the same attribute value are recognised as such, however, raster structures cannot identify the boundaries of such areas as polygons. Also raster structures may lead to increased storage in certain situations, since they store each cell in the matrix regardless of whether it is a feature or simply 'empty' space.
RDBMS	See Relational Database Management System
Record	1. In an attribute table, a single 'row' of thematic descriptors. In SQL terms, a record is analogous to a tuple 2. A logical unit of data in a file.
Reference Model	Provides the complete scientific and engineering contextual framework for a technology area. The underlying elements, rules and behaviours.
Relational Database Management System	A database management system with the ability to access data organized in tabular files that can be related to each other by a common field. An RDBMS has the capability to recombine the data items from different files, providing powerful tools for data usage.
Remote Sensing	The technique of obtaining data about the environment and the surface of the earth from a distance, for example, from aircraft or satellite.
Resolution	A measure of the ability to detect quantities. High resolution implies a high degree of discrimination but has no implication as to accuracy. Resolution is a term that is used often within remote sensing.

Scale	The ratio of the distance measured on a map to that measured on the ground between the same two points.
SDM	See Systems Development Methodology
Server	A computer which provides some service for other computers connected to it via a network. The most common example is a file server which has a local disk and services requests from remote clients to read and write files on that disk.
Spatial Analysis	Analytical techniques associated with the study of locations of geographical phenomena together with their spatial dimensions and their associated attributes. Spatial analysis is useful for evaluating suitability, for estimating and predicting, and for interpreting and understanding the location and distribution of geographical features and phenomena.
Spatial Information	Information that includes a reference to a two or three-dimensional position in space as one of its attributes.
Spatial Modelling	Analytical procedures applied with a GIS. There are three categories of spatial modelling functions that can be applied to geographical features within a GIS: 1, geometric models, such as calculating the Euclidean distance between features, generating buffers, calculating areas and perimeters; 2, coincidence models, such as overlays; and 3, adjacency models (pathfinding, redistricting, and allocation).
Spatio-temporal data	Data that is concerned with both space and time.
Spatio-temporal Database	Databases designed for the storage and management of spatio-temporal data. Most GIS only have limited capabilities for storing and manipulating temporal data, although specifically designed to cope with spatial data.
Spiral Model	A model of the software development process in which the constituent activities, typically requirements analysis, preliminary and detailed design. Coding, integration, and testing, are performed iteratively until the software is complete. See also: Waterfall Model.
SQL	Structured Query Language. A syntax for defining and manipulating data from a relational database. Developed by IBM in the 1970s, it has become an industry standard for query languages in most relational database management systems
Systems development Methodology	An integrated set of techniques and methods for effective and efficient planning, analysis, design, construction, implementation and support of computer systems.
TCP/IP	Transmission Control Protocol/Internet Protocol. A communication protocol layered above the Internet Protocol. These are low-level communication protocols, which allow computers to send and receive data. It is the communication standard that underlies the Internet.
Temporal Database	A database containing information indexed by time. Time can either be represented as discrete steps, or less commonly, as a continuous variable.
TIGER	Topologically Integrated Geocoding and Referencing. A data format developed by the US Bureau of Census for the 1990 US census.
TIN	Triangulated Irregular Network. A form of the tesseral model based on triangles. The vertices of the triangles form irregularly spaced nodes. Unlike the grid, the TIN allows dense information in complex areas, and sparse information in simpler or more homogeneous areas. The TIN dataset includes topological relationships between points and their neighbouring triangles. Each sample point has an X,Y co-ordinate and a surface, or Z-Value. These points are connected by edges to form a set of non-overlapping triangles used to represent the surface. Tins are also called irregular triangular mesh or irregular triangular surface model.
Topographic Map	1. A map containing contours indicating lines of equal surface elevation (relief), often referred to as topo maps. 2. Often used to refer to a map sheet published by the U.S. Geological Survey in the 7.5-minute quadrangle series or the 15-minute quadrangle series.

Topology	The spatial relationships between connecting or adjacent coverage features (e.g., arcs, nodes, polygons, and points). For example, the topology of an arc includes its from- and to-nodes, and its left and right polygons. Topological relationships are built from simple elements into complex elements: points (simplest elements), arcs (sets of connected points), areas (sets of connected arcs), and routes (sets of sections, which are arcs or portions of arcs). Redundant data (coordinates) are eliminated because an arc may represent a linear feature, part of the boundary of an area feature, or both. Topology is useful in GIS because many spatial modelling operations don't require coordinates, only topological information. For example, to find an optimal path between two points requires a list of the arcs that connect to each other and the cost to traverse each arc in each direction. Coordinates are only needed for drawing the path after it is calculated.
Triangulated Irregular Network	See TIN.
Triangulation	A process of subdividing a 2D space into bounding regions that are triangles.
Tuple	A row in a relational table; synonymous with record, observation.
Turn-key System	A term that describes a system (hardware and software) which can be used for a specific application without requiring further programming or software installation. The user can just 'turn the key' (switch it on) and use it.
User Interface	A method by which a user controls operation of a computer system. Typical types of user interface include command line, conversational mode and graphical user interfaces (GUI).
User Requirement Analysis	A study of the needs of a user of a system conducted prior to system development.
UTM	Universal Transverse Mercator. A grid system based upon the Transverse Mercator projection. The UTM grid extends North-South from 80 o N to 80 o S latitude and, starting at the 180 o Meridian, is divided eastwards into 60, 6 o zones with a half degree overlap with zone one beginning at 180o longitude. The UTM grid is used for topographic maps and georeferencing satellite images.
Vector	One method of data type, used to store spatial data. Vector data is comprised of lines or arcs, defined by beginning and end points, which meet at nodes. The locations of these nodes and the topological structure are usually stored explicitly. Features are defined by their boundaries only and curved lines are represented as a series of connecting arcs. Vector storage involves the storage of explicit topology, which raises overheads; however it only stores those points that define a feature and all space outside these features is 'non-existent'.
Vertex	One of a set of ordered x,y coordinates that constitutes a line.
Visualisation	A term that is applied to the field of computer graphics that attempts to address both analytical and communication issues of visual representation. Visualisation in GIS often refers to the visual representation of geographical data for purposes of spatial analysis.
WAN	See Wide Area Network
Waterfall Model	A model of the software development process in which the constituent activities, typically a concept phase, requirements phase, design phase, implementation phase. test phase, installation and checkout phase, and operation and maintenance, are performed in that order, possibly with overlap but with little or no iteration. Contrast with rapid prototyping; spiral model.
Wide Area Network	Computer data communications technology that connects computers at remote sites. WANs are composed of special data communications hardware and software and usually operate across public or dedicated telephone networks.

Workstation	A general purpose computer designed to be used by one person at a time and which offers higher performance than normally found in a personal computer, especially with respect to graphics, processing power and the ability to carry out several tasks at the same time. This performance difference however is decreasing, and in time the distinction between a desktop and a workstation will be meaningless in terms of performance.
Z-Value	The value of a surface at a particular X,Y location, for example, elevation. The Z-value usually refers to 3D features, but in GIS it can also refer to what is known as 2.5D features.

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PANEL-GI

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PANEL-GI has created a European Network constituted by EU and CEEC Organisations aimed at contributing to realise a full and integrated Pan European GI context and to foster or enable GI business.

The "PANEL-GI Compendium. A Guide to GI and GIS" has been designed as a reference book useful to have a vision of the key issues in Geographical Information. It aims at supporting user's orientation in the field, stimulating as well business approaches and initiatives for the development of new projects and products. It is meant primarily for users (actual or potential) of GI and GIS, but also for managers in private business and decision makers in the public and private sectors.

The "Compendium" concentrates on issues that a user needs to know, such as the basic technical concepts and the organisational and business aspects of GIS. Although the book tries to avoid technical details, it nevertheless gives a short introduction about the ways GIS work. This knowledge should enable readers to communicate with technicians in different GIS and mainstream-IT organisations.

GIS is a multidisciplinary field, both in its origins and in its user community. For that reason the book is aimed at readers from all possible backgrounds: Spatial Information is everywhere.

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