An Effective Spatial Decision Support System for Landuse Planning: with an example from Forest Management

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Abstract

Landuse planning problems are becoming increasingly complex, as a population with expanding needs and desires is faced with a finite amount of land. The methodological needs of landuse planners to deal with these pressures are identified and discussed. Among others, these include the need to handle data spatially, to incorporate subjective criteria, multiple objectives, and the need to handle a wide variety of data in diverse contexts. The nature of the decision-making process and the landuse planning process are briefly described, revealing the important common elements, and revealing the needs of landuse planners with regard to the computer support of this process. Computer systems offer many of the capabilities required by landuse planners, automating what they already do and opening up new possibilities. Elements of information technology (IT) are identified and their advantages and limitations with respect to the landuse planning process are discussed.

A Spatial Decision Support System (SDSS) is proposed as a system that can improve landuse planning by providing a mechanism to handle many of the complexities. A federated system based on existing easy-to-use and user-modifiable packages is suggested as a means to incorporate just those elements of IT that are required, resulting in an SDSS that is inexpensive, easily understood and very flexible. Macintosh or Macintosh-like applications are used in the example system designed here because they are both very easy to use and often user-modifiable as the user gains confidence and expertise.

An illustrative problem is taken from forest management and planning and an example federated system is designed for Thetford Forest District in East Anglia. This District is currently experimenting with the design and implementation of a scheme for restructuring the appearance and age dynamics of the forest and for rationally handling the many uses demanded of it. The problem, the organizational context and the users are all examined to determine the contents and design of a computer-based SDSS that would best assist the landuse planning and management process.

The thesis establishes the need for and the practicality of spatial decision support in landuse planning, and demonstrates that by incorporating the capabilities of existing computer technology in a form that is accessible to landuse planners, the federated design for an SDSS is a means of providing effective support to the landuse planning process.

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Dedication

To Andy,
who had to put up with me slamming doors

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Chapter 1

Introduction

Landuse planning problems are becoming increasingly complex, involving large amounts of data as a result of the breadth of the area of concern. Spatial conflicts are becoming more frequent and need to be judged against a multiplicity of objectives. Many of the criteria used in the development of plans and in decision-making are qualitative and/or subjective, and their relative importance almost always is. Public awareness is growing and the potential long-term and wide-ranging effects of some landuse planning decisions means that planners are often under close public and legal scrutiny. Thus, planners are in need of some support to the planning process in order to intelligently handle all these complexities. If only there were some way: to process all the information more quickly, to improve communication with clients and interested parties, to be able to support decisions in the face of challenges or litigation, to provide some consistency of methodology, to be able to incorporate subjective criteria into the decision-making process in a rational manner, and yet remain flexible enough to be able to handle the constantly changing decision environment.

Existing computer systems offer some of the capabilities needed by planners to address the above needs. Geographic information systems (GIS), decision support systems (DSS), database management systems (DBMS), knowledge-based systems (KBS), modelling packages and statistical and graphing packages each have the capacity to significantly aid certain segments of the planning process. What landuse planners need, however, is an integration of these elements of computer technology to enable them to address an entire landuse planning situation. They need the creation of a spatial decision support system (SDSS). In order for any SDSS to be effective in its support of landuse planning, it must be applicable to the current problem, it must be able to evolve over time, and it must be used and accepted by the planners themselves. Thus, what planners need is a system that enables them to integrate the precise capabilities required to address a particular planning situation in an inexpensive, user-friendly and flexible manner.

Thetford Forest District is the case study examined here. The current difficulties faced by the District Manager concern how to alter the management of the forest with respect to changes in recreation pressure and interests in conservation and amenity. An SDSS is designed and partially developed for Thetford Forest District with the problem, the users and the organizational environment in mind. A well-designed SDSS should provide the planner with the tools, methods and incentive for faster, more informed and more supportable landuse management and planning. The system developed specifically for Thetford Forest District is examined with respect to these goals.

A specific problem: Thetford forest as a case study

Thetford Forest, in East Anglia, offers several specific problems in need of spatial decision support. Originally established in the 1920's on primarily derelict arable or open heath land in Breckland (Macdonald 1939), Thetford forest has always been a favourite recreation site for walkers, bikers and picnickers, while providing a major supply of timber for the nation. Located in a rapidly growing area of the UK (SCEALA 1989), Thetford forest has been experiencing a substantial increase in the number of visitors. Thetford forest is the largest pine woodland in England, and as one of the oldest of the Forestry Commission plantations, it is the most mature. Typical among the pressures faced by forest managers are:

1) Accommodating for the increase in recreation pressure

Problem: To accommodate for some of the increased recreation pressure facing Thetford Forest, an additional visitor centre is being built, along with a new scenic forest drive to provide access to the centre and new trails for bikers, walkers and horsebackriders. What the visitor centre has done is brought additional interests, in the form of landscaping/amenity and the provision of recreational facilities, into a new section of the forest that now must be considered in the re-assessment of the management plans of the surrounding forest.

2) Restructuring the pattern of harvesting to increase spatial diversity of the primarily even-aged stands

Problem: Thetford forest is composed of primarily even-aged stands that are harvested by clearcut. One of the recommendations of the Thetford Forest Management Review (Simpson and Henderson-Howat 1985) was to diversify this forest landscape, especially that viewed from the road and railway. This was to be done by rearranging the age composition, spatial pattern, shape and size of these stands, and even changing the angle at which they intersect the roads to limit the visual impact when each stand is harvested and create a more varied scene for visitors. In addition, it was recommended that some of those compartments immediately alongside roads (and certain trails) should also be subject to heavy thinning to increase the diversity in individual compartments via natural regeneration. This process consists of re-assessing the harvesting cycle of each of the patchwork of forest compartments and subcompartments in order to create a more mixed spatial distribution of stand ages. The constraints are in keeping stands of large enough size to maintain access to harvesting, and in maintaining the expected level of timber production throughout the restructuring process.

3) Maintaining suitable habitat in the red squirrel conservation area

Problem: The red squirrel conservation area is a designated conservation area within Thetford forest. The red squirrel is a shy species, rare in this part of the country, which prefers pine forests for food and breeding. Originally surviving in the long rows of pines planted in the area as windbreaks in the late 18th century, the red squirrel has made its home in the pine plantations of the Forestry Commission. Under pressure from the grey squirrel, Thetford forest is one of the last places in England where the native red squirrel thrives in substantial numbers, primarily because of the size of the forest and the lack of mature hardwoods, the typical vehicle for grey squirrel invasion. The red squirrel conservation area was established within Thetford Forest as an area of focus, where forest management schemes and thus harvest rotations would be specifically coordinated to maintain a habitat suited to the red squirrel. The information concerning the red squirrel's requirements for mature trees (food), space (feeding and breeding territories) and heterogeneity of habitat is incomplete, but wildlife biologists have recently come up with figures that on the order of 50% of the forest stands must be of cone-bearing age ($\geq$ 30 years). Can this be maintained and sustained over the long term? At what increased cost to timber production (for allowing some stands to get overmature before harvesting)? And what per cent of mature trees could be maintained without any change in timber production?

As is evident from these problems, forest management and planning in the district is no longer simply aimed at maintaining a certain level of timber production. Each of the above is a complex planning problem and a plan of action for any of them would affect the other problems. Each has more than one objective. Each includes qualitative decisions on the relative importance of the different objectives of recreation (and amenity), timber production, and conservation. Each includes levels of uncertainty in the estimates of expected visitors and their needs or of the needs of the red squirrel. And all this is reflected in a wider Forestry Commission need to improve public opinion of their activities. Current opinion is based on the assumption that the Commission is only interested in timber production and consequently plant only boring conifer plantations that are devoid of all wildlife. While timber production is the primary activity of the Forestry Commission, they are taking steps to incorporate the interests of recreation and conservation in their management plans. Public opinion of their activities can be improved if they can just show that they are actually changing their management practices.

The planning problem: the functional requirements for landuse planning

The above specific problem in forest management and planning is only a typical example of the types of problems faced by all landuse planners. It is becoming increasingly evident that if well-balanced and considered plans are to remain possible amid the evolving perspectives of modern society, planners are in need of some way to be able to intelligently handle all the imposed complexities and pressures. In short, they are in need of some support in the planning process. More specifically, the needs most often identified by planners are: 1) To be able to handle data spatially, 2) to be able to coordinate and integrate the many different types of data, 3) to be able to handle the increasing amounts of data, 4) to be able to process information more quickly, 5) to improve communication both between the decision-makers and with clients and interested parties, 6) to be able to incorporate subjective criteria in a rational manner, 7) to be able to handle multiple objectives/goals and 8) to be able to support the resulting plans by some record of the decision-making process, 9) to assist in designing alternative scenarios and evaluating the effects before the decisions are taken, 10) to be able to get some idea of the sensitivity of decisions to changes in the political environment, and 11) to keep the system flexible. These needs are each discussed in more detail below.

To incorporate the spatial element

Almost all planning problems contain a spatial dimension (Klosterman and Landis 1988). Where features are located is an important factor in many problems, as are their proximity to other features, their distribution and their spatial variation -- all aspects of the spatial dimension. Obviously such planning problems as the location of a proposed road are best answered when the questions of 'where', 'through what' and 'by what' are examined, but also problems such as 'which bank branches should be closed down' are usually better addressed when elements like their relative location or the spatial distribution of the client population or the location of the serving infrastructure are considered. The economic dimension -- 'what it is going to cost?', and 'what are the monetary benefits?' -- has rarely been forgotten in any analysis of a proposed plan, but until recently the lack of a capability for easily incorporating the spatial dimension into the planning problem has frequently resulted in a lack of consideration of spatial disparities (Diamond 1991, personal communication). There is thus a need for planners to be able to handle data spatially; to be able to visualize the information and access it spatially.

To be able to coordinate and integrate the many different types of data

Data and information comes in many forms. Different types of data such as satellite imagery for general vegetation or land use, gridded or bore hole data for soil or bedrock types, population sample data for household statistics or digitized vector data for the location of infrastructure or property boundary information all exist. Each is useful because of its capacity to capture different aspects of information about objects and space. To complicate the situation still further, even data of one physical type can be quite varied and is rarely immediately comparable. Such data has often been collected in a slightly different manner each time and may be based on different criteria, assumptions or areal units. The result is that even data of the same type usually needs processing in order for it to be effectively analyzed. Some subject areas escape from the worst of this problem of incorporating disparate types of data, because the information required is best collected and held in only one or two of the above forms. Planning, on the other hand, often involves a multitude of subjects from regional finance to the sensitivity of wildlife habitats to the mechanics of road construction to personnel management (Healey 1986, Parr 1988, Janssens 1991). The end result of such a broad spectrum of involvement is that there is an increasing likelihood that such different sources and forms of data will be required and must be incorporated in as integrated a manner as is logically possible.[1]

To be able to handle the increasing amounts of data

A large amount of information is used in the planning process, and it is on the increase. There are several causes for this change. First, data can be collected and stored more easily, increasing the amount that is available to the planner. The advent of information and related technologies has meant that one can collect and store and access data with relative ease, whether it is census data, the number of car journeys over a particular stretch of road or visitors to a particular heritage site, the endangered species list, or building lots and zoning restrictions. This has increasingly encouraged not only each department in the local/municipal offices to create databases for their own use, but has also encouraged conservation, environmental protection and local interest groups to gather and hold their own data because such information is invariably power for their cause. The end result is that there is increasingly more data and information potentially

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[1]See Geertman and Toppen (1990) for a discussion of the difficulties in integrating data from several sources when evaluating building sites, Dippon (1989) for such difficulties when forming new plans for the Bureau of Land Management in the United States, Robillard (1990) for difficulties when managing water resource projects, and Ravlin et al. (1990) for such difficulties with regard forest pest management.

available which is relevant to planning decisions. Compounding this are changes in planning perspectives. No longer is a single planning problem recognized as an isolated decision. These broadening perspectives are forcing planners to look in terms of wider issues. A single town plan for the use of a wetland is now understood to have more than just local implications. Regional concerns (the need for more housing), national concerns (the need for more semi-natural opportunities for recreation) and global concerns (the need to retain suitable habitats throughout the migratory routes of birds) are all affected by the local planning decision. Any widening of the perspective dramatically increases the volumes of data to be handled if that data is available. Thus, information that was previously ignored because it was not considered relevant or information that was dismissed because it was not available is now being incorporated into the planning process. In some cases, the quantity of information made available will actually make decision-making harder instead of easier (van der Vlugt 1989, Janssen and Rietveld 1990).

To process information more quickly

Effective planning is heavily dependent upon the capability to manipulate and analyze these large quantities of spatial data efficiently (Marble and Amundson 1988). Simple automation of other aspects of the planning process would also be welcome. From information gathering to map production, the time-consuming nature of the manual work involved in planning suggests that if any element of this could be accomplished more quickly, it would in itself be a substantial support to the planning process (Schaller 1990). The iterative procedure itself that is involved in creating balanced and well-considered plans is often hampered by the practical limitations of manual production (Janssens 1991). The process of rethinking and refining information and proposals would be assisted by an automation of some of this process.

To improve communications with clients, critics and interested parties

In a business concern, communication with the client is an essential part of the product, and any commercial planner will take time to do so effectively. Where the planning and decision-making is made within one organization, communication is less noticeably emphasized, but it is just as important. With current planning problems involving so many subject areas and thus usually more than one 'expert' as a source of information, effective communication between the parties involved is essential if steady progress is to made. In addition, since the public has become more aware of planning decisions and more vocal, coupled with the fact that public opinion can become such an effective weapon, communication of the plans and processes to the public and interest groups is becoming more prevalent, either because it is required by law (e.g. United

States and Canada) or because keeping the public informed is a way of keeping them on your side.

To incorporate qualitative criteria in a rational manner

Planning involves the consideration of many factors. Some of these are relatively objective and can be described in quantitative terms that can be easily compared (e.g. the weight in lbs/in^2 that a particular type of construction will support). Other factors are less easily described in such a fashion. Some, such as the concept of accessibility are essentially abstract but may be adequately described by a quantitative estimation of what it might mean or does mean in the particular instance--in this case perhaps average journey time using the shortest route. Other factors, such as the amenity value of different landscaping methods, are less easy to describe adequately in quantitative terms. These qualitative factors are often best described and compared in relative terms. Planning support in this area would be some mechanism for consistently doing so. An additional difficulty is imposed where the interpretation of such factors varies according to the point of view. This makes them subjective as well as qualitative criteria.

To handle multiple objectives

If they ever existed, the days are gone when the size and location of a proposed housing development can be decided merely on housing need, or the route of a proposed road determined merely by the cheapest route. Almost every planning decision will have to be made in recognition of several objectives. Planning objectives may have several origins. First, there will be the immediate objective of the problem at hand -- put in a road from A to B. Second there will the objectives based on long term goals. Each planning authority will have several long-term goals reflecting an interest either to improve those aspects in which the area in their jurisdiction is less than ideal or to preserve those aspects which are. These goals may be relatively concrete, such as increasing the amount of area dedicated to recreation activities or increasing the number of jobs, or these goals may be more general but nevertheless real, such as providing for increased tourism in the area or encouraging young families. The pressures of an increasing population and diminishing free space to play with usually dictate that these long-term goals are a considered part of every decision. Third, objectives are often imposed by public interest. For example, the increasing public concern for the environment dictates that the environment will always be a consideration. In addition, special interest groups (reflecting a proportion of the public) will impose their specific concern as an objective if their interests are threatened. The result is that there are a multiplicity of goals in almost every planning decision situation, and there is therefore a need to assess each alternative management proposal in the light of each objective.

To support resulting plans

Whether the origin of the sentiment is based in self-interest or a genuine concern for the fate of the earth, public concern for what is happening to that finite space on earth is growing. As a direct result, planners, so often responsible for making decisions that affect that space, are becoming increasingly accountable for their decisions. Challenges to planning decisions are becoming more frequent, and the force behind each challenge is becoming more formidable. These challenges do take different forms in different countries depending upon the weapons available to the challenger and the precedence of similar challenges. In the US, challenges to planning decisions are increasingly manifested in the form of litigation. It is here, however that the process can get dangerously hung up -- dangerous in the fact that lengthy litigation can very easily and substantially decrease the effectiveness of a particular plan either by dragging out the time-scale until the original plan is no longer appropriate and/or making it unimplementable because the legal focus has been shifted so far to the single interest that other interests may be sacrificed, creating holes for further litigation later down the line. One current example of this problem in the US are the forest plans now required for every national forest as a result of the National Forest Management Act. Of the 94 plans that have been completed (out of an anticipated 123 plans), all but 2 are under formal appeal (Behan 1990). That is a substantial planning snarl considering that the Act was passed 13 years ago. But even where it is much harder to tie a planning decision up in litigation, the power of political opinion can be enormous. If the public do not believe in a particular decision, then any effort at implementation may be physically ignored or even sabotaged, causing delay and increasing costs while some way is found to get around the problem (Hellawell 1990, personal communication).

"Responsible decision-making demands that those in authority who make the locational decisions are accountable" (Massam and Malczewski 1990). Challenges to planning decisions are one mechanism for the public and other interest groups to voice their opinion and have their view incorporated into the final plan. Avoiding the problem by simply hiding the details from the public will only cause long term difficulties. Such difficulties typically occur during plan implementation, when the planning dictates are ignored by people on the ground. This method is no way to conduct truly responsible landuse planning. Ideally no challenges would be necessary if the viewpoint represented by the planning organization and the information they held (about that endangered species, for example) had already been incorporated into the decision-making process, but this is not always the case. The potential for challenges to planning decisions does serve a purpose in helping to ensure that public interests continue to be represented. The ability to effectively challenge a planning decision is important, and the situation can be dangerous when this is not the case, because it then relies completely on the decision-makers to be all-knowing and all-caring and voluntarily consider every aspect of a case. A lovely idea, but not necessarily true.

What is needed, therefore, is some mechanism to allow public scrutiny of the planning process. Even where the planning organization has taken the interests and evidence in question into consideration, this will not help unless they can demonstrate that they have done so. In some cases this procedure has become required by law.[2] Rules, regulation and practices are evolving so that the public "must be informed of and involved in the activities of analysts who may be using formal evaluation techniques" (Massam and Malczewski 1990). This is especially so in Canada and the United States with respect to environmental impact assessment. Whatever the current legal situation, some evidence or record of the decision-making process in landuse planning could provide some of the necessary information for informing the public. The use of some decision methodology could provide some level of consistency throughout the planning process, which might make maintaining this record even easier.

To design and evaluate alternative scenarios

Decision-making comes into the planning process when there is more than one alternative plan to evaluate, whether they are site-specific management plans or general policies. But, the final decision between the options is only as good as the alternative plans. Many have noticed that there is a substantial need for assistance in this area: a need to help design and develop alternatives for analysis (Dippon 1989, Giles 1990, Geertman and Toppen 1990) and a need to effectively and consistently evaluate those alternative management schemes or policies, including the possibility of being able to see the potential effects of a particular decision without having to implement it to find out (Dippon 1989, Giles 1990, van der Vlugt 1989, Healey 1986, Clarke 1990).

To get some idea of the sensitivity of decisions to changes in the political environment

The final decision-making effort is always a political process (Guariso and Werther 1989), since the importance given to heritage preservation, conservation, pollution or infrastructure provision always changes with the social conscience and the political environment. Planning decisions are usually in effect for the long term, very

[2]Ideally some forum outside litigation might even be better. Some forum where the presented plans could be challenged and the planners could either show that they had indeed incorporated that challenger's interest and provide evidence to the satisfaction of the challenger or a third-party judge (i.e. 'okay to go ahead') or be unable to do so and have to provide a new management plan again.

likely over a period of time that sees changes in the governing party. Especially if the plan requires a continual budget of money to be able to continue but faces an annual re-assessment of funds, knowing the sensitivity of a particular plan to a change in political emphasis would be helpful to give some sense of its chances of long term effectiveness.

To make/keep the work flexible

Finally, there is an ever-present need for flexibility. The planner's job is always changing, and the problem encountered is never exactly the same. The political scene is continually shifting, as does the breadth of society's interests which can affect the political scene in its own right, but also provides a separate influence on planning. There are also regional variations in planning problems and their influences. This variation in the planning situation over space and over time dictates the need for system flexibility in several forms. First, the system must not be fixed in its capabilities for analysis, presentation or data handling. The planner using the system should be able to tune the set of analysis tools available to the particular planning situation at hand (Fedra and Reitsma 1990). This may involve incorporating additional capabilities when they are missing, but should also involve the ability to by-pass analysis functions when they are not required. Thus, any level of computerization must be flexible enough to handle such changes.

Any adopted system must have the flexibility to fit into existing operations (Anderson 1990), respecting the way in which the planners already work. By simply making existing methods easier, this will minimize friction between the users and the system developers and minimize opposition to the use of a new tool, even by those who are naturally adverse to computerization. As planners get used to the system they will discover uses for additional capabilities and options and develop new methods as they go, but imposing a completely new methodology at the same time as a completely new tool(s) will cause considerably more difficulties and may even result in a failure of the system.

Additional flexibility of another sort is required when there is a computer tool already in use that must at least be able to share data or information with any new system. Some planning offices/departments may find themselves in the position of already using a computer system to handle a particular job and wishing to expand the capabilities of the system. Frequently this is a DBMS they adopted to handle their large amount of data. As this can represent a large investment in time and money, any new system must have the flexibility to interface with any such existing systems (Anderson 1990, Fedra and Reitsma 1990).

Planners: the system users

Most of the above needs refer to the desired information technology (IT) capabilities of a planning system. But each capability is useless if it cannot be accessed effectively by the end user. Thus, consideration of the end user is critical in the development of any system.

As mentioned before, planning is a broad subject, and planners are often trained as specialists in an application area (e.g. forestry, engineering, geography), and are rarely computer experts as well (Geertman and Toppen 1990, ten Velden and Kreuwel 1990). The big mainframe 'number-crunching' models in the '70s were neither understood nor trusted by planners nor as a result ever really used in the planning process. On the other hand, computer spreadsheets were picked up with gusto because they were easy to use, easy to understand, flexible, easy to learn and 'program' by setting up macros, and they automated some of the jobs planners did every day. Unlike the big models which were trying to innovate analytically, the computer spreadsheet started by helping the planner with what s/he already did, and as a result of the increased freedom, this gradually encouraged the planner to try new methods and forms of analysis (Klosterman and Landis 1988).

The planner (like most users, actually) is somewhere in between the naive executive user and the computer specialist (Geertman and Toppen 1990, ten Velden and Kreuwel 1990). S/he does not want to be blindly fed answers to his/her questions from a black box like the naive executive user, but wants to understand what is going on. On the other hand, neither does such a person want to have to spend years learning a computer system simply in order to perhaps be able to automate what s/he already knows how to do very well. The system needs to be easy to get into and an immediate help to him/her, but not limiting in any way so that when s/he is ready to explore the further possibilities s/he can. Thus, ease of use without being trivial and limiting is a critical component of an SDSS for planning.

Planners also operate at a wide range of scales, from national governments to local managers and individual landowners, and correspondingly operate under a wide range of budgetary constraints. The larger number of planners at the smaller scales, while still needing the support such a computer system could offer, simply cannot afford an expensive system. Thus, the cost of an SDSS for planning is also critical if it is to be widely used and be an effective support to planning.

Each level of planning runs into the same difficulties and complexities mentioned above, and each needs the flexibility to be able to access to the same type of system of support where and when necessary. Thus, from a planner's point of view, any computer system designed for landuse planning must be user-friendly, inexpensive and flexible.

The existing 'solutions'

These needs have led to the development, for the most part individually, of powerful database management systems (DBMS) for rapid information processing and retrieval, statistical analysis systems and simulation modelling systems for facilitating further analysis of a statistical, evaluative and/or predictive nature, geographic information systems (GIS) for incorporating the spatial dimension into all phases of information processing and analysis, decision support systems (DSS) as a mechanism for handling semi-structured problems, incorporating subjective information and for handling multiple objectives, and knowledge-based systems (KBS) and expert systems (ES) for recording site-specific and subject-specific knowledge and decision-rules containing that 'expert' information which might otherwise be lost between planning situations or between changes in managers.

But there is something very important missing

Individually, however, each of the above systems does not provide the planner with the complete capability that is required. There is a need for a system that offers the user more -- some mechanism that offers an integration of the systems; something that creates from the pieces an "iterative, integrative and participative process" for spatial decision-making (Densham and Goodchild 1989).

A system that is ACCESSIBLE

There is a need for another feature, one that is often missing entirely even from the above systems -- a system that is *accessible* to the average user. The term 'accessible' was introduced by Ravlin et al. (1990) to refer to the difficulty faced by forest managers in finding a computer system they could understand and use. It is an extremely apt term across the entire spectrum of planning, for despite the widely recognized benefits for planning of even GIS capabilities, the adoption of such systems by planning authorities has been surprisingly low (Stillwell and Scholten 1990) primarily because of this lack of 'accessibility'. Although many individual tools are available to support decisions, such as DBMS and GIS, these tools have not always been accessible because of their complex user interfaces, high cost, high learning threshold, lack of facilities/mechanisms for integration with existing planning practices, and a lack of flexibility to evolve as the real and perceived needs of planners change over time.

An accessible system is one that can be used effectively by the user group. Thus, accessibility is used here to refer to a system that is not prohibitively expensive, is easy to learn while providing the capability to explore additional forms of analysis or presentation when the user feels ready, is capable of integrating with existing planning practices and existing computer systems, and is flexible enough to be able to tune the analysis tools provided to the particular decision support situation at hand and be able to evolve over time to incorporate new types of analysis.

A well-designed SDSS can 'improve' land use planning

The hypothesis being tested here is that an accessible SDSS can significantly improve forest management and planning. Intrinsically inherent in the hypothesis is an alternative conceptual design for an SDSS -- that of a hybrid system made up of a partially-linked federation of existing commercially available packages.

The particular capabilities of such an SDSS will of course depend upon the elements incorporated into the system adopted, but the benefits will be planning that is more informed, faster, more supported and defensible, more acceptable, and thus more effective. It does this by providing assistance throughout the planning process, from the information gathering phase through to the implementation phase. In addition, because the implemented system is accessible, a system planners feel comfortable using, it can also improve the planning process simply because it encourages participation and concentrates attention on the problem. It therefore acts not by enforcing a new methodology but as a catalyst for becoming more comprehensive, consistent, explicit, rational and objective, and even for rethinking through the whole planning procedure if necessary. Such a system can also in and of itself be a process for gathering new information, such as the identification of those (un)conscious decision rules used by the planners and 'experts' to make decisions.

Just as the first step in the decision-making process (after initial perception and identification of the problem) is intelligence, so the first step in planning is the information. At this stage the data-handling software in the system provides the most support, such as DBMS for attribute data and GIS for spatial data. These together open up possibilities for the incorporation and manipulation of a wide variety of data and allow easier and more intelligent access to that data. Decisions are made on the basis of the information available, so any capability to handle and assimilate more information allows the planner to be more comprehensive and enables more informed decisions to be made.

Analysis is a way of generating more useful information from raw data by resolving it into simple elements and assembling them in new ways. Although some form of analysis is inevitably involved when some manipulation is required to make datasets compatible (often called 'pre-processing'), the term 'analysis' is most often used to refer to the processes used to answer questions that are subsequently applied to that data.

> Which characteristics are correlated? [statistical analysis]
> (e.g. which plant species can we use as an indicator for the presence of this particular species of squirrel?)
>
> Which areas are similar enough that they can be classified together as a single type? [statistical analysis, image analysis]
>
> Which areas have a high population of elderly people on income support? [attribute data analysis]
>
> Which areas are isolated from existing transport infrastructure and medical services? [spatial analysis]
>
> Where do planning applications and hazardous soil classes overlap? [spatial analysis]
>
> What levels of fertilization are required to maintain a balanced cycle of nitrogen if whole-tree harvesting is applied? [simulation modelling]
>
> What changes in water acidity are likely to occur under several different land uses in different parts of the drainage basin? [simulation modelling]

Analysis can be provided by many applications in many forms, the most common being spatial analysis, attribute data analysis, statistical analysis, image analysis, and analysis by simulation modelling, although these are each merely general terms for entire categories of analysis functions. When these previously separate procedures are integrated with each other and with data handling applications in an SDSS, they open up possibilities for analysis that would previously have been unavailable in any single one. In the same way, they also open up opportunities for the planner to discover new information and new insights.

Since planning has come to involve so much processing, manipulation and analysis of data, the planning process can be aided simply by the automation of some of these processes. But an SDSS can benefit planning even further. The incorporation of more specialized decision support software into the system will allow the user to handle multiple objectives more easily and objectively, and will allow one to incorporate those qualitative elements so common in planning in a rational manner.

The importance of communication is well recognized both for the transfer of information during the planning process and the reporting of results afterwards. Communication is improved both by the explicitness of the process itself and by the wide variety and graphical nature of the output possibilities at every stage in the planning process. A black box model that merely spits out answers to whatever questions are asked of it, regardless of the applicability of the analyses applied, is not liable to instil any trust in the process either by the planners themselves or by any outside parties. On the other hand, a system in which each analysis procedure and each stage of the process is determined by the planner and can be easily made apparent to all interested parties, is much more likely to be trusted and accepted as a well-considered plan.

These remarks identify some of the potential benefits that an effective SDSS has to offer. These benefits can be summarized as follows.

More informed planning

- Allows better (easier and more intelligent) access to information.
- Allows the handling of more data on the topic, enabling greater comprehensiveness than before.
- Opens up possibilities for analysis and therefore the possibilities for new information and insights.
- Allows increased objectivity by making the data and the procedures explicit.
- Facilitates iterative procedures because any step can be repeated without a great sacrifice in time and effort
- Allows the incorporation of subjective elements in a rational manner.
- Allows the handling of multiple objectives more easily and objectively.
- Allows the development, examination and comparison of different management scenarios more thoroughly and more efficiently.

Faster planning

- Automates the existing processes.

  [the extent to which the production of plans is actually speeded up will depend on how much information the planners were trying to incorporate beforehand. I.e. if 'none' and all decisions were 'seat-of-the-pants' decisions, then the decisions will not so much be faster as much more informed.]
- Creates a greater chance that a plan will be accepted the first time, saving the time required to redo it.
- And if something needs to be rerun, it is more easily identified where and how this should be done, speeding up this process.

More acceptable and supportable plans

- Natural resource planning is not a well-defined process, but installation of a system can have the effect of forcing a thinking through of the criteria, considerations etc.
- Facilitates greater consistency.
- Can provide a methodology.
- Can provide a record of the process.

- Can improve communication because of the explicitness and graphical nature of the output at each step along the way.
- Makes the planning more open and traceable and defensible.

Other benefits

- Can increase the information incorporated simply because the process has concentrated attention on the problem. Implementation of a system frequently has the effect of gathering information and ideas as a result, either because several departments will be using it or the managing department realizes it needs information from each of the others.
- Facilitates a thinking through of the criteria and considerations
- Can form the basis for gathering information, and thus be the source of 'expert' information.

The design and development of an effective SDSS is the subject of the rest of this thesis. Chapter 2 develops a description of the functional requirements for an SDSS for landuse planning from observations of the processes and the users involved in both decision-making and landuse planning. Chapter 3 compares these requirements with what existing elements of computer technology currently offer. It also discusses the limitations of existing computer systems and the dangers of currently proposed designs for an SDSS. Chapter 4 introduces a new conceptual design for an SDSS as a federated or hybrid system made up of existing commercially available packages, and discusses in detail the advantages of such a design with respect to system flexibility, applicability, cost, accessibility and overall effectiveness. The SDSS toolbox being used here is identified. In Chapter 5, the more specific landuse planning problems associated with forest management are introduced. An SDSS for forest management is constructed for the particular landuse planning problems presently being faced in Thetford Forest District. How this specific SDSS for forest management was designed, constructed and implemented is discussed in detail. Chapter 6 presents a brief summary and, in conclusion, evaluates the advantages and disadvantages of this hybrid design as an effective form for an SDSS for landuse planning.

Chapter 2

Decision-making and the landuse planning process

Decision support systems are designed to support the decision-making process. An SDSS is just a DSS with emphasis on providing support to problems with a spatial dimension. Unlike some DSS, however, which concentrate on supporting only the choice phase of decision-making, an SDSS is designed to support all phases of the decision-making process: from the gathering of information (intelligence) to implementation of the final plan. The first part of this chapter examines the decision-making process and identifies those approaches to DSS design which are considered most effective. Of particular importance to a successful system is participation by the user. The next section examines the context and the processes involved in landuse planning. Landuse planning is a complex decision environment facing specific complications as a result of the types of problems it addresses. The third section brings the main points from both the decision-making and landuse planning processes together and describes those features that would be required of an SDSS in order to effectively support landuse planning. It approaches the problem from a system point of view and identifies as 'task-oriented features' those requirements identified from the discussion of landuse planning. The list of user-oriented features considered necessary for the development of an effective SDSS are drawn primarily from the discussions of the decision-making process and the planner as user.

The decision-making process

After initial perception of the problem, decision-making is the process of designing possible courses of action and comparing these options in the light of some view of what their consequences will be (Friend and Hickling 1987). Other sources divide the process up slightly differently to include an intelligence phase in which the problem is perceived[3] and the appropriate information is gathered, a design phase, a choice phase and an implementation phase, but the process is the same. In practice, however, decision-making is not a rigid, linear process progressing neatly from data

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[3]Perception and identification of the problem is the first step in any decision-making or planning problem. Although initial perception is really the starting point before any other steps are undertaken, and thus could arguably be an entirely separate stage, it is included in the intelligence phase here because it is also a part of the iterative process (as referred to later in this chapter on page 30 and in Figures 1 and 2). Even the user's perception of the problem is subject to change and can evolve over time as more is learned about the problem in the other phases of the decision-making process.

collection through to the implementation of the chosen alternative. Rather it is a cyclical and iterative process, with observations made in the comparison/choice phase feeding back into the design phase, and even feeding back to affect additional data collection, data analysis and the incorporation of new information.

As a "process of preparing and implementing decisions for action to achieve certain goals by preferable means," planning is very closely related to the decision-making process (Voogd 1983, Rietveld 1980). Problems are recognized, information is gathered, plans are designed and the final choice is implemented. However, whereas once the problems were relatively simple, (for example: to design a route for a new road to serve both industrial and residential needs for access), planning is now increasingly complex. Given the time-scales under which decisions have to be made, the levels of uncertainty to be dealt with, the inter-relatedness of decisions, the constantly changing environment in which a decision must be made, the qualitative elements to be taken into consideration, the sheer amount of information to be considered in order to be comprehensive, and the need to communicate methods and results to clients, arbiters and the public, planners now find themselves under pressure to make decisions in increasingly complex situations. (Friend and Hickling 1987, Ehlers and Amer 1991, van der Vlugt 1989).

How can and should all this be handled? If all the above is true, then a considered decision involves getting all the data together, incorporating all the qualitative information (e.g. aesthetics, nuisance), examining multiple objectives, and ideally taking into consideration the different interests of the various organizations and interest groups affected. This is a challenging task, requiring an integration of specialist decision-makers, information and priorities.

It is here that the developments in information technology can help. Advances in geographic information systems (GIS), database management systems (DBMS), data transfer, hardware and peripherals have substantially enhanced the possibilities for the integration of information. Advances in user-friendliness (ease-of-use), networking and distributed systems can significantly improve participation in the planning process (Polydorides 1991), and developments in decision support software (e.g. multi-criteria and multi attribute utility models) have the potential to provide a framework for incorporating the qualitative elements, and handling multiple objectives.[4]

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[4]Decision conferencing, as a method of tackling the choice phase, may also have a role to play in increasing participation and the quality of that participation (see Phillips 1988). This thesis will not consider decision conferencing, however. It will instead be concentrating on those computer-based solutions which can be run entirely by the user organization. Formal decision conferencing with an outside facilitator (like that service provided by the Decision Analysis Unit at the London School of

Support to the decision-making process can occur at any stage in that process. DSS research has focused primarily on the later stages in the decision-making process: choice or design and choice, and implementation. But there is one other very important early phase to the decision-making process, the intelligence phase, on which much of the rest of the process depends. Thus, if support can be provided to the intelligence phase, then that support is also helping the decision-making process. As mentioned previously, the enhancement of the integration and processing of data to create information is primarily the job of GIS, DBMS, and other data management and analysis packages. The number of cases where these systems have been labelled decision support systems indicates the frequency with which the gathering and processing of information is considered part of the decision-making process.

What is meant by 'DSS'

So far, two definitions of decision support systems have been used. I will attempt to clarify what is meant by each. Where DSS is used in the same way as DBMS or spatial database management systems (SDBMS)[5], it is being considered as a separate application or module providing a specific function or capability for helping the planner handle qualitative elements and/or multiple objectives. This is closer to the classic, narrower definition of DSS which is providing assistance in the choice and sometimes the design phase of the process. The second definition arose when describing GIS as a decision support system because it assisted in the intelligence phase of the process. Here I am referring to a DSS in a much broader sense, as a System that Supports Decisions (in fact, maybe SSD would be better to avoid confusion). The argument over whether or not a GIS is a decision support system is really an argument over this definition. Does a system have to provide support to the choice phase of the decision-making process in order to be considered a decision support system? Or can it provide support to all phases of the decision-making process? The fact that what many organizations really need to improve their decisions is support in the intelligence phase goes some way toward arguing that the definition should be broadened (or another term found for either the broad or narrow definitions to distinguish them). It is in this broader context that the SDSS, the spatial decision support system (or SSSD, the

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Economics in their Pod) is likely to be less appropriate to many landuse planning situations anyway simply because of the expense. Although quality decisions are just as important in landuse planning, there is often less money at stake than, for example, siting a nuclear waste treatment plant, so such a large cost dedicated solely to the choice phase will likely not be appropriate.

[5]Space is not taken out to define these terms here. Please see the appropriate entries in the glossary or Chapter III for definitions.

system to support spatial decision-making), is based. A complete system would thus incorporate enough elements of computer technology such that every step of the decision-making process is supported in some way by a computer application. However, a very useful working system could consist of only one or two of these elements if that is the limit of the support required. The only essential requirement, if the system is to be a **spatial** decision support system, is some form of spatial data handling, mapping and spatial analysis (usually embodied in an SDBMS and found in a GIS).

From here on the use of DSS in its acronym form will refer to the narrower definition of decision support systems. DSS will refer to those commercially available (and not yet commercially available) computer systems which have been developed to support the choice phase of decision-making. DSS is thus an 'element of information technology' ('element of IT') capable of being incorporated into an SDSS in the same way as a DBMS of SDBMS. The use of the written-out form of 'decision support systems' will be used when seeking to include all the systems that contribute to the broader concept, of all systems that support decisions. SDSS is used as in the broader definition of decision support systems.

Uncertainty and preferences in decision-making

Uncertainty and preference are characteristic of all choice situations and are consequently the two features that most DSS are designed to handle (Phillips 1988b). Uncertainty in landuse planning decisions comes from several sources. Friend and Hickling's (1987) categories of uncertainty include uncertainty in the working environment, uncertainty about related decisions and uncertainty about values.

Preferences refer to those values given to different objectives and different consequences (Phillips 1988b). These are subjective values, representing the values and judgements of the single decision-maker or the consensus of values achieved if established by a group of decision-makers. Sometimes such values are imposed by policy (e.g. the Forestry Commission will encourage private owners to plant deciduous woodlands wherever possible over conifer woodlands) or by law (e.g. in the UK national parks conservation will take precedence over recreation in cases of direct conflict) (Blacksell and Gilg 1981), but no matter what the source, these priorities must still be intelligently incorporated into any rational and consistent decision-making process.

A decision support system is a combination of IT and people; a man-machine system

Guariso and Werther's (1989) description of an Environmental Decision Support System as a combination of information technology (IT) and people -- a man-machine system -- is a very useful approach. It recognizes formally the very important tasks accomplished by the planner, a key fact in reality but also a useful approach if one is going to try to convince any planners to implement such a system. There are many aspects to each planning problem, some of which are handled most effectively by computer applications and some of which are best handled by the human counterpart. In general, the computer-based parts of the system are best for accomplishing those more structured procedures, such as information processing, modelling and data analysis. But there are many aspects of problems that may be unstructured and these are especially apparent in planning problems. It is in these areas that the computer-based parts of the system are best used for *assisting* in their solution. For example, landuse planners are often plagued by: a lack of data particularly when it comes to environmental systems, by a lack of knowledge by the planners involved because the project crosses so many fields of knowledge, by variables that are not quantifiable and often subjective such as 'aesthetics' or 'nuisance', or by too much complexity from the magnitude of related factors and potentially conflicting interests. It is in these areas where human interaction is usually necessary and where the planner needs to apply his/her own problem solving strategies to handle the uncertainties and effectively address the problem. Several of the approaches that are provided by the human in the man-machine system are:[6]

- the use of analogy to find similar, already well-known problems
- the redefinition of the problem with different but known terms
- the deduction of a particular strategy from an existing one
- the use of intuitive approaches
- approximating a problem using another problem at a level that is easier to describe
- breaking down a problem into component parts which are easier to address

As the human takes one or another of these approaches, computers will typically come into use again as the human makes decisions that require a new series of well-structured tasks such as modelling, analysis or fast access to data. In addition, some computer applications, such as HiView, may be directly designed to assist the user with one of the above approaches. In such applications it is still the user who is making all the judgements, but the computer is providing the framework for doing so and providing facilities for automatically viewing, comparing and analyzing those judgements.

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[6]This list is based on those found in Guariso and Werther (1989).

Based on these observations, there are several approaches to DSS design which seem to be particularly applicable to landuse planning.

A dynamic and iterative approach

Planning may have been traditionally viewed as a straight forward succession from survey to analysis to final plans (P. Geddes 1911, cit. by Janssens 1991), but as Janssens commented, this description is much too simple to accurately represent the planning process. Planning cannot be considered a rigid progression from one stage to the next or else it is missing out on one of the most important (or possibly the most important) aspect of considered decision-making -- the benefits of learning during the process, of feeding information and insights gained in one phase back into a previous phase. Whether the picture is drawn as a cyclical process with opportunities to switch between stages (see Figure 1) or as a basically linear process with opportunities at every stage to feed back information and insights to previous stages (see Figure 2), the important point is that the decision-making process, especially in planning, is a very dynamic one and requires a flexible and iterative approach in an SDSS if it is going to be successful.

Friend and Hickling (1987) consider this dynamic approach to be one way of handling the uncertainties that are always present. Uncertainties are recognized and carried along until, through the iterative process, they may be somewhat resolved as new information becomes available or policies are adopted or dictated that provide some definitions. The increase in awareness now prevalent in planning of the inter-relatedness of all the different systems affecting land use (e.g. transport systems, communications systems, etc.) only serves to increase the frequency of these uncertainties occurring and makes this iterative process even more important than ever before.

A process-oriented approach

In his discussion of the weaknesses and limitations of existing DSSs and suggestions for future development, Malczewski (1990) focuses on the process-oriented approach as being appropriate for multi-criteria choice problems. The process-oriented approach concentrates on the rationality of a procedure within which decisions are made rather than on the outcome of that procedure. This approach makes a great deal of sense in the area of landuse planning, where it is recognized that there is no one single answer to a planning problem that is not influenced by the priorities of the politicians and the decision-makers in control. Thus, what is almost more important in such situations than the final answer is the rationality of the procedure by which that

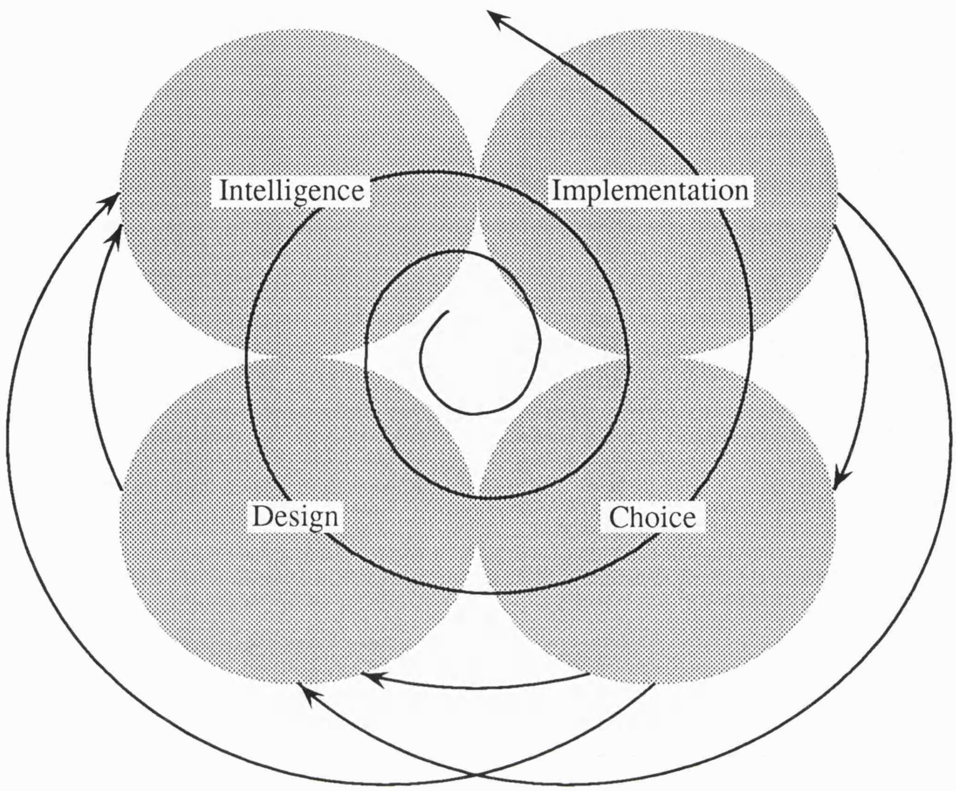

Figure 1. Decision-making depicted as a cyclical process, with opportunities at every stage to feed back information and insights to previous stages.

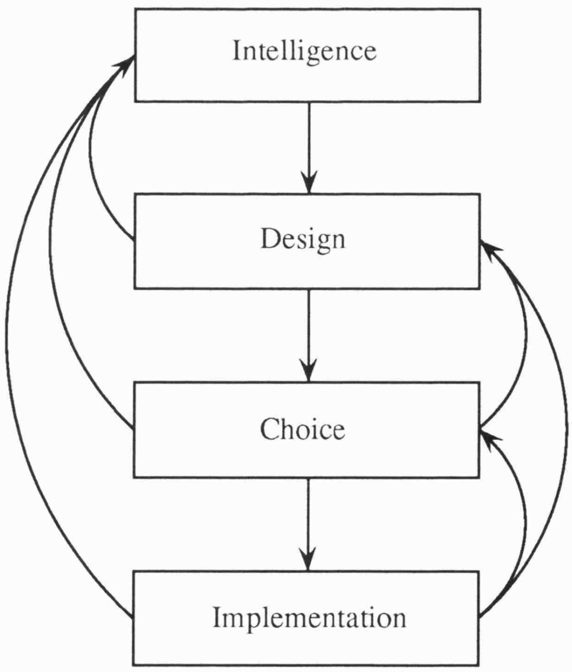

Figure 2. Decision-making depicted as an essentially linear process, with opportunities at every stage to feed back information and insights to previous stages.

landuse decision was investigated and made. Although Malczewski may have been concerned primarily with those types of decision support systems that fall into the narrower definition, of support primarily to the choice phase, his argument for emphasizing the process over the outcome is applicable throughout all stages of the decision-making process, right from the gathering and analysis of data. In the accessible system proposed in this paper, attention is focused on providing support to all stages of the decision-making process, from intelligence through to implementation. This focus is, in effect, emphasizing the entire process of decision-making -- a kind of proof that 'due process' was carried out.

An interactive approach

An interactive approach to decision support system design allows the user to become involved during the solution process. Because of the importance of the user in the man-machine system, this can be a very effective approach. First, it gives the user ultimate control over the system beyond the initial input of data and preference values. Next, it allows the development of ideas. For example, if the choice phase is made interactive, the planner's priorities, preferences and even the precise level of goals need not necessarily be established beforehand, but can be altered and refined as the planner becomes more aware of the relative effects of each.

The level of interaction used is a matter of degree. The system can be designed to run almost entirely on its own, only checking back with the user periodically when particular decisions need to be confirmed. Toward the other extreme, the system can be designed to require constant input and control from the user -- thus effectively only providing a mechanism for accomplishing certain tasks when the user so desires.

The three approaches discussed here are all closely related. The arguments for creating a system that is dynamic and iterative, process-oriented and interactive, all point to a similar lesson. The user is a very important part of any decision support system. Although there is a certain appeal to the thought of being able to enter your data, goals and preferences and having the system automatically spit out the right answer, this 'black box' approach completely ignores the value of the man in the man-machine system. This 'black box' is inappropriate in landuse planning. The enormous effect that values, preferences and political goals can have on the outcome, means that there is frequently no single 'right' solution to any planning problem. Thus, planners do not just want 'blind' solutions, because of the enormous importance of the process used to develop those solutions.

Landuse Planning

Landuse planning refers to all those areas of planning dealing with the management and use of land, and includes the fields of town and country planning and regional planning. The present complexities experienced in landuse planning reveal that it is an area in which there are many possibilities for computer-based support to improve current methods of operation. The precise form that support should take will be influenced by the context in which landuse planning is practiced.

The organizational context

Landuse planning is an activity performed by many organizations and persons, from national governments, through special purpose state agencies and local governments to landowners. Planners are thus involved in a great diversity of applications (Klosterman and Landis 1988) varying both in the type and the scale of problems addressed. These applications range from national and regional strategic plans which try to set out general guide-lines and policies for development, service provision, employment etc., to local government landuse allocation plans which define more specifically the type of landuse that can take place in a particular area, to on-the-ground management plans which lay out the action to be taken on each parcel of land. This sort of 'organizational' division of the planning process (which can also occur within individual organizations) are variously termed an 'objective plan', a 'structure plan' and an 'action plan' (Janssens 1991) or alternatively a 'strategic plan', 'management plan' and 'operational plan' (Guariso and Werther 1989). Essentially, they are referring to the different types/levels of problem inputs and decision outputs (from Friend and Hickling 1987). In other words, the decision output of the top level (objective plan or strategic plan) is primarily policy. At the bottom level (action plan or operational plan) policies developed in both of the two upper levels supplies part of the problem input, while action (or rather, decision on action) is the decision output of the bottom level (see Figure 3). This is simply because the different levels of planners are limited by the type of power they have for the implementation of policy and the implementation of action. For example, landowners will draw up plans for the physical management of their land based upon the constraints imposed by local and national policies and actions (e.g. tax incentives). Local governments will plan for the future of the local area and may draw up landuse allocation plans, but because the initiative for actual development does not lie with local government but with the private landowners instead, the resulting action of the local government's plan cannot be direct management of the land. Instead, the action manifests itself in a set of control categories for types of landuse within each of the designated zones (Davis and Grant 1990). At the

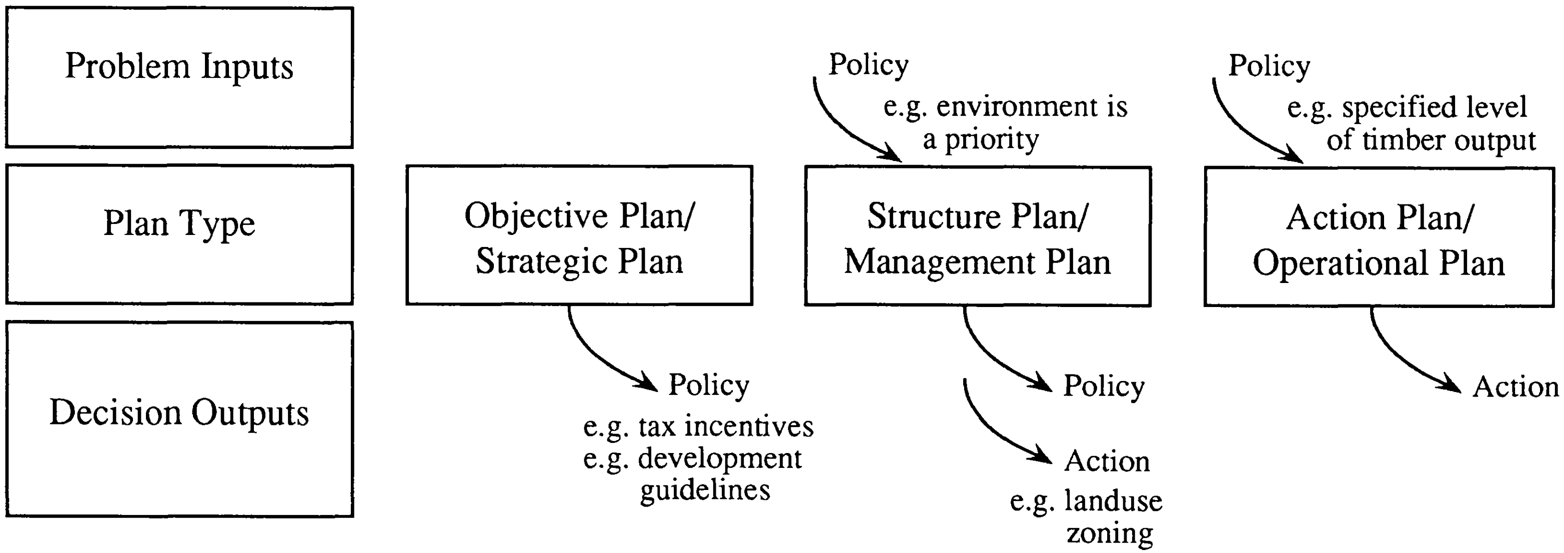

Figure 3. An 'organizational' division of the planning process, and the corresponding types of decision outputs and parameters on problem inputs.

national/regional level, development of policy to guide land management also uses distinctive tools: tax incentives, development guide-lines, etc.

In addition to the organizational context in which a landuse planning decision is to be made, the complexity of the problem will also influence the precise form computer-based support should take in order to effectively support the process. Those complexities common to landuse planning are discussed below.

Landuse planning is one of the most complex decision environments

Ecology is well known as an area of study involving a complex system. But the complexities created by the intricate interactions of the biological, chemical, and geological systems that describe what plants and animals call home are also mirrored in the systems faced by land use planners; they are the interactions of a human-based system -- the intricate interactions of landform, aspirations, behaviour, and movement (to name a few) described by the social, psychological, and all the physical systems with which we surround ourselves. Ecology may perhaps have more uncertainties in terms of a lack of data and in a lack of understanding of how each interacting system works, but land use management must bring an understanding of those physical systems together with qualitative criteria and ethical judgements. This is an added complexity to be reckoned with.

Regardless of which level in the organizational hierarchy a particular planning department is, each level is still a complete decision-making process with the stages of intelligence, design and choice described above. In addition, the management of land is based on so many factors (soil, water, history, geology, housing, recreation, zoning, wildlife, adjacent landuse, etc), demanded by so many uses (industrial, residential, recreation, conservation, preservation, agriculture, water supply) and is the domain of interest of so many organizations (FC, RSPB, MAFF, NCC, CC, EH, NT, MoD, Ramblers Association, water authorities, county councils, district councils, etc.[7]) each with their own goals and priorities, that landuse planning has become one of the most complex environments for considered decision-making (Bird 1991, Ehlers and Amer 1991, Healey 1986, Dippon 1989, Janssens 1991, Parr 1989, among others).

Several other specific difficulties confront landuse planning and render it a challenging environment in which to make decisions. For example, all of the factors

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[7]The acronyms used here refer to the Forestry Commission (FC), Royal Society for the Protection of Birds (RSPB), Ministry of Agriculture, Fisheries and Food (MAFF), Nature Conservancy Council (NCC), Countryside Commission (CC), English Heritage (EH), National Trust (NT), and the Ministry of Defense (MoD).

Guariso and Werther (1989) list as applying to environmental problems are also very much factors in the landuse planning process and apply as much to the social aspects as to the environmental aspects of landuse planning. Outlined below are some of the factors which make landuse planning such a complex process.

Dynamic. The decision environment is dynamic. For example, the process of planning the route for a new road depends to a certain extent on the existing land use of the areas over which it might be built. But existing land use is a dynamic concept, as farmers may sell off plots of land to developers, convert a field to a woodland, put up new farm buildings or allow camping in areas of pasture. Or more subtle changes may occur which do not necessarily require recorded planning permission, such as the plowing up of hedgerows. Depending upon the area concerned and the concerns of the planners, changes in any of the above can affect the original problem of where to route the new road. If, for example, Route A was discarded because it would disturb an important system of hedgerows and those hedgerows were in the meantime destroyed by the farmer who owned them, then the original planning decision would be effectively mis-informed and the planning procedure would probably have to be repeated with the new information.

Inter-dependent. Landuse planning problems are highly inter-dependent. Continuing with the above example of routing a new road, if a recreation area has been proposed for a large plot of land on or near one of the possible routes, then it becomes a related decision problem, forcing consideration of the effects of the two problems on each other. Options for the development of that recreation area could be created that might be able to accommodate a new road passing near or through the area, and ways in which the recreation area might even be served by the new road should be considered. On the other hand, perhaps a similar route for the road could be developed and proposed as an alternative. Inter-dependent problems might be best handled by maintaining the two as separate planning problems, but at the same time incorporating into each process the eventualities associated with the other related planning problem. Such is probably the case in the first example. On other occasions, however, especially where the two problems are very closely related in space, the situation is often best handled by combining the two problems as two distinct goals in a single planning problem. Landuse management of a forest or park area might easily fall into this category if, for example, the development of a new network of paths for a number of recreational uses coincides with an area that is under active redevelopment as a conservation area.

Spatial dimension. The spatial coverage of landuse planning problems make them a difficult decision area simply because of this added dimension to be considered.

A list of the names and addresses of designated areas that are legally protected is a very ineffective way to evaluate where planning proposals are overlapping with protected areas, especially when compared with map representation of the same areas and proposals. Handling and analyzing this spatial pattern effectively requires a specific capability in a computer-based system designed to support landuse planning.

A large number of variables from diverse sources. A lot of variables have to be considered and confronted in the development of a well-balanced plan (Janssens 1991, among others). For example, some of the problems confronting a planner may be:

> 1) planning the composition and location of a new housing area (e.g. van der Vlugt 1988), taking into consideration the need for housing for different income groups, the need to maintain a sufficient number and quality of open spaces, the need to maintain community balance, the need to not to overload existing services and minimize the need for further expansion of facilities, avoid development on hazardous soil types, etc.
>
> 2) planning the route for a new high-speed road link taking into consideration the distribution of population likely to use the road, the cost of construction and maintenance, those areas protected (conservation and heritage), those communities to be served by the road, etc.
>
> 3) forming a management plan for the treatment of an area for forest insect pests requires information on the hydrology, elevation, cover type, land use, species composition, value, politics, and the pest density of the land being considered (Ravlin, et al. 1990).

The result is that for effective planning, the planner must find and utilize a vast amount of information concerning a variety of types from many diverse sources (e.g. Dippon 1989, Marble and Amundson 1988, Janssens 1991, Parr 1989). This leads to two types of difficulties in the decision-making process for the planner. First, the planners must be physically and technically able to handle and incorporate these different types of data in order to effectively manage and use the information in any type of analysis. Second, to intelligently interpret such data the planner must have some knowledge of the field corresponding to the data concerned[8]. Work within the field of land policy crosses the boundaries of so many existing bodies of knowledge, however, that it may stretch the planner beyond his/her limit of understanding as an individual and result in sub-optimal decision-making. For example, Healey (1986) describes the situation with the topic of planning gain, which requires the planner to have "an understanding of developers' financial calculations, engineering principles, aesthetic principles, the values pursued in planning policy, the role of law in limiting

[8]For a good description of the problems associated with inexperienced users interpreting data, see van Deursen's (1991) discussion of the development and use of a soils database.

these, and of the politics of inter- and intra-organizational relationships." His description is a clear case of a situation in which the planner could easily become overwhelmed.

Many qualitative and subjective elements. Compounding this is the difficulty in managing the qualitative, and as a result, the often subjective elements of "measuring, assessing and evaluating the quality and quantity of impacts" of the different decision options (Massam and Malczewski 1990). Qualitative elements are those aspects of a decision which, unable to be assessed quantitatively, are subsequently harder to describe in direct terms that could, for example, be easily incorporated into a model. The aspects of 'aesthetics' or 'nuisance' are two such elements. Qualitative elements are also likely to receive a variety of responses depending upon the view and position of the particular individual expressing it, hence the subjectivity. Such elements can usually only be incorporated into the decision structure in relative terms, in comparison to another option -- e.g. that it is preferable to have a library on that street corner than a petrol station, or that it is preferable to turn that bit of roadside woods into a picnic area than a nature trail. Qualitative assessments are usually also subjective because they will vary according to the speaker.

Many specific decision-situations contain both quantifiable and qualitative elements. In some situations, these can be separated out in an attempt to decrease the uncertainty involved. In the above example, some objective points could be isolated and answered: the two uses could be analyzed for the proximity of similar facilities to the site in question, the site could be analyzed for the presence of species sensitive to trampling, the site could be analyzed for the presence of hazardous soil conditions, or a survey could be conducted across recreationists in the area as to which type of additional facility they would most likely use.

Sometimes the decision element forces a subjective response simply because of the way it is phrased. For example, "are red squirrels disturbed by the presence of a nature trail?" is a rather subjective question primarily because it lacks a solid indication of what 'disturbed' might be, and what is meant by 'disturbed' could thus be interpreted many different ways. A way of phrasing it that would be more specific and could thus be answered more objectively might be, "is the red squirrel population disturbed by the presence of 10 average walkers per day through its territory to the extent that the breeding population is reduced below that required for it to retain a stable population (or even remain evolutionarily viable?)" By that point of specificity, however, the planner may no longer be able to answer the question objectively simply because not enough is known about the red squirrel. There may be statistics over time from studies on the habitat preferences of the red squirrel for nests, and on their tendency to abandon and change nests when faced with various disturbances, but there may be no information on the effect this has on breeding success. Often, for lack of anything better, the planner may draw conclusions from similar studies and extrapolate them to apply to the present situation.[9]

The above represents an attempt to decrease the uncertainty in the planning situation by breaking the problem down into smaller and smaller pieces until there is a chance they can be answered. But while the chance to redefine a problem to make addressing it easier should not be overlooked as it can be a very useful tool, in many cases, however, this crusade toward breaking down a problem into smaller and smaller pieces until the sub-problems can be answered comprehensively and with certainty can be counter-productive (Friend and Hickling 1987). Going to such extensive efforts to decrease or eliminate the uncertainty of a problem is not justified if a) so much time is wasted that the deadline has passed and the planning situation is now changed, b) so much energy is expended that the other aspects of the decision problem are not dealt with properly, or c) the data is not available in the first place to answer the disentangled pieces. In any of the above three cases, the uncertainty should just be recognized, perhaps dealt with selectively and weighted accordingly.

Thus, as a result of differences in interests and gaps in knowledge, there are going to be subjective elements to be dealt with in just about every planning situation concerning landuse. There may be no other way to express an important concern or constraint, as even the best attempt to create a question that could be dealt with objectively may still include concepts for which the best answer is a qualitative one, as in the concept of 'average walkers' (i.e. walkers creating some 'average' amount of disturbance) in the above example. It is important to note also that trying too hard to give an objective answer may even be dangerous and/or detrimental to the decision if care is not taken, as it risks a gross misrepresentation of the problem situation. There will always be qualitative and subjective elements, so the best method is to be able to deal with it, document it, and incorporate these subjective elements right into the decision-making process.

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[9] Just to clarify some of the terms used, the concept of the evolutionary viability of a population is a long term view that requires a study of the genetics of the species (and perhaps even of the particular population in question if the species is one that varies greatly) in order to compare the genetic variability of the species with its breeding and social habits (affecting genetic mixing) in order to determine the minimum population necessary to maintain both a stable population of red squirrel in the short term, and a population that retains enough genetic variability to be able to adapt to changes in its environment and evolve over time.

A large number of demands for land (and interest groups). A related and compounding problem to the amount of information a planner must handle, especially in the area of qualitative information, is the number of different interests at issue that a landuse planner must consider. Those outside interests of local industry (including farming and fishing) and local and national conservation groups may be in addition to the several interest groups already within the organization, representing, for example, the different departments of roads, utilities, parks, recreation and housing within a local government authority. Some of these interests reflect policy developed and thus imposed by higher government, some reflect policies and goals developed by that authority's own objective/strategic plans, and some reflect the positions of outside interest groups. Most obviously, planners usually have to work under the constraints imposed by the policy made higher up the organizational hierarchy. For example, the management plans of landowners must follow the zoning rules laid down by the local government. Correspondingly, local government may have to reflect the regional plans (e.g. protect designated areas) when trying to solve a local planning problem like the re-routing of a road. The sheer number of interests to be considered does add considerably to the complexity of the planning process, but so does the great variety of interest groups and the difficulty in measuring, assessing and evaluating the quantity and quality of impacts of different decisions, be they management/action or policy (Massam and Malczewski 1990).

Massive data requirements. Landuse planning typically requires large amounts of data as a result of the number of spatial units involved and/or the wide range of phenomena to be taken into account in any one planning problem (Janssen and Rietveld 1990) -- from soil classes to agricultural suitability to finance to transport infrastructure to wildlife requirements to the national needs for timber production. The dynamic nature of landuse also generates large amounts of data (Wood 1990) as many of the parts change over time.

Periodicity. Landuse planning also has to cope with the periodic change over time of some factors such as the fluctuation in the extent of wetland areas associated with dry and wet years, or the fluctuation in habitat needs of a particular squirrel as the population periodically reaches a maximum. For example, no matter what the present state of the marsh, a planning decision over how a particular piece of land should be developed will have to incorporate the effects of such periodic change as well as those factors immediately evident if it is to be effective in the long term.

Responsibility and accountability. The planner is responsible for his/her decisions and is becoming increasingly accountable. Ever-increasing public scrutiny of landuse management decisions is forcing an assessment of the methods, assumptions and procedures used in the generation and evaluation of plans. This process is enforced by recent legal developments such as the environmental impact assessment in many countries (e.g. United States and Canada) which make it the legal right of the public to be informed of and involved in the evaluation techniques used (Dippon 1989, Massam and Malczewski 1990). Providing a mechanism for keeping the public informed (not to mention government, critics, clients and other interested parties) is thus going to be a major part of any responsible planning process. Providing information about the methods used, the criteria considered, the interests incorporated and the priorities used also demonstrates responsibility. Any consistency in the methods and approach used makes this process of providing information easier and generates more trust in the process.

With a declining land area in relation to the population, this demand for responsibility and accountability is a favourable trend in landuse planning. As Massam and Malczewski (1990) point out, "responsible decision-making demands that those in authority who make the locational [and other landuse] decisions are accountable." The problem is how to do this without immobilizing the whole process. Part of the solution probably lies outside the planning process in the legal system itself. Perhaps what is needed is a mechanism for reporting to the public, holding a public tribunal for the comments, incorporating those comments and reporting again without resorting to lawsuits to resolve disputes. In some cases, where the conflict is over private development in private lands, this might take the form of a neutral mediator (Lee and Wiggins 1990). In other cases, where the management of public lands is in question and it needs to be proven that the management plan is up to some publicly and/or previously established 'standard,' this mechanism might be by public adjudicator. A second part of the solution lies in the planning methodology applied, especially if that method can provide answers to some of the most frequently asked questions: 'was X considered in the decision-making process,' 'if so then what priority was it given' and 'if not why not.' In addition, if there is some consistency in the method, then that method can be called into question instead of going to court over every single plan that is produced using it. A third part of the solution lies in improving the statements of objectives, and finally, in improving the quality and speed of the analysis processes and the speed with which parts of the planning process can be rerun and reported if some aspect of the final plan is considered suspect (Giles 1990). It is these last two parts for re-addressing responsibility and accountability in landuse planning which could be assisted by the use of a spatial decision support system.

Landuse planning is in need of improved methods of operation

Many recent evaluations of landuse planning indicate a need for improved methods of operation. Voogd (1983) found that planners were too frequently handicapped by the pressures of time and political demands. He was also frustrated by the lack of explicit information about the alternative plans, their impacts and the underlying values applied to arrive at the solution. Blacksell and Gilg (1981) pointed out a lack of overall planning in countryside management in the UK. Meanwhile, they also highlighted the fact that the present trend of an increasing population with subsequently increasing needs was putting such a pressure on land that positive management was becoming increasingly necessary if irreversible damage was to be avoided. Other studies have reported many land uses in conflict, such as agricultural vs. conservation and residential vs. industrial; all of which reinforce the need for improved methods of operation.

This thesis investigates whether an SDSS can be a tool that is effective enough to improve landuse planning; whether it can begin addressing all those needs expressed above. The next section describes the features of an SDSS, and how each feature addresses many of these difficulties presently faced in landuse planning.

The task-oriented features of an SDSS

Responsible landuse planning requires an integration of decision-makers, an integration of data and information and an integration of priorities. Computer-based techniques are particularly applicable in addressing many of these complexities. Considering the decision-making process in the context of the landuse planning problem, there are several different ways in which existing elements of information technology can provide support to the decision-making process.

To improve the information available. This requires improving the quantity and quality of the data available and improving the analysis processes. Information technology can provide mechanisms to handle and integrate many different types of data -- more than could possibly be handled manually -- which assists the planner in incorporating all aspects of the decision problem, be they spatial or financial. Information technology can also provide opportunities for processing and analyzing the data which speed up existing forms of manual processing and analysis and introduce new forms of analysis that were previously not possible.

To handle the spatial dimension. Although technically a part of the category above, the spatial dimension is separated out because of its importance to landuse planning and the relevance of recent technological developments in the form of GIS.

Existing planning practices such as map production, editing and update can be automated, existing forms of spatial analysis facilitated, and new possibilities for analysis introduced.

To improve the speed of data processing and analysis. This is also brought out as a separate item because of its importance to landuse planning. The information-intensive and iterative procedures demanded of responsible planning mean that planning can very easily get bogged down by the time-consuming nature of the work involved. Information technology offers opportunities to automate and speed up some of these procedures.

To help manage and plan with respect to multiple objectives. Computer-based decision support techniques can provide a mechanism for identifying multiple objectives, analyzing alternatives with respect to those multiple objectives and making choices from the alternatives. Decision support techniques can also provide a way to logically break down the problem into elements of a size that can be handled more easily and effectively.

To intelligently handle and incorporate qualitative and subjective information. Qualitative and subjective factors are difficult to handle in ways that are explicit to decision-makers and to others interested in or critical of the planning process or the outcome. With some decision support techniques, however, these factors are recorded and made explicit, and usually provide a mechanism to incorporate the qualitative information together with the quantitative.

To provide a decision methodology. If a particular decision methodology were found to be effective, for example for national forest management in a particular country, then use of that methodology would provide consistency between decisions at each forest and between forests. Use of a particular decision methodology, especially one in which the path of the decision-making process was recorded in some fashion, would facilitate the support of planning decisions in the face of criticism -- an increasingly common problem in landuse planning. Some form of consistency has a beneficial effect of decreasing mistrust in the planning process as long as the mechanisms and processes used remain explicit. If both clarity and consistency could be achieved, this might even decrease the frequency with which landuse plans are challenged. A decision methodology can also often help the decision-maker formulate more specifically a problem which was instigated as only vague generalizations.[10]

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[10]The Forestry Commission, for example, was instructed by the Wildlife and Countryside (Amendment) Act 1985 to 'achieve a reasonable balance between the interests of forestry and those of

To be able to handle multiple decision-makers. In most landuse planning problems there will not be just one all-knowing person setting the priorities and calling the shots. Instead, there is likely to be a group responsible for the decision-making, one which must come to some consensus over the preferences and priorities to be used. Sometimes, when the individuals all have a similar overall goal, as in the different departments of a single company, this can be done in a group decision support situation, such as decision conferencing. In other instances their differences will be so great that mediation is necessary before any consensus can be achieved. In either case, the analytical and presentational capabilities of computer-based techniques developed in Operations Research (OR) or decision analysis (DA) can usually be of some assistance in facilitating dialogue between the interests and a discussion of the options.

The current use of computer-based systems in landuse planning in the UK

Despite the current importance of positive management and responsible planning in a complex environment, the pressure on planners and the applicability of computer technology, most planning authorities have not been in the forefront of computerization.[11] Why has landuse planning been so slow to accept and use such an apparently useful technology? Many seemed to adopt the electronic spreadsheet quite readily, but why has there been such a hesitation about progressing a little further? The spatial dimension of GIS, for example, would add a wealth of information access and analysis possibilities.

Several surveys by BURISA[12] and *The Planner* have revealed that this gap between the availability of appropriate computer technologies and its uptake by practicing planners is a complex matter involving several factors. Many of these factors reflect an organizational situation, such as a radical restructuring of local authority duties or inappropriate investment policies that render the authority unable to consider or carry out such development. Other factors affecting the uptake of computer technology do relate to that technology itself and, equally importantly, how that technology is viewed. According to Klosterman and Landis (1988), spreadsheets were attractive to planners because they were user-friendly, user-extendable and ideal for

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the environment' (Forestry Commission 1986). See chapter V for a further discussion of this problems with respect to forest management in the UK.

[11]See Polydorides (1991) for a discussion on the situation in city and regional planning and administration authorities.

[12]British Urban and Regional Information Systems Association (BURISA).

examining the 'what-if' questions which are an essential part of planning analysis. Breaking that down a little further, they describe user-friendly as easy to learn, forgiving of errors, and immediately useful with only a minimal knowledge of computer fundamentals. The conclusion to be drawn is that the rest of computer technology is not seen in this same light at all, but as hard-to-use, inflexible and unadaptable.

The planner as user

As the system user, the planner is a very important part of the system itself. S/he is a necessary part of the man-machine system and no real support would be possible without his/her constant interaction, input and control. This is true of all computer systems used in the planning process. As a result, exactly who the user is forms a critical consideration in the design of the computer side of any such system. One of the most important aspects of the user-system interaction is user-interface, as it is that part of the software through which communication with the user is achieved. Because of their interactive nature, most DSS and expert systems applications spend a great deal of time, effort and code on the user-interface.

The users of any system will vary both in their approach to the system and the capability to use it to its full advantage. This variation will be the result of their previous experience and the frequency with which they use the system. Although landuse planning covers a wide range of activities, there are some generalities about planners which can be identified. Planners are among that large group of users who:

- may eventually be frequent users of a system, but initially may not use computers at all or only use them on a casual basis;
- they are neither computer experts who are knowledgeable in programming,
- nor executives wanting only the final answers provided (they might best be described as researchers in their own specific field);
- they will not want to spend a great deal of time learning how to use a system,
- but they will also not want to be limited in what they can do with the system;
- they will be learning with the system and will want to be able to explore new methodologies and new forms of analysis;

The above list is a very demanding one, and not many existing system fulfil all those criteria in the user interface. Many systems which provide extensive capabilities are almost unintelligible to the first time user. At the other extreme, systems which try to improve the user interface by surrounding the system in a user-friendly shell to 'protect' the user from the frightening[13] command line instructions, also significantly restrict the user's use of the system.

The user-oriented requirements for an SDSS

The above aspects of planning place many demands on the computer side of this man-machine system, if an effective SDSS is to be created out of the union.

The complexities of the decision-making process in landuse planning, combined with the realities experienced in the landuse planning process, reveal several conditions which must be met by any system that is going to provide effective support to the entire planning process. Although they are coming from the fields of regional planning and decision analysis, respectively, Voogd (1983) and Phillips (1988) are both very concerned with the user. They recognize the fact that it takes much more than just raw capability for a system to be effective, and each lists many of the same features as desirable and/or critical for a successful system. Expanding from their lists, I have identified those user-oriented criteria that apply directly to the design of a spatial decision support system for landuse planning. I have added the category labels to parallel the previous definition of an accessible system.

User-friendly

- it must effectively integrate with the planners themselves to create a successful man-machine system

Explicit

- it must be transparent in its operation, and based on easy to illustrate principles so that users will understand and trust the results (e.g. the behaviour of the models must be known). It can not provide 'black box' answers.
- it must be able to incorporate values and preferences and make that process explicit
- it must be able to incorporate subjective criteria and make them explicit

Flexible

- it must provide flexible tools that can be adapted to the problem at hand
- it must be sufficiently flexible to adapt to the different needs of a variety of planning situations
- it must be capable of evolving as the planners and planning methods change over time

[13]To a beginner user, definitely!

Inexpensive

- it must be inexpensive in its purchase, implementation and application--so that it can be afforded by all levels of planning organizations in need of it, and so that resistance to its implementation is minimized.

Emphasize communication and presentation

- it must facilitate dialogue and discussion between the decision-makers and between all those departments or interests being represented
- it must facilitate communication between the decision-makers, the public, and anyone interested
- it must present the results in a meaningful format

The process:

- must be problem-centred rather than computer-centred
- must be process-oriented, rather than just providing data, expertise, or focusing on the outcome

Overall, the system must be quick. Time-consuming methods and techniques are much less preferable because of the dynamic nature of the planning process, as changes in the political, natural or social environment will often necessitate re-runs of analyses and parts of the planning process. In addition, the system must not promise too much. It cannot guarantee good answers, just indicate good processes. As a result of all of the above, the system must increase insight into the planning problem, and into its solution.

Concluding comments

The decision-making process is composed of several phases, intelligence, design, choice and implementation. The traditional emphasis of decision support systems on supporting primarily the choice phase of the process is too limited in the context of an SDSS for landuse planning. Difficulties are faced by landuse planners in every stage of that decision-making process, and computer-based support used at almost any stage can have a significant impact on the quality and effectiveness of landuse planning. As Copas and Medyckyj-Scott (1991) note, simply providing a means of exploring data and presenting it can be a powerful decision-aid to many users. There are many different potential users facing spatial decision problems, and some of these may only be in need of particular elements of support. For real-time control in emergency operations, for example, provision and presentation of timely and accurate information is of ultimate importance. Landuse planning, however, has demonstrated a need for all aspects of support, although it will be suggested later that this support may still best be acquired gradually in many cases.

The realities of the decision-making process and the planning process raise a multitude of complexities, many of which can be addressed by existing computer-based systems. But the planner, the human, is an essential part of any successful decision support system. The problem is how to integrate the capabilities of the computer systems with landuse planners to create an effective spatial decision support system. By considering the reality of the decision-making process and the planning process, it is evident that this imposes many additional demands on system design. A successful SDSS will have to be inexpensive, user-friendly, explicit, flexible, quick, interactive and facilitate communication. If it is successful such a system would not only support existing planning methods, but would begin to improve those methods by allowing greater integration of data, people, interests and both subjective and objective criteria, greater iteration as elements of the process have been made faster and more efficient, and greater participation in the planning process because the procedure has been made more explicit and more accessible to more people. Interaction with the system would no longer be solely the domain of the information specialist. The end result would be more positive management and more responsible planning as planners' capability for handling the complexities is significantly enhanced.

Chapter 3

GIS/DSS and all that

The computer makes such a difference because it enables the exploration of the issues concerned "in ways that are impossible with verbal arguments alone" (Phillips 1988). Phillips was referring to the use of 'preference technology' -- the use of computers to help people form preferences, form judgements and make decisions. It is precisely this enabling feature of computers that makes them so useful in most forms of information manipulation and analysis required by landuse planners. Computers and the software written for them allow the exploration of the issues concerned in ways that are virtually impossible by manual methods alone.

There are developments in computer-based technology which directly address some of the issues and needs raised in the previous chapters. These developments can be roughly divided into the various 'elements of information technology' (elements of IT) which represent those pieces of functionality as they could be incorporated in a spatial decision support system (SDSS). The following section is a discussion of those elements of IT currently available, and the applicability of each to the needs of landuse planners. Geographic information systems (GIS) and decision support systems (DSS) are later introduced as two major computer systems that often boast they can provide the planner with everything s/he needs. The advantages and limitations of both systems for spatial decision support are highlighted.

Some definitions

Information technology refers to those computer-based technologies which have been developed to assist in dealing with data and information. The tasks information technology has been designed to address range from: the classic tasks of simple data processing (e.g. sorting, mathematical manipulation etc.), to presentational tasks (e.g. graphing, mapping, diagraming), to modelling techniques applied to structured or partially structured problems (e.g. simulation modelling), to techniques which store, elicit and/or apply human knowledge and rules of reasoning, to techniques to assist the user in tackling less structured problems (e.g. preference technology), to techniques in which computers are attempting to emulate human reasoning and recognition. This chapter is concerned with each of those individual tasks and the extent to which they assist in the landuse planning process. To clarify the terminology being used here, 'element of IT' will be used to refer to that software which performs a single category of those tasks listed above, be they manipulation, analysis or reasoning tasks.

Although the term 'computer systems' is often used to identify the software (or hardware and software) that accomplishes these tasks, it is too loose a term to be used here. Most 'computer systems' sold in the market today contain facilities to handle more than one of the above tasks, and the term will be used here to refer to just that -- the broader, commercial definition. There will be only three exceptions to this rule concerning the use of the word 'system': the database management system (DBMS), the spatial database management system (SDBMS) and the expert system (ES). DBMS is commonly recognized to refer to those tasks associated with the storage, manipulation and analysis of attribute (non-spatial) data, and it is used to mean the same here. Some computer systems sold as DBMS also offer additional capabilities such as graphing or more sophisticated statistical analyses. These capabilities would be part of the computer system but are not considered to be part of the DBMS. Similarly, SDBMS is used to refer to those tasks associated with the storage, manipulation and analysis of spatial data. Expert systems, also referred to as intelligent knowledge based systems, are composed of a knowledge base and an inference engine. It is this inference engine that is unique and is primarily referred to as the 'element of IT' when the term ES is used. For clarity, each term will be used in their acronym form. If, for example, the broader commercial form of a DBMS is intended, the term 'computer system' will be used in conjunction with it.

The elements of IT

Database Management Systems (DBMS)

A DBMS provides a mechanism for the capture, storage, retrieval, transformation, manipulation, analysis and display of attribute data. Here, attribute data refers to those normative, hypothetical or actual characteristics of real-world objects (Webster et al. 1989). The way in which data is organized in a DBMS is as important as that in an SDBMS, as it influences how that information can be accessed, analyzed and used. The major data models used in DBMS to define that organization are rectangular (flat file), hierarchical, relational and network (see Armstrong and Densham 1990 or Guariso and Werther 1989 for further description of each type of data model).

A DBMS is a very useful and almost essential element for landuse planning because of the large amounts of data typically involved. DBMS provide a way of storing and accessing data in user-defined subsets or summaries. They also provide a way of manipulating data to generate the information required to address the landuse planning problem. In addition, a well-designed DBMS can provide the mechanism for maintaining and improving the quality of the data. For example, consistency of data can be created and maintained by enforcing rules associated with data entry and actuality of data. The latter, referring to the maintenance of the most up-to-date or accurate values, can be provided by a mechanism for selective updating. Integrity of data can also be checked by a DBMS (Guariso and Werther 1989).

Spatial Database Management Systems (SDBMS)

An SDBMS is the essence of a GIS. It is a term invented here to represent that part of a GIS which provides the mechanism for the capture, storage, retrieval, transformation, manipulation, analysis and display of spatial data. Here spatial data refers primarily to those locational and/or topological characteristics of real-world objects[14]. There are several types of SDBMS because there are several types of design models for describing and defining spatial data. Raster, vector and object-oriented are often considered the major types[15]. Each implies different assumptions about the real world. Each type is also best at handling different types of data and performing different types of spatial analysis, because the design model influences the types of relationships that can efficiently stored and derived from the data elements (Armstrong and Densham 1990). Which type(s) of SDBMS a landuse planner requires will thus vary depending upon the problem.

An SDBMS is a very useful element in the landuse planning process simply because of that spatial element. With it the user can collect, organize and access data spatially--selecting an object because of where it is or where it is in relation to another object. Via its display capability, a SDBMS also provides a means for visual inspection and comparison of spatial features. Many users are of the opinion that simply visualizing the context and structure of a landuse planning problem and of the alternative solutions in this way can be a very powerful component in the intelligence phase of decision support (Fedra and Reitsma 1990). With its capability for map production, the SDBMS can also offer a way of speeding up a very time-consuming process -- improving the planning process as more up-to-date and immediately appropriate information can be quickly portrayed. In addition to this rather simple

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[14]SDBMS is really just a special type of DBMS, and designs are under development to create a DBMS that will handle both spatial and non-spatial data together. Two examples are the extended network model described by Armstrong and Densham (1990) and the object-oriented approach described by Guariso and Werther (1989). However, as most existing computer applications and computer systems still store and handle the two databases separately, they are considered to be two separate elements of IT here.

[15]These design types are in addition to the data models described in the above section on DBMS. For example, a quadtree SDBMS is an example of a hierarchical data model raster design type.

function, an SDBMS can also offer a wide variety of means for the editing, manipulating and analyzing of that spatial data.

Other analysis tools

There are many other computer-based tools which provide the mechanism to apply a single type of analysis. Tools for image processing, statistical analysis, simulation modelling and graphing are all general categories of such elements and all provide alternative ways of analyzing, manipulating and integrating data quickly and effectively. If these are available to the landuse planner and can be accessed when they are needed, such analysis functions have the potential to significantly aid landuse planning.

Decision Analysis (DA)

The term 'decision analysis' has evolved over time from referring to one of four relatively distinct schools of decision support,[16] to become the term primarily used in conjunction with decision support techniques directed at the choice phase. Decision analysis has been described as a process of decomposing a problem into two parts, "one to indicate the probabilities of different possible consequences of each alternative and the other to evaluate the desirability of those consequences" (Bell 1977). More recently, it has become apparent that in many cases it is not possible to obtain all the data required for such analysis, and rarely is there complete agreement among all interested parties regarding the alternatives and consequences (Massam 1988). This points to the need for additional methods to accommodate for uncertainty and multiplicity of objectives, respectively, and many DA techniques have evolved to address these. In general, DA represents a rational way to tackle a range of difficult choice problems. Although not all DA theories and methods also exist as computer applications, many do, and it is in reference to these computer versions that the term DA is being used here.

There has always been a problem with assessing which management alternative or strategy to choose, and several methods have developed to handle the situation. Computer applications of methods for evaluating alternatives and making decisions exist in several forms. The two principal types of solution techniques are programming techniques and heuristic methods. Among the programming techniques, one early way of tackling the problem was to run a cost/benefit analysis on all proposed alternatives to see which came out the best. This method produced a 'best' alternative and provided a

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[16]Stabell (1987) defined the four relatively distinct schools of decision support as: decision analysis, decision calculus, decision research and the implementation process.

list of those criteria which were associated with the costs and benefits applied. The next method of tackling the problem was linear programming. These methods could handle the problem of incorporating criteria which were not so easily given a monetary cost or benefit. Instead, criteria and variables could be measured in more appropriate units, such as visitors per year. However, linear programming still only allowed the maximizing or minimizing of a single objective. Goal programming was a development on linear programming in which more than one objective could be incorporated in the search for the choice solution. Closely related to that, multi-criteria decision making (MCDM) techniques go still further to "allow information on planning goals and objectives to be converted into evaluation criteria and to brought into a framework that incorporates the opinions of interest groups" (Massam 1988). Preference technology, "the use of computers to help people form preferences, make judgements and take decisions" (Phillips 1988), represents the computer application of heuristic methods.[17]

In general, applications of these techniques in landuse planning have witnessed a progression from the early cost/benefit analysis, through linear programming and goal programming to applications of multi-criteria decision making and preference technology, such as the application of multi-attribute utility theory. In the political and judgemental context in which the landuse planning process exists, these latter two could form a very important part of the landuse planning process, as could other developments like them.

DA provides a structured procedure for evaluating alternative strategies, in which multiple objectives, qualitative criteria, decision-makers preferences can all be taken into account. It provides consistent results, as the decision-makers preferences and any judgement made concerning uncertainty are always handled in the same way. DA can also report the parameters and preferences that were involved in the final decision, making the procedure much more explicit than any 'black box' methods that only output the final choice.

DA procedures offer several things to the landuse planning process.

- it forms a rational framework for a decision which can then be justified more openly and easily
- it provides a mechanism for providing explicit information about the weights and parameters used in the decision problem

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[17]Heuristic methods are, by definition, those methods which assist and train the users to find out things for themselves (Onions 1973). Although some other methods may be technically programming techniques, such as the MCDM techniques described by Massam (1988), these methods could begin to be be described as incorporating some heuristic characteristics, as many are effectively training users to think through their alternatives, criteria, objectives and priorities.

- it provides a mechanism for rationally handling subjective criteria
- it provides a mechanism for handling multiple objectives
- it provides a mechanism for investigating the sensitivity of management strategies to changes in priorities (as often happens as a result of political shifts)

Begg (1987) found that just the process of applying DA to the problem had a positive effect on the decision-making process. She noticed that it had the effect of forcing the decision-maker to consider a more comprehensive view of the problem, and of ensuring that there was discussion about the problem in some depth. In short, simply the process of organizing information can be an integral and valuable part of the planning exercise (Massam 1988).

Knowledge-base (KB)

A knowledge base is a computer-based system/technique in which information is stored in a particular structure reflecting relationships of reason. This is different from a DBMS, which stores data according to their taxonomic relationships. A tree-structured knowledge base, for example, links a sequence of facts in a line of reasoning that can be projected forwards or backwards (Webster et al. 1989). Thus, while information is created from the data in a DBMS by its manipulation and further analysis, the data in a knowledge base is given meaning by the way it is structured in that knowledge base. A knowledge base may also store many more types of data than that in a common DBMS. Webster et al. (1989) described six distinguishable types of data as:

- Empirical knowledge: recording attributes of the real world which may be actual, hypothetical or normative. This type is synonymous with the data in a DBMS.
- Modelling knowledge: often taking the form of procedural rules, applying to qualitative data or precise mathematical formulae.
- Derived knowledge: referring to the facts or data produced by the application of modelling knowledge.
- Meta knowledge: referring to the rules which direct the application of other forms of knowledge. For example, rules which determine the modelling knowledge to apply to a certain set of empirical knowledge in particular instances.
- Linguistic knowledge: referring to the rules which interpret or reference those terms a user may use to those recognized by the system. For example, a rule which tells the system that a 'beech' and a 'oak' are both 'hardwoods.' This is typically used in relation to a system's user interface.
- Presentational knowledge: referring to the rules which affect display and presentation. For example a rule which selects map symbols appropriate

to the scale of the map. This is also typically used in relation to a system's user interface.

As is evident from the description of the different types of knowledge bases, they can have many different applications. A knowledge base can be used to determine which procedure the computer system initiates from a user command, for example which process is required when the user requests all 'hardwoods,' or it can be used to prompt the user with a reasonable option given certain existing conditions, such as the size of map symbols, or the most appropriate analysis to apply.

In landuse planning applications, a KB, often as part of an ES (see next entry) might be used to indicate to the user what management modifications to make to encourage a certain wildlife species, or to identify which elements of data are necessary before a particular model can be successfully run.

Expert Systems (ES)

An ES contains a knowledge base and an inference engine. Thus, it contains both the data relevant to a particular field and the rules that an expert would apply in interpreting that information--representing both the knowledge of an expert in that field and his/her experience in interpreting it. In short, an ES provides facts as well as reasoning rules to manipulate and evaluate these facts to arrive at a solution. Since it is only using the rules that have been programmed into it, an ES can always justify any particular answer by listing the procedures it used to provide the information. A typical example of an ES might be a system that prompted the user to input the facts of a particular situation (e.g. site of planning application), assess the situation according to its programmed rules (e.g. zoning rules that apply in that area) and output the solution that applied (e.g. the types of development allowed without a permit). The user of an expert system can therefore be a layman in the domain for which the system was designed.

Expert systems are useful in those areas where the skill level of an expert is required more frequently than an expert is available. Expert systems have been used to perform interpretation, diagnosis and prescription, design and planning, monitoring and control, and instruction activities (Ortolano and Perman 1990). Expert systems have only relatively recently been applied to planning, so many more are in the research stage than have been finished and are actually in use in the field.

An ES incorporates the knowledge base and the decision rules that represent one area of expertise. It is thus designed for a particular purpose, such as providing advice on a particular decision-making problem. As opposed to the function of decision analysis, an ES is designed to replace the human decision-maker in that particular decision situation. The user of an ES merely inputs the data when prompted; it is the computer system that reports on the final decision. For both of the above reasons, an ES is therefore applicable in only very specific problem environments, especially those which are characterized by relatively limited and well-defined relevant knowledge. As a result of the time and energy involved in the development of an ES, they are only useful in those decision situations that occur frequently enough to justify the initial expenditure. Obviously any single decision in landuse planning would almost certainly fail to qualify as a candidate for the application of an ES, but perhaps small sections of that process would apply. An ES could, for example, be used in conjunction with other elements of IT to:

- check what rules are being followed and check for inconsistencies.
- ensure use of the expert's knowledge even when s/he is not there (or retired, or left)
- could aid in determining which data should be applied in particular situations and prompt the user for those that are missing.
- can be used to interpret and apply the rules in such knowledge intensive areas as landuse laws or zoning regulations.

A ES might have a real role to play in landuse planning when the planner is faced with a problem which involves more areas of expertise than s/he is able to handle or find experts for. As a source of expert knowledge on how to interpret data and information in those fields, the ES could provide rules which the planner could follow in order to get meaningful results. One example was provided by van Deursen (1991, who developed an ES interface to a DBMS containing data on soils. The ES could effectively interpret the layman's queries on suitability for building, for example, and return, derived from the raw data in the database, answers that the layman could correspondingly understand.

Knowledge Elicitation (KE)

Knowledge acquisition is the process of translating knowledge in any of its varied forms into a formalized machine-readable structure (Webster et al. 1989). The nature of this process will of course depend upon the type of knowledge required, and the procedures and rules that an expert uses in the process of his/her decision-making is probably the most difficult. Knowledge elicitation is the process by which that knowledge, especially those less straightforward forms of knowledge, is captured from the expert.

Some sort of mechanism for knowledge elicitation might provide the capacity for the database in an SDSS to grow intelligently over time.

User-interface

User-interface is not usually a separate module, but it is a necessary part of every computer system. It is that part of the software dedicated to communication with the user, and "may take up to half or more of the entire code in modern interactive computer applications" (Guariso and Werther 1989). Thus, even from a development point of view the user-interface is a significant consideration in the development of any computer application. Such techniques as menus, dialogue boxes, form fill-in, direct manipulation, and the use of graphic elements are all developments that have enhanced user comprehension and interaction through the interface. A user-friendly interface can be an intimate part of each computer application (as in most applications on the Macintosh), or it can be added as a separate module forming a user-friendly shell around applications which are less friendly to the average user. User-interface is included in this section because it is so important to the acceptance, use, and ultimately the success of any computer system.

From the perspective of landuse planning, it has been long appreciated and numerously documented that one of the reasons computer systems have not been more widely adopted in this area is because of a well-grounded perception that they were hard to use. Since the field of landuse planning can involve such a wide variety of users, the concept of a single user-friendly shell may not be ultimately appropriate to systems supporting the landuse planning process. The aim of an SDSS is to be interactive, integrative and participative. As the user-interface represents the interface of interaction between the user and the computer in the man-machine system, an SDSS's ability to meet this aim is highly dependent upon the appropriateness and effectiveness of this interface.

Other developments

There have been several developments in computing recently that are occurring outside particular applications, but, they nevertheless have a significant impact on the flexibility and usability of applications across the board. Many are a combination of research developments in both hardware and software. Windows and menus are evolving to dramatically improve user interfaces and increase the potential for user participation with computer systems. Similarly, there has been a general improvement in the variety, cost and quality of input and output peripheral devices such as digitizers, scanners and printers. This improves the availability and possibilities for communication between humans. The potential for networking is expanding to include possibilities for communications between unlike operating systems and unlike hardware platforms. Finally, common data types and common data formats like postscript and

PICT[18] are being established and used with corresponding improvements in the success of data translation applications and general data transferability.

Other output and communication tools

Communication, whether between decision-makers, interested parties, clients or the public, is a critical part of the landuse planning process. Ideas, methods, the results of analyses, alternative plans, and the final result all need to be communicated from one person to another. This communication, whether via a hardcopy medium or electronic mail, will usually take place in the form of graphs, tables, text or maps, or formal reports encompassing all of the above. Thus, facilities for presenting and reporting information can be a very important part of an SDSS. Some of these facilities are often available as a part of many of the other tools as, for example, is map output a part of an SDBMS. There exist, however, some tools which specialize in creating high quality output. One popular example is desktop publishing (DTP) for creating high quality reports that integrate a wide variety of presentation techniques. As such, DTP is used here as an element of IT. DTP might be used as a part of an SDSS in landuse planning if the organization was generally responsible for the creation of high quality, informed reports.

Reasoning and deduction

At present, in the SDSS system being described here, the only use of computer systems in the areas of reasoning and deduction (the primary domain of the human component) is as a catalyst to get the user to work more effectively. The fields of Artificial Intelligence (AI) and Operations Research (OR) are currently exploring ways in which computers could actually perform part of this human component and provide more direct support in unstructured situations.[19] At the moment, however, most of these systems are in their experimental stages and the practicality of including them in an SDSS is at present quite limited. Such systems are thus not considered here. When and where systems become available that are appropriate to support decision-making in the planning process, they should be able to be incorporated into the type of SDSS being described here.

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[18]See Hershey and Whitehead (1990) for a full definition of these and other data types and formats used on the Macintosh.

[19]To a certain extent ES and knowledge-based systems (KBS) may also fall into this category, but these two really only provide the basis upon which AI would work, and are not quite yet replacing a human component. For a discussion of the present developments in AI and related technologies, and of possibilities in the near future, see Brand (1989).

Existing computer systems

This section investigates GIS and DSS, those existing computer systems which occasionally claim to be spatial decision support systems. These systems typically incorporate several of the elements of IT discussed earlier in this chapter, similar to an SDSS. However, although these systems each have a lot to offer landuse planning, they each fall short of including the full range of facilities required for a complete SDSS. Furthermore, they often lack those features necessary to render them accessible to landuse planners. Most importantly, many are missing the capability to readily evolve into a complete, accessible, and thus effective, SDSS.

Geographic Information Systems (GIS):

There are many definitions of GIS (Fedra and Reitsma 1990, Densham and Goodchild 1989, Parker 1988, ...) and equally many types of computer systems that are called GIS, but they all, to varying degrees, have the function for the capture, storage, retrieval, transformation, manipulation, analysis, and display of spatial data. A GIS can often handle analytical operations or queries on several levels. Queries of an entirely spatial nature, such as calculating the area of a proposed reservoir or determining how many buildings will be displaced by the proposal, could be considered primary operations, as would distance calculations, network analysis and buffer zone determination. Compound problems, questions that involve a combination of several primary operations or a combination of spatial and attribute searches, are also still well within the realm of present GISs. An example of a compound question might be, "how many protected areas will the proposed highway intersect, and in which of those are there especially sensitive species."

Now, the range of computer systems that have been developed under the label of GIS is very broad. At one extreme, GISs are essentially only computer-aided mapping packages. Others are closer to full spatial database management systems with facilities for the manipulation and analysis of spatial data. At the other extreme, GISs have been customized to incorporate a wide variety of capabilities such as modelling, enhanced presentation and statistical analyses.[20] Somewhere in the middle is a common form of GIS which includes both a spatial data and analysis component and a

[20]These computer systems go beyond the definition of GIS used here. Some are essentially combinations of existing packages and are examples of steps toward the SDSS being designed here. Others are attempts to develop a single comprehensive system for spatial decision support from an existing GIS. The argument of this thesis is that the route to creating an effective SDSS is not necessarily that of customizing a single GIS until it includes all the necessary capabilities. This method is often just not possible and can be a clumsy and expensive process.

DBMS for the attribute data. Many of the present systems which do include a DBMS do so by combining them as two separate modules in a single more or less intimately-coupled system. There is a current tendency among GIS developers to create systems capable of functioning with several DBMS, in an attempt to widen their appeal to users who are already dedicated to or have requirements for a particular DBMS.

The advantage of a GIS is that it can bring in the spatial element. A GIS can access data spatially and provide a means for its visual inspection, comparison and analysis. There are occasions where just this is a substantial support to the planning process. As Fedra and Reitsma (1990) point out, "in many applications it is the automated mapping and cartography, and the basic collection, organization, and management of spatial data that are of primary importance." Data available from GISs are by their nature useful to support decisions with a spatial dimension, and a GIS can thus be considered to be a 'special class of decision support system' (Fedra and Reitsma 1990, Janssen and Rietveld 1990).

But a GIS cannot provide support to all the difficulties faced by landuse planners today. A GIS itself does not provide the full scope of analytical capability a planner might need. A GIS lacks the ability to handle the semi- or ill-structured problems faced in landuse planning. The decision-maker must know the questions s/he needs to ask in order to be able to use the analysis capabilities of a GIS. Providing a rational mechanism for incorporating qualitative criteria or multiple objectives is also beyond the scope of a GIS. The functions available in a GIS are an essential component of any landuse planning problem simply because of its spatial dimension, but the problems are becoming complex enough to require some additional support.

While a GIS can be used to address quite complicated problems, they are still very structured questions -- i.e. the user knows exactly the type of answer s/he is looking for, and knows the facts necessary to get it. The decision-maker, on the other hand, typically faces a problem that is much less structured than the above examples. This is often addressed by selecting viable solutions from among a set of competing alternatives.

Although GIS is occasionally purported as being a decision support system, it is not capable of supporting unstructured problems. For example, a GIS has no facility for incorporating the essentially qualitative considerations and value judgements typical of semi- or ill-structured problems. It has no facility to place different weights or emphases on variables and relationships, as would be required in order to record the decision-makers preferences for a solution. In addition, analytical modelling capabilities are usually lacking, such as those which might be used for testing the effects of various value judgements. Another example can be found in the situation where the decision-makers are unable to articulate clearly both the objective of the analysis and their preferences for the characteristics of the solution. A GIS does not inherently provide an iterative process that records or compares the results of several positions, which often allows the development of objectives and preferences.

Decision Support Systems (DSS):

DSSs are systems (here assumed to be computer-based systems) developed to support managers' decision-making processes in complex and ill-structured situations (Keen and Morton 1978). "DSS provide a framework for integrating analytical modelling capabilities, DBMS and graphical display capabilities to improve decision-making processes" (Densham and Goodchild 1989). They typically include DA (decision support techniques) and often a KB, along with a well-developed user interface. Most have been designed with analytical modelling capabilities and provide a substantial amount of interaction between the user and the solution processes provided by the computer. A DSS could provide the planning problem with all the benefits provided by DA, such as a decision methodology, comparative analysis of the alternatives, insight into the sensitivity of decisions to changes in attitude and preferences, guidance in developing alternative scenarios, and a method for incorporating qualitative criteria and preferences.

However, a DSS alone, as it has already been developed in management and business information systems, has several drawbacks when applied to unstructured *spatial* problems. Capturing the full dimensions of spatial problems is often very difficult or impossible, as spatial information is not held in any form, it is only referred to. This can lead to difficulties because there is no way to assess if the variables selected, the level of resolution and/or the geographic extent of their coverage have been inappropriate. Without access to the spatial data itself, there can be no checking for the appropriateness of the level of analysis after the initial identification of the problem. Right from the beginning of the landuse planning process, formulation of a new plan often involves the identification of spatial problems, such as land allocation conflicts, and developing an array of reasonable alternatives for analysis (Dippon 1989). Unless previously documented by complaint, this process is very difficult in standard DSS. A DSS also lacks a facility for map presentation, a form of communication that is important when dealing with the location-bound data common to landuse planning. Finally, there are usually spatial implications associated with the implementation of any landuse plan. For example, if boundaries are of great importance, a lack of precisely mapped planning documents can have a devastating effect on the implementation of any future plan (Dippon 1989, van der Vlugt 1989).

A Spatial Decision Support System (SDSS)

The SDSS was devised in response to this need for decision support in a spatial context. It was designed to support decision-making for complex spatial problems effectively by incorporating facets of GIS with that of DSS. Among other things, an SDSS may integrate a variety of spatial and non-spatial data like a GIS, provide a range of spatial analysis functions like a GIS, facilitate the use of analytical and statistical modelling like a DSS, incorporate knowledge used by experts as in a KBS or ES, and could be designed to tackle problems with subjective criteria and multiple objectives like a DSS. Most importantly, it will do so in a form that is easy to use and flexible enough to adapt and evolve with the needs of the user.

In general, an SDSS provides a framework for integrating analytical and modelling capabilities, DBMS, SDBMS, and graphical and non-graphical display and report capabilities to improve decision-making processes. So how should this framework be created? Armstrong et al. (1986) defined one form of architecture for an SDSS as an *integrated* set of *flexible capabilities* implemented as a set of *linked software modules*. This seems a very flexible and appropriate approach, especially when the level of linkage between the modules can be left up to the user depending upon his/her needs and means.

The limitations of the current definitions of SDSS

The description of SDSS that has been introduced above is modified slightly from those published definitions (Densham and Goodchild 1989, Armstrong and Densham 1990). The modification is only one of degree, but the differences can have an enormous effect on the overall effectiveness of a particular SDSS. Listed below are those areas in which I think the published definitions of SDSS may be going too far.

1) The definitions are trying to be too all-encompassing in their list of features. Densham and Goodchild's (1989) definition, for example, is essentially identical to the one above except that they leave out the term 'may.' According to their definition, an SDSS incorporates *all* of the above features or it is not an SDSS. This leaves no option for any piece-by-piece development which might be a very useful method for some organizations, a fact that is likely to be especially important in much of landuse planning.

2) In trying to exhaustively list all the capabilities an SDSS must possess, the definitions are giving the impression that those features listed are the *only* ones a user might ever need. In reality, there is no way that a single list can be useful to everyone

because of the range of landuse planning problems and the wide range of decision-making strategies people have in addressing them.

3) Densham and Goodchild's definition goes so far as to describe the conceptual design of an SDSS as being modular in construct, but emulating a 'seamless entity' from the user's perspective. It is this insistence on a 'seamless entity' that can substantially reduce the flexibility, applicability and user-control of the SDSS and significantly affect its effectiveness as a tool to support the landuse planning process.

4) Cost is never mentioned as a factor, whereas in truth it can have a dramatic effect on the implementation and acceptance of any computer-based systems.

Densham and Goodchild (1989) mention that there are 'impediments to the adoption of the SDSS approach.' They are referring to deficiencies in the present development of computer-based technology, such as the lack of a perfect SDBMS, or a better format for knowledge elicitation. I wish to suggest that there are equally great impediments to the adoption of the SDSS approach because of its design. It is in danger of being inaccessible to some of the very users who need it most by insisting that the 'best' is they only thing they need and must afford. But this is not necessarily true. In any system that is designed to support decisions, it is ultimately successful only as a man-machine system. Thus, the user is an essential part of the whole process. If for any reason the user cannot gain access to the system, whether it is because it is too expensive, too unfriendly, too simplistic, or inapplicable, that system is rendered ineffective. The published definition for SDSS lays open too many opportunities for this to occur. The following section expands on the above criticisms.

1) As was pointed out in the previous chapter, effective support for spatial decision-making is not limited to supporting the *entire* decision-making process only. Support provided to individual stages in the process does help the effectiveness of the planning process as a whole. In landuse planning especially, this insistence on 'all or nothing' will lead to systems that are less effective simply because they may not be quite applicable to the planning problem at hand or may be just too much at once for the user concerned. Trying to be too all-encompassing can make a system quite unimplementable. For some evidence of this, one can turn to examples in GIS, since there are no records yet of full SDSS being implemented or even developed. When full-blown systems are dumped at once on the user they are frequently far less effective.[21] Perhaps this latter problem stems from the fact that it does not follow the

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[21] Specific references to this beyond hearsay are hard to come by. As Medyckyj-Scott (1989) pointed out in his discussion of the implementation of GISs, it is difficult to put figures on the level of success of such systems. "Suppliers are not likely to advertise GIS difficulties and user organisations

user's typical progression into computerization (see Crain and MacDonald 1983). In addition, there is ample evidence that systems that are incomplete in terms of Densham and Goodchild's definition have proved successful in supporting landuse planning.

2) There is a chance the user may need capabilities beyond those defined by the SDSS experts, Armstrong and Densham (1990) and Densham and Goodchild (1989) etc. Their definitions are appropriately broad, but there is no way a specific definition can hope to cater for both the problem area and the decision-making procedure of the user. Densham and Goodchild mention a knowledge base as being important to an SDSS. There are other elements of IT which probably have something to offer an SDSS, many of which can already be found in existing DSS and GIS, and many of which may only be found as simple separate applications (e.g. the spreadsheet).

3) Beware of the myth of 'seamless entity.' This is especially applicable with such a broad concept as SDSS. A 'seamless' entity' is often quoted as the most desirable because it is imagined as the only way to make a system easy to use. As will be proved in chapters 4 through 6, this is not true. The 'seamless entity' approach is too limiting as a definition, and is dangerous even as an ideal goal, because of the sacrifices that are often made in trying to reach that ideal. In particular, the difficulties with the 'seamless entity' are:

a) It is a massive endeavour, especially with something as broad in scope and application as an SDSS. Densham and Goodchild (1989) identify no less than 5 major areas in need of research development before an SDSS as they imagine it will be possible. But landuse planners are desperately in need of support to the planning process now, and of computer-based support for spatial decision-making. If an SDSS is defined in such ideal terms, it may be a very long time before they will even see such a system, and even longer before one exists that they can afford. What landuse planners want is something they can use to support the landuse planning process almost immediately.

b) It is an ideal. In its perfect form it could be very effective, but systems will fall short of such a high ideal, and there are very important facets that will have a tendency to be the first to be sacrificed if developers strive blindly for a 'seamless

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are not overkeen on their problems being made public." Of the few studies that have been conducted on the success of large computer-based systems in organizations, the results have indicated a poor success rate. McCosh (1984, cit. by Medyckyj-Scott 1989) found in his study that only 5 of the 15 cases of decision support systems that were introduced into organizations were a success. Similarly, Coopers and Lybrand's (1988) study on the success of GISs in the US adopted after a simple pilot study, reported that 60% of the systems did not fill the requirements of the purchasing organization.

entity.' These will usually affect the flexibility of the system, user-control over the system and the applicability of the system to the specific problem and the planning strategy at hand.

The first common problem may be a user interface that limits the user to that level of use set by the developer. A system that appears a 'seamless entity' can be created by the development of a user-interface module or shell to bind all the data processing, analysis, presentation and reporting modules, to name a few of the possibilities, together. The concept of a user-friendly shell has been used frequently in the past to buffer the user from the unfriendly interfaces of existing packages, and the difficulties with the process are well-known. It is relatively easy to design a shell that caters for one particular level of user, for example, for providing only several specific options for query, response and output. It is much harder to design a shell that caters for several levels of user, or even for a single user who changes in his/her ability as s/he becomes more confident and interested in interacting further with the system.

Flexible tools that can be adapted to the problem at hand is another essential feature for an effective SDSS. In landuse planning the problems themselves can vary considerably, as can the strategy of the planning team as the environment in which they are working changes over time. But the flexibility to modify a system to deal with these changes is another feature that is too frequently sacrificed when developers strive toward the ideal of a 'seamless entity.' Being able to incorporate those capabilities, and only those capabilities, which are appropriate to the user and the planning problem, is essential if the computer-based system is going to support the user in the decision-making process instead of running it. The user will very often be limited to those features which the developer of the particular system provides and supports. If the developer does not specialize in the problem area of the user, this can be a particularly limiting obstacle.

System inflexibility can lead to the dangerous situation in which the problems addressed by the owner of such a system are computer driven instead of problem driven. In other words, users apply those analysis functions which the system already has a capability for instead of applying those analysis functions which are most appropriate to the problem. This situation can occur when it is difficult to add particular capabilities to the user's SDSS. The developer of an SDSS will only be able to include in that system those modules which s/he has designed and supports. As a result, there is a tendency for the resulting system to reflect the supplier rather than the application problem. Adding any additional capability to such a system would mean going back to the developers and having them write the module in if they are able. The possibilities and the success of this will depend upon the design and the developer, of course, but there is a tendency even among developers of modular GIS to provide only a small variety of possibilities for additions to the analysis or presentational capabilities of their system. Indeed it would be expensive for the developer to maintain an enormous variety. The developer may also not be an expert in the application field, and may not be able to provide the precise analysis capabilities required by the user for the job at hand without going to a third party expert and developing a specific system for the user.

An SDSS that is designed as a 'seamless entity' can remove much of the control of the system itself from the user, which is just what Densham and Goodchild did not want. Often this happens because all the functions and details are hidden underneath an impenetrable user-interface. Both Phillips (1988) and Guariso and Werther (1989) specified that a system must be explicit and unambiguous if it is to effectively support the decision-making process. Far from being transparent in its operation, so that users will understand and trust the results, many of the processes in a 'seamless entity' are rendered inaccessible to the user and s/he must blindly trust the results. As needs evolve over time, the user must rely on the developer for any changes to be made to the system. Once a system is purchased, the developer is frequently the only place the user can turn to -- there is no way for them to 'shop around' for a cheaper price or a more appropriate form of analysis. The people who set up the system will understand the details of how the SDSS operates in its support of landuse planning, but these people will be the technical support staff and not the planner. It is the planners who are expert in their application area, however, so why should the control of such details be out of their hands?

4) The cost of a system is very important. Landuse planners in particular are as likely to be (or more likely to be) members of local government agencies as members of large corporations, and therefore seem to be perpetually strapped by budgetary constraints. Even to wealthy companies, however, cost is a factor. Voogd (1983) observed that the more expensive a system is, the more resistance there will be to adopting it.

Cost is an important consideration at several stages, and a system designed as a 'seamless entity' seems to come out expensive at every stage. First, seamless systems are expensive to develop. Like a DSS, an SDSS is most effectively designed and implemented for a specific problem domain. Getting a custom-built system, however, is always an expensive operation. Next, seamless systems are expensive to implement. There are two reasons for this. First, because the system exists as a single piece of software, it will typically be implemented as a single unit, thus completely changing in a single day the working practice of the entire department. This does not leave any time for those affected to get used to the system or to any new automated methods gradually, and there can be substantial resistance to its use as a result. The second factor concerning cost during implementation, is that when a single system is designed to be so self-contained, it often cannot incorporate existing systems or elements already in the department. Typical examples would be a DBMS or DTP system that had been developed in-house to suit particular requirements or that the staff had become used to. If a newly acquired SDSS cannot incorporate elements of the user's existing system, it incurs an extra cost for the user as workers must be retrained, data converted and existing systems scrapped. Finally, seamless systems tend to be expensive to maintain. With such an architecture, the user is usually cut off from the underlying program and is not encouraged to understand it. Thus, such a system will usually require a permanent staff of programmers to maintain it, as even routine problems cannot be addressed by the user without help.

Concluding comments

Many computer systems exist that partially address the difficulties faced by landuse planners. None, however, come close to providing everything needed. Distinguishing the broad classes of tasks and approaches which are provided by computer systems makes it possible to more easily identify which of these 'elements of IT' address the landuse planner's needs. What is needed is a way to be able to put these 'elements of IT' together in a fashion that directly reflects the landuse planning problem, creating an SDSS. Previously published definitions for an SDSS stress the importance that such systems be easy to use, flexible and specific to the problem at hand. They also, however, focus too much on the ideal system without providing any indication of how this could be achieved without waiting for new research and the usual massive investment of time and money. The principal limitation in these definitions is the ideal of a seamless entity. Seamlessness is apparently still thought to be the only way to make such a potentially complex system easy to use. As will be demonstrated in the next chapter, the Macintosh and developments in user interface and ease of data transfer means that this is no longer the rule. A modular approach that succeeds in being user-friendly without being seamless appears to be an answer to this dilemma.

Chapter 4

A conceptual design for an effective SDSS

To be effective a spatial decision support system for landuse planning must include several important characteristics. An SDSS must have the potential to address all of the difficulties commonly faced by landuse planners as described in chapter 1 (see pp. 12-18). It must also be accessible to the user: inexpensive enough to be available to the planners concerned, flexible enough to be able to evolve, and user-friendly enough so that it will actually be used. In addition, as pointed out in chapter 2, an SDSS must be directly applicable to the problem. Previously proposed designs for SDSS are in danger of violating one or more of these criteria for effectiveness. It is therefore proposed that a new design approach is needed to ensure that all these criteria are met in the resulting system.

A new description for an SDSS

With respect to these danger signs, a new conception for the design of an SDSS is proposed here. It represents an exploration into the possibility of implementing such a system in a personal computer (specifically Macintosh) environment using existing software in a federated, hybrid or coupled manner. The specifics of this design, along with its benefits and limitations for landuse planning are discussed in this chapter. Such an SDSS may still be complicated if such is the nature of the problem, but it will be understandable, flexible, and will be more effective because it will be better used. The general features of this design that make it different from other proposed SDSS are:

- use of existing easy-to-use software packages
- many of which are user-modifiable
- the precise combination of packages incorporated is problem and situation specific
- the user, their problem and their organization are intimately involved in system creation

The result is a system that is:

- much less expensive to develop and implement. The federated structure[22] makes it less expensive to develop a system that is tailored to the problem at hand, and much less expensive to implement it as the parts can be installed gradually.

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[22]This is defined fully later in the chapter, on page 73.

- a level of complexity that is up to the user. The essential organization is very simple, while the complexity of each element incorporated is up to the user, and can easily evolve in complexity as the user becomes more experienced and confident. Simple tasks should be presented clearly and complex tasks not forced upon a user until s/he is ready for them
- almost always applicable. Each actual SDSS built will be a particular combination of packages and will thus be specific to the problem at hand. Individual software packages may even allow for user-modification.
- almost infinitely flexible. The system is not software-specific and need not be hardware-specific if current trends in networking and electronic communication continue.
- less demanding on resources once implemented, leaving fewer requirements for dedicated technical support staff. The user has a greater understanding of the system as s/he was part of its design.

To be effective it must be accessible

Although many computer-based tools exist to support planners and decision-makers, by assisting in interpreting, integrating and analyzing data, those users are often unable to use these tools effectively. Either the complex user interfaces, high cost or lack of flexibility have been too much for many users to come to grips with. None of these tools were *accessible* to managers.

Lessons from the development, implementation and use of GISs, an example of another relatively large and complex system, indicate that there were some difficulties. Among the many success stories in which GIS was a truly enabling factor because of the new analysis functions it provided, there are also numerous instances in which GIS has suffered from the failure of implemented systems to be fully incorporated into the organizations into which they were established. It has also become apparent that there has been a complete lack of uptake of GIS in several sectors of society for which the technology would otherwise clearly be ideal. The causes for both of these observations are rooted in the fact that GISs are, or are observed to be, hard to use, inappropriate, inflexible and expensive. There can be a number of components to each of these effects.

Hard to Use. "For a GIS to be adopted and used, the greatest challenge is the development of user-interface." Such is the sentiment of many users and authors (e.g. Arbour 1983, Collins 1983, Crosley 1985, Little 1978, Nicholson 1983, Rasche and Cowen 1987). The inability of a system to present even a simple task clearly will almost certainly frustrate a user (Goodchild 1990) and this is too often the case. Many systems that started their existence as research tools, and thus had specifically trained users in mind, have not considered any softening of the user-interface at all until very recently. This has likely not hindered experienced or constant users much, but any user newly submerged into the GIS world is likely to be drowned by the cryptic command strings and non-interactive approach. Learning the functionality of a GIS is not made any easier when even the simplest instruction entails complicated manoeuvres. Thus, one reason a GIS can be considered hard to use is because the user interface is actually very poor. A second aspect that can give a user the impression of being hard to use occurs when the user is presented with too much just as s/he is getting started. When an exploratory request, perhaps while searching for a particular overlay, reveals a list of possible commands a mile long and including everything from changing colours to building topology, the user can easily be left baffled by the choice and/or the complexity of the tools and analyses being offered.

Inappropriate. What users really need can vary greatly from what is offered by the 'full-blown' off-the-shelf GIS systems. This leads to the second common complaint about GIS--that it too often proves inappropriate to the tasks the user really wants to do. Just as users newly introduced to GIS are not fully aware of its capabilities, they are also often not fully aware of their own needs, so a feeling that the system they ended up with is inappropriate is a frequent problem. For example, if getting map information updated and quickly out to teams in the field turns out to be of primary importance to the user, then the fact that the particular GIS purchased does superb network analysis does nothing to alleviate the frustration of its inability to generate the desired maps. And vice versa. Alternatively, a GIS could be considered inappropriate if there are just too many tools provided, forcing the user to sift through all of them to find the one appropriate to the task at hand. As van der Vlugt commented from his experiences, "using a GIS toolbox is like giving someone a complete set of carpenters tools, including axes, chainsaws, hammers and drills, if he wants to do some delicate woodcarving. What he really wants is just the tools for this specific application, some of them preferably tailor-made. He does not want the rest because it only makes his toolbox heavier" (van der Vlugt 1989).

Inflexible. A complaint of inflexibility usually crops up when the user tries to do something different with his/her GIS--usually reflecting either a new need, or a need they have just recognized. The user may want to handle some new data from another GIS or data source and find s/he is stuck. Or the user may want to produce some new output in a slightly different format, perhaps a publication quality map, and find s/he is unable to do so. Or, recognizing that his/her current system configuration cannot do it, s/he may want to expand the GIS to include that specific capability, but finds no mechanism for doing so.

An impression of inflexibility can also be the result of trying to make a package more user-friendly. The development of user-friendly shells represents an attempt to take the 'hard to use' out of unfriendly packages. Users are inevitably at several levels of experience, however, and have a variety of needs, which is much more difficult to address with a single shell. However well-intended, there is always the danger when developing such shells that the interface will be too simplistic. In fact, this is frequently true, for as an individual uses the system they become more experienced and inevitably want more control in the system to put their ideas to the test. Cowen (1983) noticed this with the shell interface in an interactive mapping system he helped develop. After apparent success initially, their system fell quickly out of use again as the menu-driven operating system of the shell "was cumbersome and tedious for the experienced user." This leads to the next problem, that in the process of protecting the user from the unfriendliness of the underlying package, shells often cut the user off from the rest of the system so they are unable to explore further facilities when they are ready for a little more.

Expensive. There are several types of cost incurred when acquiring a GIS system: the cost of determining what system(s) is appropriate, the cost of installation (including hardware and software and disruption time), the cost of data, and the cost of maintenance.

This first cost represents both the time and money spent prior to the time when a satisfactory working system is in operation. Gilfoyle (1991) commented that during his visits as part of the Chorley Committee of Enquiry he saw "far too many examples of organizations that had bought the wrong system simply because they had not spent time in advance defining precisely what they required". This emphasizes one form of the cost involved -- that of rectifying mistakes made when money and time is invested in one product that is later discovered to be inappropriate to their needs. To reduce the chance of mistakes, an organization can initiate a pilot project to establish just what the needs of the organization are and how that relates to the GIS technology available. But although this is arguably a better option, it does not come cheaply either, and can take typically six months for a full study. Furthermore, a pilot project is not foolproof. Among others, Clarke (1986) recommended that extreme care should be exercised and additional research pursued prior to commitment to a given off-the-shelf GIS. Thus, unless an organization already has the expertise in-house to make such decisions or is just plain lucky, the cost of determining exactly what that organization needs in a GIS can be quite considerable.

The cost of system installation starts with the cost of the hardware and software. Although this can be a relatively small cost when the expense of data input is considered (some quote hardware and software as contributing only 20% of the total cost), high costs in those areas can still be a stumbling block. One of the reasons for this can be that although data costs can be spread out over time, purchase of hardware and software is more likely considered as a lump sum. Even if it is paid in instalments, the thought of a large amount of money already spent from the budget for the next few years can still be overwhelming. Second, the 20% figure may represent large projects, but where the area involved is only a single London Borough, the cost of the hardware and software commands a much higher percentage of the total cost. All totalled, the start-up costs of acquiring the necessary hardware and software can be a significant hurdle (Gilfoyle,199). But the potential costs of installation do not stop there. It takes time to get the system fully operational and there may be severe disruption costs associated with that, while the system is physically put in, any existing databases are incorporated and all the teething problems are worked out. In addition, it takes time to get the personnel fully trained to use the system, with its associated cost. This last aspect relates directly to ease of use, for the harder a system is to use the more time-consuming and thus costly this component of the cost will be.

An extremely large or complicated system will require more permanent staff just to keep the system maintained. At one extreme it takes permanent additional specially trained staff just to run the GIS. At the other end, existing staff can just adopt the GIS into their present work environment. In general, the more the system user can understand about the system, the less remote it seems to them, the less extra permanent staff will be required to keep the system running and answer user's operational queries.

These lessons from GIS -- that it is too often hard to use, inappropriate, inflexible and expensive -- are directly applicable to the concept of an SDSS. The above factors are, in fact, even more important with reference to an SDSS because of the necessarily interactive nature of systems intended for decision support. All the above evidence suggests, in short, that one criteria for a system to be effective is that it must be accessible to the users for which it was designed. Thus, one of the emphases in the design of this system for landuse planning is that it is accessible to planners.

Definition of accessible

Easy to use -- because the planner is not a trained computer technician. Although planning occurs in a wide range of circumstances, planners occupy that well-populated level of computer expertise in between that of the naive user or executive user and the techie. Planners do not want to have to spend a lot of time learning how to communicate with the system instead of spending time working with the system to learn more about the data or the problem at hand.

Non-trivial and non-limiting -- because the planner is not an executive user. The planner wants a system that is easy to use, but s/he does not want to be fed only answers to pre-arranged questions about a pre-specified area over a pre-determined time period. The planner is more like the researcher, in that s/he will want to explore further as the answers to his/her initial questions may prompt him/her to think differently about the problem and ask different questions.

Inexpensive -- because the planner may not be attached to a national government or major corporation and have a large budget to spent on IT support to the planning process. On the contrary, much of landuse planning can come under the jurisdiction of local authorities. Computer-based spatial decision support should not be limited to those authorities with large budgets if it is at all possible. In addition, the less expensive a system is, the less resistance will exist to applying it (Voogd 1983).

Flexible -- because the planning process is not well-defined. Problems are varied and many aspects of the problem and the process change over time. The possibility that the planner's initial explorations with the data may even prompt him/her to wish to use different analyses means that the flexibility to incorporate such capabilities into an existing system is essential. Flexibility also means that any changes in the analysis and procedure of the planning process, inevitable over time, can also be incorporated within the same system. This type of flexibility enables system evolution, a cheaper and easier solution than having to ditch a previous system for a new one each time.

Federated in structure[23]

A federated system is an approach that does seem to address these existing difficulties. A federated SDSS would, as the name suggests, consist of more than one separate but cooperative software packages which can be linked or coupled to varying degrees. Typically each package specializes in only one or two types of functions.[24]

In order for this to work there are several critical features. Most importantly, the incorporated packages would have to have a high degree of data transferability, be it

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[23]Wiggins (1990) use the terms 'hybrid' or 'coupled' to refer to a similar structure. Their terminology evolved from the environment of expert and knowledge-based systems, in which a system developed from more than one software type could no longer be attributed to a single type but was a 'hybrid' system. I have persisted with the use of the term federated because it seems to better express the effective structure rather than software lineage.

[24]Examples of individual packages might be: mapping and spatial analysis (SDBMS), statistics, graphing, simulation modeling, 3-D modeling, contouring, DBMS, spreadsheet calculations, projection translation, format translation, editing and image processing, to name a few.

in the form of maps, data, calculations, or graphics. Since several different packages will be used in a federated system, user-interface is also very important in order to avoid having to spend large amounts of time learning how to operate each different package. A high degree of similarity between packages can aid the learning process even further.

Development of a federated SDSS might follow a general format of purchase of a database and mapping system, followed by packages specializing in statistics or modelling functions, for example, depending upon the users requirements. Or it might just as easily begin its existence as a database and statistics federation and grow from there. This feature of incremental development is precisely the principle advantage of a federated system -- allowing the user to develop the system piece by piece, mirroring his/her own evolving needs as well as the continual developments in technology. As will demonstrated by the partially developed system created here, this can quite effectively improve the flexibility, appropriateness, cost and acceptability of a newly acquired SDSS for landuse planning.

Will keep it flexible

It has been observed that virtually all long-lived information systems proceed through a characteristic evolution from an inventory tool, to an analysis tool, and finally to a management tool (Crain and MacDonald 1983). That observation in 1983 is still relevant today as organizations face the same difficulties of initially simply needing a mechanism for the input, storage, update and intelligent retrieval of data, followed by a need for more complex, even spatial retrieval of data, analysis capabilities (from statistical to spatial analyses) and additional forms of information display. Finally, many users may discover and/or develop the need for modelling and more specific decision support capabilities. This pattern of development is almost inevitably true, because despite the fact that all of these processes may be well known to an existing user, those just entering into the field are usually unaware of either the full extent of the possibilities of computer-based systems or of the full extent of their own present and future needs. Thus, the implementation of an SDSS will be partially a learning process. The three stages of evolution (from an inventory tool to an analysis tool to a management tool) described by Crain and MacDonald seem not only typical but preferable, if many of the potential pitfalls faced by the user are to be avoided. Clarke (1986) put it even more strongly when he said, "systems die, or are murdered, mainly for their inability to evolve in this pattern." Yet, how can this evolution be fully realized if an SDSS is acquired as a single system? Certainly not without incurring extensive costs in customizing that software. A break away from the ideal vision of a single seamless software system is necessary to fit SDSS technology with the realities faced by users (see chapter 3, from p. 62).

Will keep it appropriate

The federated system will always directly reflect the current needs of the user, because the software elements incorporated are chosen by the user at the time s/he is in need of that capability. When the choice is only a single comprehensive package that does not easily share data with other systems, that initial choice becomes much more critical. With a federated design, the user is freed from that 'catch 22' position when faced with the decision on the timing of system acquisition: acquiring it quickly, before they have fully identified their requirements, or acquiring it too late after some users may already be committed to other systems.[25]

Will keep it inexpensive

The incremental purchase of software in a federated system decreases the start-up cost substantially as only one or two packages will likely be purchased initially. The absolute cost of software is likely to be substantially less too. Individual packages vary from a few hundred to a few thousand pounds sterling (£), but it would take quite a few of these to add up to the cost of a single GIS which typically starts in the 10,000's. An SDSS, with its requirement for specificity to the user and the problem, would undoubtedly cost much more. This great cost differential is certainly a significant factor for those institutions and agencies on low budgets, but it is equally significant for those institutions who must experiment and familiarize themselves with sample systems first before making large investments in the technology (Polydorides 1991). In any event, a high cost-effectiveness would almost certainly be realized, as no software package would be purchased and incorporated that was not going to be used.

Lost productivity during the process of implementing a GIS is minimized with a federated system. With a federated system, one element or module, such as the DBMS, can be installed and implemented at a time. This limits disruption to one department at a time (e.g. just the records office), and further modules need not be implemented until the previous ones are up and running smoothly.

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[25]At present, no complete SDSS are commercially available to choose from, but when they are, they will probably appear in the form of a modular skeleton that can be tailored to the user at the time of purchase. Some generic SDSS may appear, but these are likely to be less successful than generic GIS because, even more so than just a GIS, an SDSS must be applicable to the problem at hand. Thus, the 'catch 22' position described here applies more to the acquisition of GIS than SDSS. However, the fact that a federated design offers the potential for incremental acquisition, which in turn almost ensures system applicability, still applies.

That same modular structure of the federated system also shows itself to be an advantage during system maintenance. If a mistake is made at some point, as is entirely possible when a package is purchased and tested that does not do all it claimed or just could not handle all the demands put on it by the user, the most the user has to spend time and money replacing is that one inappropriate package and not, as in a single system, the entire system.

It will also be substantially cheaper to accommodate a very specialized capability in a federated SDSS. A requirement, for example, for being able to map and analyze bore hole data directly from survey results is more likely to exist as a separate package than as part of an existing, complete, commercially available system. If a specific function is required that must be tailor-made for the user, then it will more than likely be cheaper to have it developed on its own than it would be to ask a particular developer to build it into their SDSS. The user would also have the freedom to use specialists in the field to develop the specialist package rather than rely on the developers of his/her present system to implement his/her desires.

Will keep it acceptable

Introduction of a large computer-based system into some organizations may meet opposition in the form of an unwillingness to accept the new technology. Organizations where previous computerization has been at a minimum or hidden from the majority of users in the 'computer department' are most susceptible to this reaction. This can be an especially daunting problem if these same users will be asked to change their working habits, such as putting their records or data (be in it forest inventory data or social service records) into the computer themselves or formatting it in a new way so that it can be input more easily. With an incremental system users will be brought more gradually into the system -- piece by piece as it is implemented -- spreading out the learning time and decreasing the chance that they will balk altogether at the prospect of becoming computerized. In a federated system the user is always intimately involved in the choice and implementation of the elements making up his/her unique SDSS. This frequently has the effect of getting potential users excited about the system and what it can do for them, rather than apprehensive about what it will require of them.

Degrees of linkage

The software packages or modules in the SDSS can be linked in varying degrees, from a very loosely connected 'ad-hoc linkage' through 'partial linkage' to a single system with 'full linkage' in which the system components were specifically designed to work with each other (adapted from Badji and Mallants 1991). Linkage is thus a measure of the degree to which each software package has been designed around another package. Evidence of this can be found in similarities in the way the data is structured and handled in each package, and whether each package will output data in a format that can be directly used by the other package. Although the more intimate forms of linkage can result in faster analysis in many ways, the disadvantages of a lack of flexibility and the cost of such a system can be completely debilitating. At the other extreme, a system composed of very loosely coupled modules (ad-hoc linkage) provides maximum flexibility in terms of cost, tailoring to the problem at hand and system evolution. The primary disadvantages with ad-hoc linkage are the potential problems with data transfer between applications requiring different formats. There are trade-offs with ease of use at both extremes, with the potentially baffling effect of having too much at one's disposal in a single system, and the potentially confusing aspect of having to learn how to operate modules held in very different applications in the ad-hoc structure. Partial linkage allows, to a certain extent, the best of both worlds, including some flexibility in system design and evolution, while reducing the difficulties in data transfer between the software packages/modules. Nevertheless, it is primarily a form of the ad-hoc linkage which is used here. Its advantages of flexibility, inexpensiveness, appropriateness and explicitness are of primary importance to most planners, and the choice of hardware platform and component software can substantially reduce the disadvantages of this structure. Partially linked packages may be used if the user finds those packages appropriate.[26] The difference is that the federated system is *not* limited to those instances in which additional software has been developed.

In the Macintosh environment, many packages do output data in common formats. Although the effect is the same, the commonality occurs because each package has been designed around a standard, rather than being designed around another specific package. This is not considered a form of linkage here, although it could be (i.e. it could be argued that most software packages for the Macintosh are already partially linked according to Badji and Mallants definition). Instead, only packages that are known to have been developed with reference to each other are considered to have linkage beyond 'ad-hoc linkage'.

Borrowing from the Macintosh environment, the term 'package' will be used to describe the individual elements of the system instead of 'module'. Although package and module represent just about the same thing in a system, meaning 'a specific function or capability', because these are so often individual pieces of software

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[26]Examples of partial linkage that might occur within this federated system are MapLink™, MapView™ and MapCon, as they were designed by ComGrafix™ and AquaTerra to work with MapGrafix™.

(software packages) in the federated structure, 'package' provides a better description of their stand-alone capability.

Degrees of coupling

Coupling is a measure of the degree to which functions in one package can be directly controlled from another. Modifiers usually used with it are rough descriptions such as: 'loosely coupled', 'moderately coupled' and 'intimately coupled' (see the individual entries in the glossary for a definition for each of these).

The term 'federated' is used here to refer to "a cooperation of existing commercially available packages" (Hershey and Whitehead 1991). A federated system is usually an example of some combination of packages with ad-hoc linkages and partial linkages. These packages can in many cases be developed further by the user to automate or facilitate the movement of data and information or even to enable the control of one package from within another. This is what is termed coupling between the component software packages. The degree of coupling that will be used will depend upon the needs of the landuse planning problem and needs and expertise of the user.

The primary platform: the Macintosh

Marble and Amundson (1988), Klosterman and Landis (1988), Polydorides (1991) and Bossard (1991) all recognized the micro-computer as a breakthrough for planners. Compared to mainframes, micro-computers represented computer technology that was inexpensive, reliable, flexible, easy to use and simply offered less psychological distance between user and machine. These features indicate that micro-computers are a suitable platform for a spatial decision support system designed for landuse planning. In addition, there have been several developments in computing recently which are beneficially affecting these features. Windows and menus have dramatically improved user interfaces, networking has been developing, and common data formats are being established with corresponding improvements in data transferability. But although other platforms may be gradually coming up to standard, the Macintosh hardware platform has the highest standards in each of these areas.

When considering a federated approach to system design there are several additional criteria. In particular, what makes this simple cluster of packages work together as a single integrated system is that the *transfer of data and information is easy*, and can be simplified and/or automated where such automation would be helpful. In addition, *each package is easy to use*. User interface is critical because functions will not be accessed via a single interface or shell; instead users will have to learn how to use more than one package. Ease of data transfer is critical because the user will be transferring data and information in between packages. It is in precisely these areas that the Macintosh is presently the best suited platform for a federated structure.

The Macintosh is easy to use. The graphical user interface (commonly known as WIMP, for Window, Icon, Menu, Pointer) is well established as the most user-friendly type of interface in computing. Its advantage is that it allows the functions of a micro-computer to be accessed without a great knowledge of commands or of the way information is being handled (Whitehead and Hershey 1990). That highly interactive human-computer interface, combined with the WYSIWYG (What You See Is What You Get) approach used by most of the applications developed for it, makes using the Macintosh almost intuitive even for the most inexperienced of users,[27] allowing them to become familiar with the system very quickly and providing the confidence for experimentation. In addition, there have been quite demanding standards developed in the structure of the interface which all but ensure a similarity between all Macintosh packages[28]. A federated system "can be very hard to use if a variety of existing interfaces and command syntaxes are incorporated into one system" (Densham and Armstrong 1987). When the interfaces of the component packages are similar, the combined effect can dramatically reduce the learning time for each additional package added to the federated GIS.[29]

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[27]For a discussion of the advantages the WYSIWYG approach and the on-screen manipulation of images affords to digitizing, see White et al. (1987).

[28]There are a few exceptions to this rule, primarily among packages freshly ported over from other platforms. Macintosh users are a demanding group, however, and most packages conform in later versions.

[29]The *User's Guide to STELLA®Stack* (High Performance Systems, Inc. 1989) phrased it extremely well when it describes what it is about the Macintosh that makes it so easy to master.

> The driving vision behind the Macintosh was, and still is: *learn by "playing around"*. Why do you think it takes people so much longer to learn how to use a PC than it does to master a Mac? Many would argue that it's because when you buy a PC, you're *taught* how to use it. You're "lectured to" (albeit in writing). The lecture follows a pre-set sequence, reflecting the particular logic that's been programmed into the piece of software that you're trying to learn how to use. Contrast this process with what goes on when a user is trying to come up to speed on a Mac. Within a minute, the user is "mousing around" -- doing something. She, or he, is *exploring* the environment -- and *he* or *she* is the one directing the exploration. Although each piece of Mac software is somewhat unique in *what* it does, *how* it does it, is generic. This means that users are spared the onerous task of memorizing the specifics of *how*, for each piece of software. They can instead focus on mastering the *what* -- i.e., getting the job done. And, as a user progressively discovers how to "get the job done", motivation grows. As motivation grows, learning accelerates. More learning then feeds motivation and we're off to the races. It's these kind of self-reinforcing processes that make "learning by playing around" work.

Movement of data between packages is easy. Developers on the Macintosh must have realized early on that their particular package will not be the only one in use. It has been the norm for packages on the Macintosh to provide facilities for the import and export of data from one package to another, and often in several different formats. Again, standards in presentation and layout established in the Macintosh environment have made this transfer a straightforward task, whether is it a transfer of raw data from a data source, subsetted data from a database, manipulated data from a spreadsheet or a model, a graph from a statistics or drawing package, a graphic, a map or the results of spatial analysis.

The user maintains control. The WIMP interface on the Macintosh is not like a user-friendly shell that has been devised for only one user level. The user is being offered more and more opportunity to, when ready, modify the packages to suit his/her needs, primarily in the form of preferences, layout, style sheets and the extent of the menus, a technique used to avoid frightening the beginning user with the apparent complexity of too many commands. Beginning with Hypercard®, the user has even been given user-friendly programming capability within packages. These are often called 4th generation systems or 4th generation languages.[30] Avison and Fitzgerald (1988) describe such software packages (and the systems created from them) as being designed for 'self help,' because in such systems, much of the development work can be carried out by people who are not programmers. Such 4th generation languages are being included in an increasing number of packages. In some cases the user can open up other software packages and extract data from them, all within one program script, bringing even closer together those packages in the federation. Recognizing a desire from some users to have even more control in customizing their software, some developers have done just that and now provide a developer's toolkit along with the package. MapGrafix™, an SDBMS, is just one of these. Developments in the Macintosh system, available with System 7.0, will introduce true multi-tasking and live links between packages, opening up additional possibilities in terms of user control and user-defined connectivity between individual packages.

One of the historical disadvantages of moving to the Macintosh platform has been the relative lack of software packages available. This, too, is rapidly becoming a thing of the past. The Macintosh has become a popular platform for many specialist applications, from 3-D modelling to geochemistry mapping and geologic software, to name but a few. Most of the developers seem to be specialists in their field first and

[30]The other languages being machine code (first generation), assembler (second generation) and high level procedural (third generation) (Avison and Fitzgerald 1988).

programmer/developers second, ensuring an intimate knowledge of the specialist subject area.

As a result of not having to wait for a programmer to do all the work, development of specific applications is often faster and changes can be made quickly and accurately, making such systems easier to maintain (Avison and Fitzgerald 1988). As an increasing number of powerful programming and development tools are being put within reach of the average user, so are the opportunities for the user to introduce more intimate coupling between the most frequently used packages. This development allows the user to gradually implement even the advantages of an intimately coupled system without sacrificing flexibility.

The Macintosh's graphical user interface allows an extremely interactive approach and creates a computer environment that is friendly to users from a wide range of experiences and backgrounds. It's historical disadvantage in computing power is rapidly disappearing, allowing it to begin to address even the more process-intensive functions (e.g. image processing) in its typical user-friendly and task-effective manner. Many organizations have chosen the Macintosh for map-making and presentation tasks because of its quality graphics, flexibility and easy-to-use interface. When the analytical capabilities required also exist on the Macintosh it seems absurd to force the user back into less friendly environs.

Where people have chosen the Macintosh as the hardware platform for their more sophisticated applications, they have always been surprised and impressed by the results (see, for example, Whitehead and Hershey 1991). In particular, they have been most impressed with three things: 1) the way that staff have been able to so quickly begin working effectively with the new system, 2) the way that staff previously adverse to the imposition of computer technology into their working environment have accepted the new technology when it is presented in the form of the Macintosh, and 3) the way that the friendly interface allowed users and applications people at the bottom end to be intimately involved in the development and evolution of the system.

The Macintosh was thus chosen as the hardware platform for testing this conceptual design for an SDSS because it provides the greatest possibilities for the success of such a federated system.

The 'toolbox'

Existing software packages represent the 'toolbox' from which an SDSS can be made. This SDSS toolbox could even be considered to be one of the three types/states of SDSS, like the 3-part framework Sprague (1980) defined for decision support systems, consisting of an SDSS toolbox, an SDSS generator and a specific SDSS. A specific SDSS is the actual system that is implemented in a particular decision-making environment. It would be a system designed specifically for the particular application and situation in which it will be applied. Chapter 5 discusses an example of a specific SDSS designed for a situation in forest management and planning. The SDSS generator is used to quickly develop prototype implementations. Prototypes are less necessary when building an SDSS piece-by-piece, but can still be very useful, for example, when planning more elaborate user-interfaces for something like knowledge elicitation. The SDSS toolbox is used to construct both of the other two. Chapter 5 is an example of a specific (partially developed) SDSS as was created from some of these tools.

The toolbox used here includes:[31]

- •MapGrafix™--a mapping and analysis package--the SDBMS
- •FileMaker Pro™--a DBMS
- •4th Dimension™--a DBMS
- •Wingz™--a spreadsheet package--one of the extra analysis packages
- •STELLA®--a simulation modelling package--one of the extra analysis packages
- •Hypercard® (and STELLA®Stack)--a 'hypertext/hypermedia' system; a linking, interfacing and prototyping package[32]
- •HiView--a decision analysis package
- •Microsoft® Word--a word-processing package (and DTP); also used as a utilities package for text processing
- •WhizSurf--for 3-D modelling; one of the extra analysis packages
- •StatView@--one of the extra analysis packages (e.g. for simple statistical analyses)
- •SPSS®--one of the extra analysis packages (e.g. for cluster analysis)

The hardware required to run such a system will vary depending upon the software packages chosen for the federation, the amount of data it will be asked to handle and the demands of the user. A very comfortable setup for a single workstation would be a Macintosh IIfx with a 19" colour monitor, 8Mb RAM, and something on the order of 40 Mb of storage space.

Output devices, necessary for hardcopy output, are not discussed here in detail, except to say that there are a wide range of possibilities supported by the various packages in

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[31]This is neither an exclusive or inclusive list of the software packages required for an SDSS toolbox, it is merely a representative list, from which the tools used in this case study were chosen.

[32]For a discussion of the possibilities for using Hypercard® as a rapid prototyping tool, see Medyckyj-Scott et al. (1990).

the toolbox. The options range from dot-matrix printers like the Imagewriter (also supporting colour), to laserprinters and inkjet printers (standard and colour), to vector plotters and electrostatic plotters. The output devices range enormously in size, quality and type of output, and of course, price. All of the tools referred to above output to both low-end and high-end output devices of one or more types, allowing the user to choose the devices that best fit his/her requirements.

What will be tested by the partial development of an example system

The questions about this system design that I hope to be able to answer after partially developing an example system are:

Is it accessible to planners?

- is it easy for the forest district manager and his crew to use, understand and set up or add user-defined components
- is it inexpensive enough so that enough can be purchased by the user department for it to be immediately useful.
- is it easy to use now, without any modifications
- is it too flexible--does the user get side-tracked

Does it support landuse planning?

- does it improve data acquisition
- does it improve analysis
- does it help handle the complexities
- does it help handle the large amounts of data
- does it help handle multiple goals
- does it facilitate an understanding of the situation
- does it assist in the design of alternative management schemes

Does it fit in with the existing organization?

- can it make use of existing data
- does it automate existing practices
- does it facilitate otherwise 'impossible' tasks

Can it be developed and implemented by planners themselves?

- what level of expertise is required to design such a system
- what level of expertise is required to make additions or changes to such a system

Can it be further developed toward the ideal?

- can routine jobs,such as standard report generation, be set up to be accomplished automatically--i.e with the press of a single button or menu command
- can more intimate coupling be created between those packages commonly used together (i.e. the user can run routines in several packages from one package--e.g. the SDBMS)
- can the user set up a 'user-friendly shell' to guide certain users to specific tasks (e.g. specific data entry or standard report generation), but the

system can still be accessed normally for all other purposes. (this might be a form of knowledge elicitation).
- can functions be automatically disabled (available with override if necessary) if the certain conditions are not met
- can alerts be attached to the DBMS etc. to warn users of incompatible conditions or potential problems (the pre-conditions would probably be set up in knowledge-bases)

What is the extent of its limitations?
- can a log actually be created to automatically keep track of and document the entire planning process

Does starting simple work?
- does it get a foot in the door
- does it encourage further investments of time and energy
- does it encourage further thinking and ideas
- does it encourage use by everyone and a conversion over from old ways
- does it encourage general enthusiasm

The ideal system is one that integrates precisely the information processing, analysis, display, and reporting facilities required in a form that the user can modify and fully understand; allowing the user iterative, integrative and participative interaction with the system, in a manner that can evolve over place and time. A system that meets all the above objectives would be well on the way to this ideal.

Concluding comments

The full definition for an SDSS offered by Densham and Goodchild (1989) is that of an impressive, powerful and complex system. Certainly no planner or decision-maker can hope to be able to use such a system to its full capacity without specialized training. Just as likely, no organization may be ready for the complete overhaul of its planning and decision-making processes that would be imposed by the sudden adoption of a such a single, all-powerful SDSS. Equally, few organizations are likely to be able to afford the development costs of such a system for their specific landuse planning work. The conceptual design of SDSS described in this chapter offers a way of creating an SDSS that is inexpensive enough, specific enough and user-friendly enough to get computer-based spatial decision support into the hands of those planners who need it. The federated structure is also flexible enough to facilitate building an SDSS up as gradually and as frequently as is necessary. Most importantly, the design of any particular SDSS is driven by user's needs and their landuse planning process There is no better way to ensure that these needs are taken into consideration than to put specific system development into the hands of the user, and this is made more possible by the use of existing, commercially available, user-friendly packages in the federation.

The ad-hoc linkage used here means that the SDSS is extremely interactive. Since there is nothing automatic built into the system, the planner is involved in every step of the process, as it is s/he who initiates and controls the movement of all data, the application of any analyses and the presentation of all information. Automating some of these procedures can relieve the user of some of that involvement while still keeping him/her firmly in control. The degree to which the packages in the federation will be coupled in this manner will depend upon the needs, experience and expertise of the users. Such ad-hoc linkage also facilitates an iterative approach to decision-making as there are no inherent limitations to restrict movement from one phase back to an earlier phase. This system will not specifically direct the user to be iterative (unless specifically modified to do so), but it will not restrict him/her either.

Chapter 5

A specific SDSS for forest management and planning

The increasing pressures and complexities facing forest management and planning mirror those found in other areas of landuse planning. Itemization of the issues has been clearest in the United States (see Appendix III), but a changing awareness and focus has been occurring in the United Kingdom as well. As one of the largest forested areas in England, situated in a popular area for recreation, Thetford Forest is a good example of an area of forestland currently under pressure. In particular, the Thetford District Manager is currently trying to restructure the manner and pattern of stand management to create greater visual diversity, provide for greater recreational usage, and maintain suitable habitat for the red squirrel, while maintaining levels of timber production.

The creation of a specific spatial decision support system (SDSS) requires a study of the problem, the current management and planning processes, and the structure of the organization into which the system will be operating. It requires a specific assessment of the user's needs and of the software packages suited to addressing their needs. This chapter discusses the methods and results of such an assessment.

A sketch of the SDSS

Given the above management problem, an SDSS was designed and partially developed for Thetford Forest District from existing commercially available packages. Below is a sketch of each of the elements of IT and the corresponding software package chosen, outlining the general purpose of each with regard to forest management and planning and also the specific functions it is capable of. I have also identified where the particular software package falls short of the ideal, where this seems to be significant with respect to its use in forest management. This approach mirrors what would be the first stage of a real implementation situation.

<u>Spatial Database Management System</u>: using MapGrafix™

purpose:

- to keep an up-to-date and accurate record of the forest subcompartment and all features which relate to their management
- to enable the manager to analyze the area spatially

functions:

- can perform a multitude of spatial analyses

• can output maps easily in several forms
• can output information easily
• can couple the package to call data directly from DBMS
• easy to edit accurately
• very visual
• can export maps to reports

where it falls short:

• as it lacks (does not keep track of) topology, one cannot run queries based on the adjacency of objects

Database Management System: using 4th Dimension™

purpose:

• to keep an up-to-date record of the management and status of all the subcompartments and rides

functions:

• includes all data needed for the national Subcompartment Database
• includes additional data needed only at Thetford
• includes system generated data, such as the current date, present age of stand etc. (via formulas and logical sequences built from input data)
• any new or changed data can be easily exported in the appropriate format
• easy to edit
• easy to search and perform queries
• security can be set up so that anyone can query the data but only a few can make changes
• can set up reports for standard jobs like: expected felling volume this year, list of jobs for this year (felling, thinning and ride edge cutting).
• can set up reports to provide the answers and information needed for comparison of the different management proposals in the choice phase
• includes a capacity for textual descriptions and comments

Spreadsheet modelling package: using Wingz™

purpose:

• to automate the application of known models based on understood, or partially estimated, relationships (e.g. a flow model for the spread of a certain pollutant through water, or population projection)
• to automate jobs requiring iterative calculations (e.g. assign a planting year to each subcompartment such that the difference in planting age between a subcompartment and its adjacent neighbours is no less than 15 years).

functions:

• can automatically read data from files exported by other packages
• can run operations manually **or**
• can run sophisticated models written in a relatively easy-to-learn programming language
• can automatically output results in files readable by other packages

example application:

• identifying which subcompartments have planting years that are less than 15 years from its adjacent subcompartments

Simulation modelling package: using STELLA®

purpose:

- to test a theory or model a system in an attempt to decrease some uncertainty because of unknown relationships. (e.g. does prescribed burning affect the nitrogen cycle?, or how does stand age and stand structure affect the red squirrel population?)
- to help, by modelling, figure out what the factors are and how they affect each other

functions:

- is visual in its approach, perhaps even object-oriented, to make easy the exploration of factors and their relationships
- can read data directly from files exported by other packages
- can report results in both graphic and tabular

example applications:

- Forestry Inventory and Analysis Package (FIAP)
- the forest process model: how forest growth responds to management options
- modelling the red squirrel's life and habits
- modelling the cycle of nitrogen through the stand

3-D modelling package: using WhizSurf

purpose:

- to expand SDSS capabilities to include visualization and analysis of terrain and slope

functions:

- can provide graphic representation of areas in 3-D
- can provide slope and terrain analyses
- can output the results of such analyses for import into other packages
- can read data directly from files exported from other packages
- can combine 3-D images with maps

example application:

- finding a suitable route for cyclists that maximizes the ruggedness of the terrain

where it falls short:

- cannot display data on the map other than height information

Advanced/additional Statistics: (possibilities: Systat® or SPSS®)

purpose:

- to enable the appropriate statistical analysis of information exported from any of the other packages necessary

functions:

- can interface (import/export data to/from) with the other systems
- provides an extensive range of functions

where it falls short:

- the Macintosh interface is still not yet fully developed

Decision Analysis: using HiView

purpose:

- to make explicit the criteria considered in the evaluation
- to make explicit the values/preferences applied to each criteria
- is designed not to be run with data automatically derived from the rest of the SDSS, but to remain an entirely separate utility to encourage human participation and consideration of the problem

functions:

- will help the planner identify the criteria under consideration by allowing a gradual breakdown of the component criteria into smaller parts
- will provide a mechanism for the planner to assign weights and preferences
- will report the results in both graphic and tabular output

where it falls short:

- requires an additional machine (because this one is not yet designed on the Macintosh)
- the results cannot be easily automatically incorporated into a report because of the lack of an adequate translation facility for graphics between DOS and Macintosh environments

Knowledge-based system/Expert system: (possibility: Nexpert)

purpose:

- can be used as an alert mechanism -- to warn the planner of any violations to any pre-set conditions (e.g. this year's scheduled cut will leave the red squirrel area with <50% of the trees of cone-bearing age)
- can be used as an interface to the various models that exist, providing suggestions as to which models are appropriate depending upon certain pre-set conditions
- can be used to help apply the rules which have been accepted as standard management (once that management scheme has been chosen)

Text editing/Word Processing: using Microsoft® Word 4.0

purpose:

- to facilitate the viewing and manual manipulation of data and information where it becomes necessary; this is an important backup facility
- to facilitate the dressing up of reports to improve communication

functions:

- can read any ASCII text files[33]
- can perform global changes to both text and formatting commands

The degree to which the packages in this federation are coupled reflects its early stage of implementation. The system contains the basic data-sharing capacity common to most Macintosh packages. In other words, each package can read data output from

[33] American Standard for Computer Information Interchange (ASCII)

all the other packages in the federation that might be used with it. Similarly, each package can output the results of any analyses into formats readable by any other package. Automation of functions can be a time-saving device, especially when somewhat involved processes are pre-programmed to run when activated by a single button or menu command. Thus, automation within a system typically occurs after the user has had a chance to identify what tedious functions it is that s/he uses most frequently. Although the user should be able to set up functions for automation at any time, several examples are already given in this SDSS. In this SDSS, the user can automate the generation and export of the annual update to the Forestry Commission Forest Research Station at Alice Holt Lodge. The user can also automate the generation of any hardcopy reports needed for information or publicity, or as a way to take information to the choice phase.

Most of these software packages were chosen because each is easy to use initially, but can be developed later via more sophisticated languages or techniques to include more automation or more intimate coupling between packages where necessary (e.g. can couple SDBMS and DBMS such that DBMS data can be called directly from within the SDBMS).

The specific landuse planning problem: Thetford Forest

Originally established as three separate forests, Thetford Chase, Swaffham and The King's Forest, Thetford was the first forest created by the Forestry Commission. The area now incorporated as Thetford Forest was acquired gradually, primarily during the period from 1922 to 1939. Planting on the mainly derelict agricultural land or open heathland began immediately as the land was acquired either by purchase or by lease. Presently, the area of Thetford Forest occupies 20,000 ha. The soils are primarily sand in varying depths over chalk. The climate of the area includes periods of drought and frost, which proved to be the primary limiting factor on the species of trees that can be grown successfully in this area. Having been successful when planted as windbreaks in the area in the late 18th century, Scots pine was chosen for planting in extensive areas of Thetford forest along with Corsican pine. Since then more emphasis has been placed on planting Corsican pine as it is faster growing than Scots pine and is also less susceptible to diseases. Many of the other conifer species planted originally (Lodgepole pine, Japanese larch, Douglas fir, Maritime pine, Sitka spruce, Norway spruce, Western hemlock, Western red cedar and Grand silver fir) were much less successful and remain only as relics of those earliest plantings. Of the broadleaved species planted, the oaks were apparently more successful than the beech, and cherry proved to be especially frost hardy. The conifers, however, have always been and will continue to be the primary species for timber production at Thetford. (Macdonald 1939, Backhouse 1957, Simpson and Henderson-Howat 1985).

Thetford is presently covered by a mixture of species, approximately 47% Scots pine, 37% Corsican pine and 10% hardwoods, primarily oak, beech and birch (Simpson and Henderson-Howat 1985). They represent the results and relics of past management schemes and natural incidents such as the drought of 1978 or the storm of 1987. Concentrations of hardwoods, for example, exist in areas that were previously locations of forest offices, a relic from the time when that was standard practice. Single storey stands exist alongside stands with two significant crops, left over from a time when underplanting with a shade-tolerant species was the preferred policy. Current management and planning at Thetford must respond to present policies within the constraints imposed by the existing situation on the ground and the pressures imposed by other interests in the woodland environment.

Why Thetford Forest District?

Thetford Forest District was initially investigated as the subject for the application of an SDSS upon the recommendation of the Forestry Commission (Betts 1990, personal communication). Closer inspection revealed that Thetford was a very good subject for several reasons:

They were in need of spatial decision support.

- The Thetford District office is involved in both the operational management associated with the implementation of existing plans and policies, and the strategic management involved in the design of new management plans. In the case of Thetford District, both were in need of additional support.
- Thetford has a mix of demands upon its resources, including timber production, recreation, conservation and amenity/landscaping. (This latter demand is very much related to the middle two, but is frequently separated out as a distinct goal in many Forestry Commission plans.)
- They keep track of a large amount of both spatial and attribute data that is constantly being modified, and they need to use that data to make management decisions.
- Its problems are neither trivial nor overly complex.
- The management of Thetford would benefit from an open discussion of the goals, and of the limitations and constraints facing each problem and affecting each solution.

They had a need for accessibility

- The Forestry Commission would not look at an expensive solution.
- All the staff are foresters first, and very few of them are familiar with computers.

- Most of the jobs involve a high degree of human interaction.

They had a need for flexibility

- They do not know exactly what they want out of a computer-based system.
- They do not know the full range of possibilities of a computer-based system.
- There is a good chance that their needs will change over time as the brief of the Forestry Commission shifts gradually from timber production to include more wildlife-, conservation- and recreation-related planning as well.
- They need to interface with existing systems (i.e. the national Subcompartment Database)

They were willing subjects

- They had expressed an interest in new methods
- They had current problems that they were having difficulty addressing effectively with their current methods and technology.
- They had recently undergone a change in district manager, and were acutely aware of the perennial problems associated with manager (and other staff) turnover, such as a lack of consistency and a loss of information, such as those unwritten details about every subcompartment, the local lessons learned and the policies that were the basis for decisions during their term of office.
- They had no idea what computer-based systems could do for them, so they needed some education in this regard, but that meant that they had no preconceived ideas about what the system should do and couldn't do, etc.

Thetford Forest District was thus a unit involved in forest management and planning that was facing many of those difficulties an SDSS is intended to address. It was also a good example of an organization requiring the flexibility and accessibility offered by the coupled or federated design.

The current management and planning process at Thetford

After an examination of the current planning process, it is evident that it is relatively simply organized. The forest manager is entirely responsible for the planning and management of his/her forest district. Major changes in forest management policy may be instigated anywhere in the Forestry Commission hierarchy, but the policies are usually interpreted and the changes formulated in the District office. Any proposed changes are then later checked with the appropriate conservancy headquarters (for Thetford this is the East England conservancy) to make sure they conform with national policies. With the exception of the Thetford District's market commitment to maintain a sustainable timber yield of 200,000 m^3 annually for the next 5 years, national policies tend to be very vague and general,[34] and their interpretation is up to the district manager and conservancy manager.

The district manager typically makes management decisions based on his own experience, intuition and accumulated knowledge of the particular forest s/he is charged with. The information used to make that decision will thus vary from district to district, as will the priorities used, both because of the different situations at each forest as well as the different managers. Thus, since the only 'management plan' is devised and implemented by the local area manager, there are a limited number of overall plans for UK forestland, and there is a limited overall understanding at Forestry Commission Headquarters of the system of lands being managed (Betts 1990, personal communication). Some important but basic statistics on the standing timber resource exist in a national database (the Subcompartment Database), but there is no way to aggregate or summarize the information in each forest manager's head (Horne and Whitlock 1984, Horne 1984). In such situations, the very real danger that much information is lost when an existing forest manager leaves is presently too often the case. The district manager will be trying to incorporate wildlife, recreation and conservation and landscape needs along with a timber production quota into a management plan, but there will be some lack of consistency across managers as the job of representing all interests is up to each individual and subject to whatever influences that individual is sensitive to, as well as being subject to the political and social environment at the time. Often, however, the district manager may not even have the time or the appropriate information to think or plan strategically.

The exceptions to this control by the forest district manager can occur when regional (conservancy level) or national interests (or authority) dictate a management decision for the district. This occurred recently at Thetford when it was decided that the area needed a visitor centre. The design and siting of this visitor centre were decided at conservancy headquarters and the results dictated to the District. The disadvantage of this approach is relatively obvious. Without the involvement of those who know the forest, important factors, such as existing landscaping features or the visual suitability (species make-up) of the surrounding stands, may not be taken into consideration, with the result that it is unlikely that the optimum site is chosen.

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[34]From the Countryside Acts in the 1960's, the Forestry Commission was instructed to "have regard to the desirability of conserving the natural beauty and amenity of the countryside." Under the Wildlife and Countryside Act of 1985, the instruction was restated as, "to achieve a 'reasonable balance' between afforestation, forest management and timber production on the one hand and conservation of landscape and wildlife on the other" (Mather, 1991). Neither phrase defines anything like a management strategy for the Forestry Commission, only a expression of general intent.

Thetford forest is the largest source of home-grown pine timber in the UK, outside Scotland and Wales. Thus, the primary daily activity occupying the Thetford District Office is the harvesting of timber and its supply to various mills, and the subsequent tasks of site preparation and replanting. Whether this is accomplished by their own labour force or contracted out to independent firms, the District office still has the continual task of identifying which subcompartments are scheduled for work, getting the appropriate information out to the teams in the field, and collecting back information about the work accomplished. Maintenance of every other stand in terms of thinning, and less frequently, in the problem assessment and application of pesticides and fungicides, is also a continual task accomplished by the District office. Other daily tasks involve the maintenance of those recreation areas within the District. Areas such as nature trails, bridle paths, parts of long distance trails, picnic areas and the new visitor centre all need care, such as mowing or occasional clearing, as well as any more specialized maintenance of trail markers or signs, and the re-routing of trails during periods when harvesting obstructs the original path. In addition to the daily tasks, the District office has the annual job of identifying all changes to the subcompartments in the past year, documenting those changes on special forms and sending them to the Forestry Commission's Forest Research Station at Alice Holt Lodge for input into the national subcompartment database.

The Forestry Commission is in a good position to make and implement landuse plans. Unlike local or regional planning authorities, the Forestry Commission does own land and therefore has complete management control in those areas. With respect to the mandates laid down for them by policy for timber production and recreation provision, and with respect to popular pressure for conservation and amenity, the district office can both design management plans and implement them with relative ease. Even the National Parks, which do have to submit management plans and have arguably been some of the most successful attempts at positive management in an area of multiple uses, are much more limited in the extent to which they can actually apply their objectives because of the difficulty of persuading private landowners to manage their land according to those objectives (Blacksell and Gilg 1981).

The example area and problem

The area of interest is known as High Lodge, a small section of Thetford Forest located just south of Santon Downham in north Suffolk (see figure 4). It was chosen because it has been the subject area for most of the other studies by the Forestry Commission regarding possible alternatives for multiple-use management in the district. The area of interest includes within it a new visitor centre and scenic drive, in addition

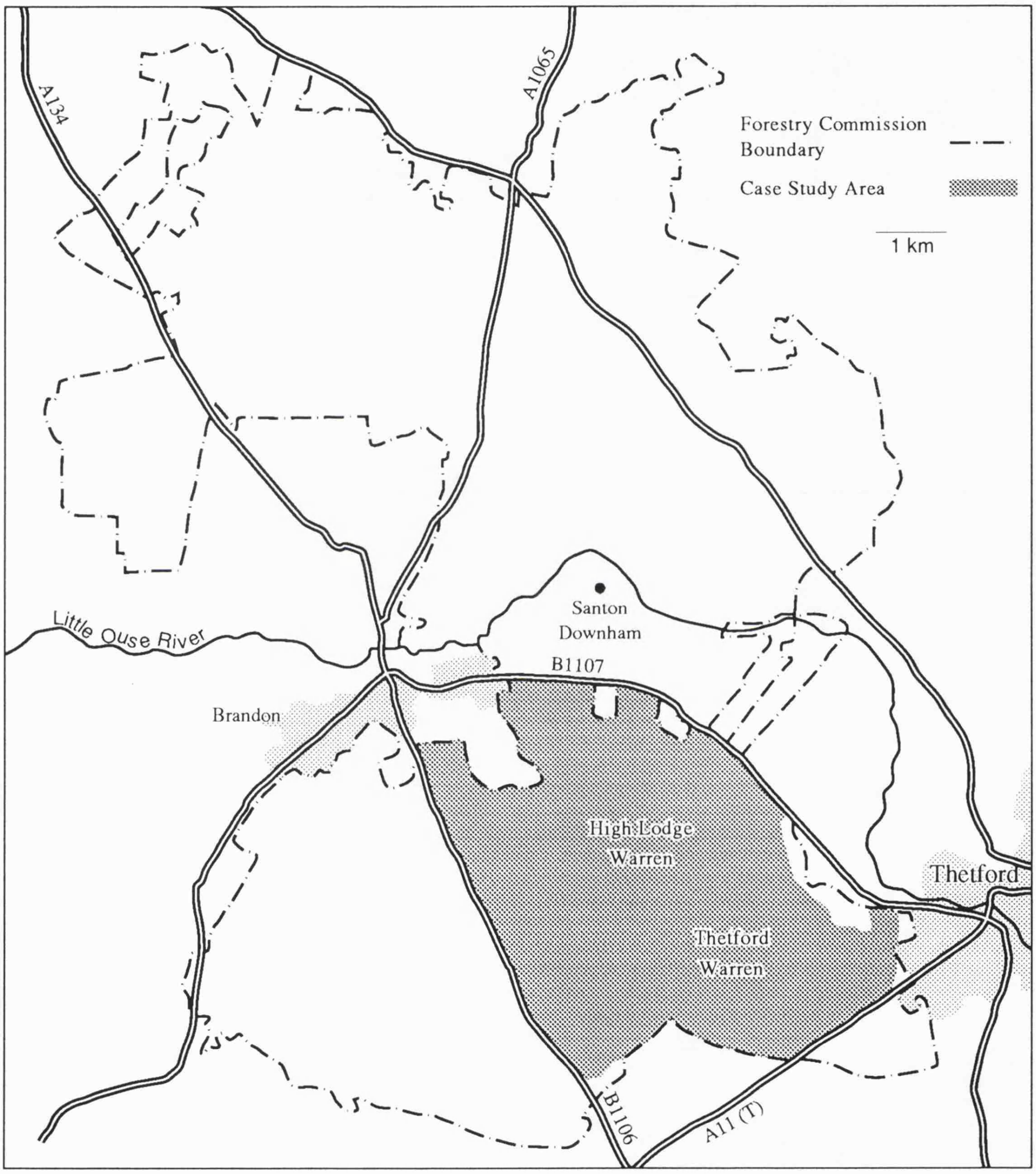

Figure 4. The location of the case study area within Thetford Forest (one portion of the area managed by the Thetford Forest District Office).

to nature trails, portions of bridle paths and long distance trails, and more general recreational use by walkers and dog teams. These uses are the source of several goals with regard to recreation and amenity.

- Increase the structural diversity of the forest by restructuring the pattern of harvesting to maintain a difference in the planting year (roughly equivalent to stand age) between adjacent subcompartments of at least 10 years, and 15 years where possible.
- Maintain levels of hardwood species currently present in Thetford (about 10%). The hardwood stands are usually less dense and are managed less intensively for timber purposes, and thus provide a visual diversity not found in the conifer stands.
- Increase the spatial design (layout) of the subcompartments to reduce the visual effects of harvest by clearcutting by varying the shapes and edges of the subcompartments.
- Consider the establishment of a trail for mountain bikers, utilizing the most rugged terrain Thetford has to offer.
- Consider the possibility of improving the understory and the level of natural regeneration within stands by thinning more heavily. There is a higher cost involved at the time of harvest with this type of management, but it would provide increased visual diversity in conifer stands. Of highest priority for this type of management are those stands in the vicinity of nature trails and scenic drives.
- Improve the appearance and natural diversity of the forest rides by alternating the mowing of those rides (This is also a conservation interest).

This area of interest also incorporates within it the Red Squirrel Conservation Area. Although the red squirrel is found to varying degrees throughout Thetford Forest, this particular area has been set aside for management with direct consideration to the needs of the red squirrel. This designation has imposed several additional goals within that conservation area:

- To maintain a certain proportion of trees that are of cone-bearing age.
- To limit the stands of large-seeded species of hardwoods within or adjacent to the red squirrel conservation area in order to avoid encouraging invasion by the grey squirrel.
- To prefer Scots pine in this area, especially during the restructuring phase, because its annual crop of seeds is typically more dependable than Corsican pine.

Maintaining present levels of timber production remains the first priority for Thetford Forest District. This is deemed important to maintain national levels of home-grown timber and to keep the regional timber mills in supply. Corsican pine is thus favoured toward this goal because of its faster rates of growth and lower susceptibility to pests and disease.

The biggest difficulties/hindrances to effective planning at Thetford

1) Management decisions are presently handicapped by a lack of historical and descriptive information about the management of each stand on which to base present decisions. The only data permanently retained is that coded information required for the national Subcompartment Database. This data is maintained without any descriptive explanation besides that corresponding to the definition of the codes. This situation causes immense difficulties when the current manager wishes to make decisions concerning the forest as a whole or even concerning individual stands. For example, the reason a certain stand has been marked for conifer retention[35] becomes important when the manager is considering a new strategic plan or an amendment to the old one. If it is known that a stand was marked for long-term retention because it is located in the Red Squirrel Conservation area and represents a key habitat or corridor for the red squirrel, then the manager will know to continue to retain it until an adjacent stand is of a suitable age to replace it. On the other hand, if it is known that the stand had been retained because it was the site surrounding the old forest office in the 1940's, it could be brought back into active production because that site is no longer used. Without such information, a change-over in the management staff could, using these two cases, lead to the retention of one stand unnecessarily and the felling of another stand that is important to maintain. Since one manager often does not know why certain stands were marked for retention, the past tendency has been to blindly keep marking for retention those stands which were marked in the past. This reduces the total area available for active production, and consequently limits the manager's room for manoeuvre when considering the retention of other areas for recreation or conservation. The maintenance of additional data about the subcompartments/stands, including room for textual explanations for the decisions presently in force (e.g. retention the stand for an additional 10 years to aid the process of forest restructuring) can improve the effectiveness of management and planning at Thetford.

2) There is a lack of on-site information: to enable the viewing and analysis of subcompartment data when making management decisions. Presently, all subcompartment records are held only at the Forestry Commission's Forest Research Station at Alice Holt Lodge. Thus, if a forester at Thetford District is interested in viewing a particular subset of data or running an analysis on that data, s/he must file an order for a particular analysis from Alice Holt Lodge and wait for the results (up to a month for a production forecast). The location of a database on-site at Thetford would

[35]Conifer retention = retaining a stand beyond its original felling age.

enable those foresters who are making management plans and taking management decisions at Thetford to have immediate access to that data for inspection and analysis, instead of being limited to the present two choices: making a decision without that information or making that decision after a significant time delay while that information is accessed. Thus, access to on-site information would also improve the effectiveness of management and planning at Thetford.

3) The design of coherent management plans (such as is involved in the process of forest restructuring) requires much more support, particularly when faced with the task of generating alternative designs/plans, and in the running of additional analyses on those alternatives to ensure they are valid. Generating ideas for alternative plans requires the capability to analyze the spatial and non-spatial forest information in ways which may be very difficult, time-consuming or tedious to do manually. The availability of facilities to model proposed situations, run iterative or comparative analyses, or just quickly display the characteristics of the proposed alternative would improve the effectiveness of forest management and planning.

4) There is a discrepancy of time frames between the growth of a forest crop and shifts in the political and/or managerial scene. Forestry is not a subject well-suited to frequent changes in policy with every new manager or new government. Unlike the annual rotations of agricultural crops which allow the farmer to swing more easily with new policies dictating the fashionability of certain crops, planting trees automatically represents an investment of at least 30 years. While the Forestry Commission is directly controlled by the national government, shifts in policy as a result of a change of governments will remain beyond the Forestry Commission's control.[36] An SDSS can, however, provide a mechanism to maintain consistency through changes in forest district manager.

Design and implementation

The procedure for the development of this SDSS

The procedure for the development of this SDSS was, as was expected, a very iterative one. Initially, I drew up a rough sample system design for forest management and planning based on my understanding of the problems of forest management in the UK, and specifically, that faced by the Forestry Commission at Thetford. Over a period of six months, two meetings and several letters and phone calls later, I have been able to gain a better understanding of Thetford's management and current

[36]Although the use of some decision analysis software can help to prepare somewhat for this -- see page 101.

problems, more closely define their needs, and refine the design of the system to suit. A large part of the success of this approach is due to the fact that I was able to educate them gradually with the possibilities of computer-based systems, and was able to work with them to define what capabilities they needed (see Appendix IV for an outline of the exact sequence of events).

Isolated from the iterative process, my tasks were:

- To determine Thetford Forest District's (and the Forestry Commission's) present method of forest management, both in terms of daily tasks and short and long term planning. (i.e. including operational decision-making and strategic decision-making).
- To determine where the district was facing difficulties with their present management, identify what was causing the difficulties, and how they could be improved or solved.
- To determine if a computer-based solution was applicable and identify how that could be done: which elements of IT were appropriate and what system design features were necessary.
- To determine what stage of computerization they were at, and what the requirements were for incorporating a computer-based SDSS into their organization and present system of management.
- To educate them in the possibilities of a computer-based solution, and to do so gradually, so as not to frighten, baffle or alarm them. To encourage them to think about their present management and their current difficulties in new ways, and especially in the light of their newly realized computer-based possibilities.
- To determine which aspects of that management were at present unchangeable because of policy or national directive.

Assessment of the needs

Extensive discussion between myself, the Forestry Commission and the Thetford district manager and his team[37] provided the basis for establishing their basic and future needs for forest management and planning. As expected, it was evident that their ideas went through substantial development as they became more aware of the possibilities a computer-based system had to offer, and took the time to identify precisely what their present management was and what they would like it to be. What is outlined here is the result, as of October 1991, of that dynamic process.

For information. The biggest need at Thetford was for better access to information. This included both on-site access to the type of data that was already kept in the national subcompartment database, and the maintenance of additional data that

[37]see Appendix IV for the full names and positions of those persons I worked with.

was particularly relevant to the management at Thetford. The format of the data should not be as strictly coded information, but should also include the capacity for textual descriptions. This would provide space to further define those stands where the codes did not quite apply, and to explain why certain designations such as conifer retention (operational decisions in their own right) had been applied. To be able to easily maintain the data on-site was also important, as both the spatial definition of the subcompartments and their corresponding attributes change completely at every harvest and can also change somewhat at every thinning -- a continual process. In addition, the data had to be presented in a form that was easy to understand and maintain.

For analysis. Calculating the production forecast for each subcompartment, to estimate the amount of timber expected from each at harvest, is an analysis required regularly. Presently recalculated every three years, the estimate actually changes with any adjustments to the stocking level made by thinning or exceptional growth. As a regular annual output is the first priority, any management decision that affects thinning levels or dates, harvest dates, or the species to be planted will require the calculation of a new production forecast with the new variables. If this can be made easier, then more management alternatives can be devised and tested. Access to simple spatial analyses, such as identifying which subcompartments lie within 50 meters of the scenic drive, or which subcompartments fall within the dog-sledding area, would also be very useful, as would any facilities to query the attribute database (DBMS). Three dimensional analysis would be helpful if the District became involved in projects in which information on slope and terrain were important.

For reports and output. Communication is an essential part of both management and planning, and forestry is no exception. To provide annual update information to the national Subcompartment Database, it would be useful if all changed records could be easily exported in the required format. In addition, the output of subcompartment records for forest operations would ensure that the teams going in to thin, harvest, site-prep or plant had all the information they needed as well as the appropriate form to elicit their recording of the job done and changes made. Frequently maps are also required for the operator to record any changes made there, as subcompartment boundaries are frequently adjusted at the point between the harvest of one crop and the planting of a new crop. Finally, maps, tables, statistics and subsets of data may also be randomly or regularly required for other reports.

For designing alternative management plans. (see the section on 'For analysis').

For defining goals and the criteria for their assessment, and for demonstrating which criteria and weights went into the final choice. Timber production is the first priority, but recreation, conservation and amenity are also recognized as important considerations in the design and choice of a management plan. Assistance in determining how these goals are defined and assigning relative weights to their importance can help in setting up the framework to assess management plans in a multi-objective environment.

For qualitative assessment. Presently everything must be presented in monetary terms: how much a particular plan will cost to implement and how much it will generate. This practice is more out of habit than anything else, however. If it were possible to compare alternative uses in their own terms, and be able to handle qualitative criteria without converting everything to monetary terms, it would much more closely match the real situation. Money is not really the ruling factor here, the production of timber is, in order to fulfil contractual agreements already made and to maintain national levels of production. Calculating the cost of retaining timber beyond its normal rotation age in terms of the pounds and pence of revenue lost does not make sense. Rather, discussing the cost in terms of expected volume of timber harvested is easier to compare to the annual quotas required by contractual commitment to the mills to the annual levels expected nationally.

For assessing the sensitivity of management plans to shifts in priorities. Management priorities can change easily with shifts in public opinion, personal priorites or political pressure. Tree crops, on the other hand, remain relatively fixed with time frames on the order of 50 years -- over the period of several changes of government. Thus, being able to assess how sensitive a particular choice of management plan is to relative shifts in the goals originally specified could help defend the existing plan and avoid the wasted effort involved in applying a different management plan later.

Implementation

In this section, I will briefly describe how those software packages used in the SDSS for Thetford Forest were set up and implemented. In this partial implementation of the system, I have set about to examine first those aspects which were critical to the proposed design. To determine whether a planner could develop and implement such a system themselves, I kept track of the amount of time spent on a particular task and the amount of expertise required to do it. In each case I have expressed this last factor in terms of the time required to gain enough expertise to use the software package. These are conservative estimates, assuming a user has no prior knowledge of the package concerned or of similar packages. Table 1 sets out to what degree each element of IT and each software package was tested for incorporation into the SDSS.

SDBMS. MapGrafix™ (£ 4995) A spatial database was set up in MapGrafix™ to include data on: subcompartments, rides (for access), nature trails, riding trails, public footpaths, long distance trails, the visitor centre, trim trail, scenic drive (for recreation), and the red squirrel conservation area (for conservation) (see figure 5). Setting this up was relatively straight-forward. One day was spent in digitizing the area of interest from the stock maps (1:10,000) held at Thetford (sheets 17 and 18) and two additional days in cleaning and assigning IDs[38] to the spatial data. As the DBMS was only to have information on subcompartments initially, only these objects were given IDs at this point. IDs were chosen to correspond to the national Subcompartment Database and to ensure the uniqueness of each subcompartment at a national level. An additional day was required to sort out discrepancies between objects in the map and those in the data from the national subcompartment database. Some discrepancies had been expected, and they occurred as a result of the difference in the edition dates of the two data sources.

DBMS. 4th Dimension™ (£ 620). A database was set up according to all the criteria identified for Thetford (see Appendix V). Finding a software package that was capable of everything took a little more time than expected. Many of the DBMS packages tried contained at least one fatal flaw (i.e. FileVision IV®, FileMaker Pro™, and FoxBASE+/Mac™) with respect to the needs of the forest management and planning at Thetford Forest District (see Appendix V). I was looking for a DBMS which best demonstrated the full advantage of the Macintosh -- one that was initially easy to use, but which allowed the user to pre-define settings, automate functions, and even delve into a bit of 4th generation programming language to couple the database more intimately with other packages and create a more user-defined environment. I finally settled on 4th Dimension™ as a suitable database. The national Subcompartment Database was initially examined to determine the data maintained by the Forest Research Station in Surrey (a day). Next, approximately a week or two (scattered over a period of time) was spent on carefully defining the needs and uses Thetford District had for data. The information gained was used to modify the list of data fields required and design the ideal formats and layout (see figure 6). About 2-3 days were spent in setting the DBMS up once the data and layout had been defined.

Spreadsheet modelling. Wingz™ (£ 295). As mentioned earlier, Thetford District was in the process of restructuring the forest stands -- diversifying the shape,

[38]IDs are alphanumeric labels ('identification') that are assigned to spatial objects and to their corresponding attribute record in the DBMS. When an object and its corresponding record have been assigned the same ID, they can be linked and automatically retrieved.


Case Study Area
within Thetford Forest District
subcompartments
red squirrel area
riding trail
nature/forest trails
long distance trail
public footpath
visitor centre
scenic drive
1 km

Figure 5

ID
33043A

Location 212
geographic block 3
3043 A
county 81
grid reference TL835840
survey year 1986
legal status L

LANDUSE AND MANAGEMENT

landuse code PHF
rotation 1
mixture M
PFTB 82
local_1 30
PF2
present stand age 65

CONSERVATION STATUS

forest park 1
FC conservation
conservation
ancient monument

RECREATIONAL USE

inside no
edge yes - forest trail

FELLING INFORMATION

felling year 2082
felling volume total 1599
next thinning 1990
exp. thinning vol. 0

WILDLIFE-existing features

deadwood habitat
raptor nest sites
woodlark
nightjar
scarce species

ENVIRONMENT

soil type 94
terrain type 111
windthrow hazard 1
altitude
landscape
habitat type
understory

management description

subcompartment history

single storey stand
Selective thinnings:
1950
1970

local plans

COMPONENT INFORMATION

	species	storey	planting year	yield class	product area	unproduct area	felling volume	origin	propogation
33043A1	SP	1	1926	10	21	.	753		
33043A2	EL	1	1926	8	32	.	846		
33043A3	BE	1	1926	6	21	.			
33043A4	BI	1	1926	6	10	.			
33043A5	OK	1	1926	2	21	.			

Figure 6: A sample layout from the DBMS as it might be arranged to facilitate browsing for different management uses.

spatial pattern and relative age of the area's primarily even-aged stands. The forest manager must work with what already exists on the ground. Therefore, the last objective, that of relative ages, is accomplished by adjusting the felling year of a stand to affect the planting year of the next crop (and therefore its age relative to its neighbours). Thus, by the next complete rotation, ideally every stand will comply with the management directive. To accomplish that, the district forester needs first to identify those subcompartments which are too close in age to an adjacent subcompartment. Ideally, each subcompartment will be as much as 20 years different in age from its neighbours, but if they could get at least 10 years difference it would be a substantial improvement. To address this problem, the spreadsheet was set up to compare the planting age of each stand with that of its adjacent stands and identify all those which failed the criteria (initially set at 10 years). With that information, the forester could go back to the map and database (SDBMS and DBMS), get a visual image of the results, adjust the felling years correspondingly ('restructuring'), and run the model again with the new values to see if the forest will look any better the next time around. Setting up the iterative model here required some level of expertise, because some basic programming was involved in writing the scripts to perform some of the comparative and iterative analyses. The script language is somewhere between programming and macros in both ease of mastery and potential power. In this case, it took on the order of several weeks to learn the language and a few days to write the script for this particular problem. Wingz™ offers a lot of flexibility for automating functions in a spreadsheet format. It is also very useful for the development of functions to fill in where other software packages have fallen short. In the SDSS for forest management at Thetford, Wingz™ was used to aid the process of designing a new management plan. It did this by identifying those areas which presently failed certain criteria, and testing any revised plans created by the forester for success with respect to that criteria.

Simulation modelling. STELLA® (£ 195). A demonstration model was set up to explore how, to what extent, and at what rate different management techniques affect the nitrogen cycling in a forest stand. Nitrogen is an essential element who's availability is "crucially important to the growth of both natural and managed stands" (Carlyle 1986). However, levels of nitrogen may not be an issue at Thetford. It was used here simply as a demonstration of how an existing model (or a newly invented one) could be implemented in a simulation modelling environment in an SDSS. The graphic nature of this particular package gives the user the chance to understand and be critical with the process of the model without having to know and delve into the specific computer language it was written in. The pictorial format also allows for easy manipulation and isolation of model components for testing or observing sections of the model at a time. It would take only about a week to master STELLA® itself. The time required to set up a model will range dramatically depending upon the level of complexity and the number of parameters. This particular model took a few weeks to get fully set up and initially tested. A simple model can be implemented in a day or so. Although not implemented for Thetford, this package can be set up to run models via a user-defined shell in Hypercard® using STELLA®Stack. This setup is less appropriate for analyzing the model as it is for facilitating use of the final model by individuals who only need the results.

3-D modelling. WhizSurf (£ 210). This element was not fully implemented in the SDSS for Thetford, but previous experience with this software package allowed an estimation of the time that would be involved to learn and use this element of IT. Terrain information for the High Lodge area of Thetford would be captured by digitizing the contour information from the same 1:10,000 stock maps that were used to set up the SDBMS (one day). Height information is added to the digitized data afterwards in the spreadsheet package (Wingz™) (1/2 day). From this data, a grid is generated using WhizSurf, and a variety of 3-D maps and views can be created to give a picture of the relief of this area of Thetford. Several days would probably be required to become familiar with the package and produce maps. These maps could be visually examined to plan several routes for cyclists based on the terrain, for example. At this point, neither the 3-D map nor the resulting routes can be exported to the SDBMS from WhizSurf. Another software package, MapCon, is reported to be able to do so but was not available for testing.

Statistics. e.g. SPSS® (£ 545). This element of IT was not implemented in the SDSS for Thetford District, as they had no need for such analysis at present.

Decision Analysis. HiView (£ 600). Once the user has already conquered the inventory and analysis stages and reaches the point where s/he needs some support with the choice phase of decision-making, the software required may vary considerably depending upon the exact type of decision problem being faced. Many such systems will exist entirely separate from the rest of the system, as DA packages are largely asking questions of the decision-makers themselves (e.g. preferences) and using information the decision-makers derived from the rest of the system (e.g. analyzing a management option for its benefit to walkers), but not usually raw information that would be directly incorporated into the choice analysis. In the case of Thetford Forest District, the problem of setting goals and weights for recreation, conservation, timber production and amenity, and choosing a management scheme based on those preferences suited the use of HiView, a decision analysis software package designed by the Decision Analysis Unit at the London School of Economics. A few days would have been sufficient to learn how to operate the software and generate the variety of graphics it offers. Significantly more time is required to analyze the decision environment and prepare the information for input into the software package, and several days might be required for the decision-makers to determine among themselves what preferences to apply. This lengthy process, however, is a reflection of the planning problem and not the software package itself. In the case of Thetford, the package would also have handled very well a problem like the choice of a site for the new visitor centre.

KBS/ES. Nexpert. This element of IT was not implemented in the SDSS for Thetford, as they had no need for such analysis at present.

Text editing/word processing. Microsoft® Word (£ 275). This package was used extensively during system development to check data formats and to manipulate those format where necessary before a translation facility was set up. Only a few hours experience at most are required to be able to use this package effectively.

The first three elements, the SDBMS, DBMS and spreadsheet modelling packages are recommended for immediate installation and use. The next three elements, the 3-D modelling, simulation modelling and statistical analysis packages, are recommended when and if the district office decides to incorporate those additional approaches to assist in addressing other problems, such as those mentioned in the outline under 'example applications'. The next element, the decision analysis package, is recommended once the district has designed several management schemes and needs assistance in weighing each up against the district's long and short term goals, preferences and policy directives. The next element, the knowledge base, might be useful after the system has been in use for a while, and rules for either its use or the application of the chosen management scheme have been developed. The last element, for text editing, might not be considered an essential part of an SDSS, but it is very useful as a backup editing and communication facility and is highly recommended as an additional utility.

Table 1. The degree to which each element of IT and each software package was tested for incorporation into the SDSS for Thetford.

Element of IT	Software package	thoroughly tested	somewhat tested	not tested	'fatal flaws'
SDBMS	MapGrafix™	✓			
DBMS	FileMaker Pro™	✓			yes
DBMS	4th Dimension™		✓		
spreadsheet modelling	Wingz™		✓		
decision analysis	HiView		✓		
simulation modelling	STELLA®		✓		
3-D modelling	WhizSurf		✓		
statistics	SPSS®			✓	
hypertext	Hypercard®			✓	
KBS/ES	Nexpert			✓	
word processing/ editing	Microsoft® Word 4.0	✓ *			

The degree of coupling and automation used

Initially, this SDSS design contains no additional coupling of the software packages. They are linked only by the ease of data transfer inherent in most Macintosh packages. What is important is that even with just this ad-hoc linkage between elements, it is effective. Meanwhile, the possibility remains open to more tightly link the elements. The user can either do this themselves (MapGrafix™, for example, includes a developers toolkit for such an eventuality) or hire a 3rd party developer to do

* except for the degree to which greater coupling with other packages is possible.

the job[39]. In this partial implementation, I have automated only a few of the features possible. The ones I have chosen are some of the simplest, and yet each still represents a powerful enhancement from the user's point of view. To the DBMS I have added the automatic generation of a few standard reports and the automatic export of data for the national Subcompartment Database. In addition, the model written in the spreadsheet Wingz™, represents an automation of those iterative calculations required to identify errant subcompartments.

Concluding comments

The experiment was trying to set up a system in which the user organization could, if they so desired, repeat the operation themselves and begin to develop a similar system without extensive training and without too great an expense. In the case of Thetford Forest District, of course, much of the initial work of identification of the problems and their needs, and assessment of available software packages has already been accomplished.

As a test of all those questions posed at the end of chapter 4, this experiment was only partially successful. In addition to the time contraints, the experiment was handicapped by the fact that it could not actually be implemented at Thetford to test how well it fit in, how easy it was for them to use and develop themselves, and whether it did actually improve landuse planning. Thus, although I could successfully develop a system that addressed their present difficulties and fit into their organizational structure as it was described in my discussions with them, I could not prove that the system actually succeeded in doing so in practice.

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[39]Third party developers offer services associated with intimate linkage of software packages and with the setting up of databases to suit user requirements. Some developers offer such services as well, but the presence of 3rd party developers means that the user can shop around even after s/he has purchased a particular software package. When provided with a list of requirements for Thetford District, Admiral Computing Limited, for example, gave an estimate of £8800 to assess Thetford District's precise functional requirements, set up a DBMS intimately linked to MapGrafix™ and provide full documentation of their work. Although, as just demonstrated, this can be more expensive than the original packages themselves, it offers the user an alternative, and may be appropriate depending upon the circumstances. In the case of Thetford District, some work has already been done to provide an assessment of their precise requirements in this study. It may, therefore, cost them somewhat less for such a service.

Chapter 6

Conclusions

Landuse planning is an increasingly difficult area of planning, often involving complex decision-making in the development of alternative plans and in the final choice. The amount of information needed in the development of landuse plans can be enormous as a result of the breadth of the area of concern. Planners are correspondingly faced with an increase in the incidence of spatial conflicts concerning landuse. These conflicts and multiple objectives, some of which are inevitably impossible to quantify, must somehow be integrated into the planning process so they can positively affect the design and choice of management plans. The creation of a spatial decision support system (SDSS) is suggested as an effective tool with which to tackle the problem.

An SDSS was devised in response to a recognized need for decision support in a spatial context. It was designed to support decision-making for complex spatial problems by incorporating facets of a geographic information system (GIS) with that of a decision support system (DSS). Among other things, an SDSS can integrate a variety of spatial and non-spatial data like a GIS, provide a range of spatial analysis functions like a GIS, facilitate the use of analytical and statistical modelling, incorporate knowledge used by experts as in a knowledge-based system (KBS) or an expert system (ES), and could be designed to tackle problems with subjective criteria and multiple objectives like a DSS. Most importantly, it will do so in a form that is easy to use and flexible enough to adapt and evolve with the needs of the user.

In chapter 1 it was revealed that landuse planners have, on various occasions, expressed frustration with the current planning process (and this is not just in the UK, see Voogd 1983). Many have even pinned down their frustrations to a lack of specific capabilities which could significantly improve methods of operation and benefit the landuse planning process. Summarized, the most frequently identified needs were: 1) to be able to handle data spatially, 2) to be able to coordinate and integrate the many different types of data, 3) to be able to handle the increasing amounts of data, 4) to be able to process information more quickly, 5) to improve communication both between the decision-makers and with clients and interested parties, 6) to be able to incorporate subjective criteria in a rational manner, 7) to be able to handle multiple objectives, 8) to be able to support the resulting plans by some record of the decision-making process, 9) to assist in designing alternative scenarios and evaluating the effects before the decisions are taken and 10) to be able to get some idea of the sensitivity of decisions to changes in the political environment. These were labelled the functional or task-oriented requirements for an SDSS for landuse planning.

In chapter 2, additional analysis of landuse planning and the decision-making process was undertaken. Decision-making and planning have been shown to be very closely related in structure, both containing recognized stages: the gathering of information, the design of alternative plans, choice of an 'optimal' plan and implementation of the final choice. The traditional emphasis of decision support systems on supporting primarily the choice phase of the process is too limited in the context of landuse planning. Landuse planning would benefit from support at any stage in the process.

Chapter 2 also suggested several other approaches that affect the design of an SDSS for landuse planning: iterative, process-oriented and interactive. An iterative approach is desirable because planning is a dynamic process. To make use of the benefits of feeding information and insights gained in one phase back into a previous phase, opportunities must be readily available to the planner to switch between each phase. An SDSS should also facilitate a process-oriented approach to planning by concentrating on improving the methods of operation. Any decision support system is a combination of information technology (IT) and people. Each part provides complementary capabilities, and an effective combination of the two can create a powerful system for landuse planning. An interactive approach in the design of a decision support system ensures that the planner is involved throughout the entire process. Related to all of the above, the landuse planner, in particular, is not likely to be a sophisticated computer user. Thus, to create a system for the landuse planner as user in this man-machine system, and to facilitate an interactive and iterative approach, several features were identified as very important for the design of any effective system: 1) user-friendly, 2) explicit, 3) flexible, 4) inexpensive and 5) emphasize communication and presentation. Thus, there are several other features which must be imposed on SDSS design if it is going to be effective. These were labelled the user-oriented features required for an SDSS for landuse planning.

In chapter 3 it was demonstrated that computer-based systems offer many of the capabilities needed by planners to address the frustrations they identified. To determine which parts of computer technology best address these identified needs, present computer technology was broken down into 'elements of IT.' Those discussed here were: DBMS, SDBMS, other analysis tools (spreadsheet modelling, statistical analyses, simulation modelling), decision analysis (DA), KB, ES; and two related items, knowledge elicitation (KE) and user-interface. Each of these elements of IT were assessed for their applicability to problems faced in landuse planning. It became evident that landuse planners would need more than one of these elements of IT in order to effectively support landuse planning. GIS and DSS, two computer-based systems already in existence that encompass more than one element of IT, each fall short of providing the breadth of support required for landuse planning.

An SDSS was thus needed that fit both the functional requirements and the user-oriented requirements identified. Previously published definitions of SDSS do not seem to be able to do this. They may provide an ideal final product, but they offer no method for achieving it without a significant amount of research and enormous amounts of money.

In chapter 4, a federated structure was proposed as an immediate and effective alternative design for an SDSS for landuse planning. Unlike the other definitions, a federated SDSS is intended to be relatively inexpensive and extremely flexible. Furthermore, it is designed to be acquired gradually and evolve indefinitely, as long as there are developments in technology, changes in the problem environment or shifts in users' needs.

Several prerequisites were identified as necessary before a federated system would work. Each software package must be easy to use and the movement of data between the packages must be very straight-forward. Although developments in user-interface, data format standards and communications are improving across computer systems, the Macintosh was determined to be the most suitable platform at present for a federated system. Its historic disadvantage of somewhat limited processing power was not critical at this stage in the implementation of an SDSS, and is also rapidly disappearing as the technology develops.

In chapter 5 a case study in forest management was used to evaluate whether a federated SDSS can effectively improve landuse planning. The current forest management and planning situation at Thetford Forest District provided a most appropriate case study on which to test both the applicability of an SDSS and the effectiveness/success of this new federated design. The forest manager at Thetford is involved in both operational and strategic management, and both are in need of additional support. Thetford forest has a mix of demands upon its resources, and is in need of a mechanism for handling them all in an integrated manner. In addition, Thetford had a need for accessibility and flexibility in any system they adopted, which recommended the federated design to this application. They were also willing subjects

-- acutely aware of the difficulties they faced and interested in trying new methods in order to address those difficulties.[40]

An example SDSS was designed and partially developed for High Lodge, a particular area of interest within Thetford Forest. The specific task currently being tackled in this area of Thetford is that of forest restructuring -- an attempt to diversify the forest landscape by rearranging the shape, spatial pattern and relative age of the area's primarily even-aged stands -- and the SDSS was aimed at addressing this task. In addition, the SDSS was also aimed at addressing the management practice and problems of daily forest management at Thetford.

The SDSS was implemented for Thetford to test the effectiveness of the federated design, and see if a federated SDSS could improve landuse planning. The procedure for implementation of the SDSS at Thetford was as follows:

- study of their problem situation
- analysis of the current planning process and organizational structure of the district office and the Forestry Commission (affecting how the system will be used and accepted)
- identification of their specific needs for every aspect of the system
- determination of which elements of IT are appropriate and choice of the software packages which suit their requirements
- development of the SDSS, including: data acquisition, setting up the presentation to suit their needs, setting up some standard outputs, imports and exports, setting up some models to aid analysis, (investigate possibilities for more intimate coupling)

The computer system implemented here is only a partially developed SDSS, as compared to its complete form (i.e. including DA elements as well to fully support the choice phase). However, this partially developed system is still a fully working system, and in this form could already contribute much to forest management and planning at Thetford.

An Evaluation of the federated SDSS

Although the example SDSS, even in its partially developed stage, was never actually used by the management at Thetford, I was able to get a good sense of which aspects of this design were more than likely going to make it effective in practice because of the input from the forest manager and his team during the development.

As a result of the examination, I conclude that the federated SDSS would be very effective in supporting forest management and planning. First, it could be adopted

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[40]There is a very different attitude throughout other parts of the Forestry Commission as a whole at this point.

by landuse planners because it is ***accessible*** to them. The cost of the system would more easily fit into their budget than any other related system, and they would be able to begin using it immediately, without extensive training. The federated structure makes the system easier for the layman to understand: which element is performing which tasks, exactly what analyses are being applied, what format the data is in, etc. This, in turn, leaves all users of the system more informed about what is happening throughout the planning process. Second, the SDSS was ***applicable*** to the situation. It provided the forest managers at Thetford with just those capabilities they required at the time the system was designed. Thetford Forest District had never really used computer-based systems before. Thus, they were only interested in (and could probably only handle at this point) those elements which support the early phases of decision-making and landuse planning -- the gathering of information and the design of management plans. In other words, they needed first those elements which facilitated the acquisition, manipulation and analysis of data. The SDSS was also applicable because it fit in with the existing management practices in the district office. It made use of existing data, made easier many of those tasks which the office already performed, and made possible those tasks which were necessary but previously almost impossible. Third, the SDSS was ***non-limiting*** and very ***flexible***. The existing federation of elements of IT could be more intimately coupled, additional models or analyses could be written, and many frequently used functions could be automated to perform at the push of a button or the selection of a menu command. Each of the above could take place when the forest manager became familiar enough with the software packages to do it him/herself or had enough money to contract someone else to do it. In addition, more elements of IT could always be added to the federation whenever the problem situation demanded the additional capabilities.

An effective SDSS can improve landuse planning by making that planning more informed and by speeding up parts of the planning process. The system also has a tendency to make the management and planning process more explicit. Ad-hoc decisions are discouraged because of the effort that has gone into the development and rationalization of methods in an SDSS. Ad-hoc decisions are also often less necessary because the facility is often now available to re-assess all available information concerning the problem. The management plans that are produced using an SDSS will, thus, more likely be supportable and sometimes even more acceptable to critics than previously. My examination of the example SDSS developed here, along with Thetford District's reaction to it, indicated that it could provide all of those things. In comparison to the situation that presently exists at Thetford, where much of the forest information is accessible only from the Forest Research Station at Alice Holt Lodge in Surrey, this SDSS would significantly improve the on-site access to both data and information. By automating and making easier some tasks and making possible others, the SDSS also frees up the forest manager to think strategically, and perhaps encourages him to investigate additional ideas to reconcile the many, sometimes conflicting, uses at Thetford.

The advantages outweigh the disadvantages

The advantages of a federated SDSS, of applicability, accessibility and flexibility far outweigh the disadvantages in most landuse planning situations. These disadvantages are the sacrifice of a modicum of speed, the lack of full linkage, and the absence of one-developer dedication. The primary disadvantage is that one can almost never get a fully linked system in a federated SDSS. Even a system that has been developed to the stage of intimate coupling, in which the user only has to query one package and data is automatically retrieved from any other, will not be fully linked. To do so, each individual software package must have been developed in direct conjunction with the other packages in the federation so as to '*think*' like the others do when it comes to handling data. Even data standards will not ensure that each separate package handles data in precisely the same fashion. The disadvantage is that there may be some inherent sloppiness in a federated system with regard to subject areas like data transfer and data analysis. Instead of being able to use an internal format that makes maximum use of the space available and facilitates faster analysis and data movement, a federated system will probably make use of standard formats that may be a little less compact and somewhat slower, but can be shared by more systems. The individual packages will often translate the standard format into an internal format for better processing, but the sloppiness is still there in the need and the time taken for the translation. Another somewhat related disadvantage is that some speed is sacrificed in a federated system because analysis may be performed across several different software packages.

Not always, but generally, when a user purchases a large computer-based system (GIS, SDSS, or whatever), the user also receives the dedication of that one developer to help make that system work. The kind of backup can be very reassuring to the user and can, when that support is prompt and helpful, even replace the need for an on-site computer programmer to maintain the system. This situation of user-developer intimacy will work best in very large and specific application areas (e.g. telecommunications or electric industry) where the developer can dedicate him/herself to be an expert in that particular application area. Landuse planning, however, is not such an application area. It is worth observing, too, that such dedication comes at a price. A developer who sells a system for £495 will not be able to provide the same user dedication as the developer who sells a system for £40,000 - £100,000. In essence, user support is built into the selling price of the latter system, and the user has already paid for it regardless of whether or not it is needed.

The flexibility of a federated system outweighs the sloppiness and loss in speed in the context of landuse planning, thus countering to some extent the first two disadvantages outlined above. In addition, the suitability of the federated design for gradual or incremental implementation is also a major benefit. Developing any SDSS is a gradual and iterative process, as the potential user defines the problem environment more closely, learns more about what computer-based systems can offer, and develops more precisely what he needs from the computer system. The federated design allows this much more readily.

Unresolved difficulties

In the federated system, it is more difficult to maintain a record or log file of everything that occurs during the planning process. It has been suggested that this is desirable so that the procedure could be repeated, or checked for whatever reason. Such automatic record-keeping is much harder to accomplish when each package is operating completely separately, as in a federated system. It would be easier if the packages were linked within a single shell (e.g. via Hypercard®), but that requires additional development. As long as all packages are all used on the same machine, logging activities could possibly be accomplished in a federated system by some kind of system-monitoring software like Empower®, as long as the user was able to define the parameters of the record to keep track of such particular activities as the use of a particular statistical function with the package StatView™.

Support in the choice phase is very important in landuse planning. Because landuse planners have as their charge a finite land resource, it is imperative that the objectives and the criteria for any assessment of management plans for land be critically and consistently assessed. This kind of support is what can be supplied by decision analysis and related software. The concept of HiView allowed me to explore many of the features DA has to offer, and to sketch how it could be applied to Thetford. What I was not able to test was how to get planners themselves to make use of such a facility, and what experience was required on their part to do so. Although HiView was originally intended to be used either in a decision-conferencing environment with a paid facilitator guiding the discussion, or as a tool for the trained decision analyst, I am confident that once a user has been introduced to the fairly simple and straight-forward concepts involved, s/he would be able to use the system effectively to explore and assist in the analysis of his/her particular choice problem. This was never put to the test, however, so it remains unresolved whether landuse planners would adopt such a method of support.

Other major observations

The federated design allows one to start in a simple way. It enables one to look independently at portions of the final system -- one capability at a time. I did not have to teach the forest managers all about spatial data handling, theories of decision-making and simulation modelling in order to start demonstrating elements of the SDSS. This proved to be the thin end of the wedge. At first the Forestry Commission was adamantly against investing any time, energy or money whatsoever to apply a computer-based system to improve forest management and planning. Gradually, however, starting simple encouraged them to invest a little time and energy, to think further about their present planning situation and to consider converting from old ways of data acquisition and analysis. Most importantly, it encouraged a general enthusiasm for the idea.

The fact that it was easy to learn was a revelation to the users. The user-interface provided by the Macintosh is a surprise to many landuse planners. Being for the most part well outside computing environments, many only come in to contact with computer systems in the form of some very old (in computing years) mainframe analysis package that is closely guarded and kept mystical by its maintenance staff. They are thus often extremely wary of the introduction of any computer-based system into their own working environment. When I was able to easily demonstrate with the Macintosh that computing was there to serve them and not the other way around, it immediately broke down several barriers.

The value of information to landuse planning was very apparent. In my discussions with the foresters at Thetford, they were initially thrilled just at the prospect of being able to easily access information about the forest stands. According to Aybet (1991), "decisions are made on the basis of the information available," and it was apparent that at Thetford decisions had frequently been made without adequate information. Anything done to facilitate access to information was certainly going to improve management and planning at Thetford as far as the managing foresters were concerned.

Even little things help. When I mentioned that it would be possible to set up as standard reports the type of information required by the forest operations groups in the field, and even to set it up at the touch of a button, they were thrilled. What seemed to be a relatively trivial thing from a computing point of view was apparently a task that would be extremely helpful in practice.

In order to provide full support, each SDSS is designed for a very specific problem area. Hence the iterative exchange during development between the steps defining the user and the problem and those defining the capabilities of the computer system. The exchanges with the forest manager and his team at Thetford Forest District were very successful. From my experience in working with Thetford, this process is made significantly easier when each party (the user and the developer) has at least some knowledge of the other area. Knowledge of their problem area is essential.

The appropriate software packages must exist in order to create a federated system. If nothing suits then a developer must be approached to create one especially for the job. I experienced a little of this trial when trying to find a DBMS that was ideally suited to the situation at Thetford. This will always be a problem, however. Whether a user is looking for individual software packages to make up a federation, or whether s/he is considering a single system, the chance always exists that the perfect software is not available. In fact, because there are a larger number of individual packages available, it could be argued that the user might be considered more likely to find one of this type.

There are several other aspects worth noting about federated systems. First, although a federated system puts complete control in the hands of the user, it also puts a substantial amount of responsibility in the hands of the user. It is up to the user to assess each software package for inclusion into his/her particular SDSS. Software developers, let alone salesmen, are rarely completely objective when determining the appropriateness of their product for the user's problem. However, the purchaser of an additional software package for a federated system will already have a good idea of precisely what it is that s/he needs from their experience with the rest of the system, and can ask more specific questions which are harder to talk around. In addition, in a federated system, especially one composed of software packages with only ad-hoc linkage, the user is involved in every stage of the planning and decision-making process. This entails more work on the part of the user, but it also ensures the users involvement and reinforces his responsibility for the outcome.

Can it be developed and implemented by the landuse planners themselves? That has yet to be seen, but judging by the relatively small amount of time and effort that was required to gain the expertise to create this SDSS, I think that the outlook is optimistic.

Future developments

Apple® system 7.0 should dramatically improve the options available for coupling between software packages on the Macintosh. It represents a major redesign of the system and was intended specifically, among other things, to improve communication and coupling of separate software packages. Although the system software is technically available already, I was not able to investigate first hand the full range of possibilities presented by the new system, and can only be guided by what others have said.

Thetford Forest District was not quite ready for decision analysis support in their choice phase by the time this project ended. Yet, it is important that they achieve this eventually because of the number of objectives and the qualitative criteria that need to be rationally incorporated. Unfortunately, this aspect of the federated SDSS did not get fully implemented for Thetford because it relies so heavily on information and ideas generated by the rest of the SDSS, which was not yet in operation. Decision analysis has been frequently applied to site selection and other location problems, but it has never been formally applied to landuse planning. Applying DA to landuse planning problems should certainly be investigated further in another study. As mentioned earlier, there are several different approaches to solving choice problems, and these should be investigated with respect to landuse planning to determine which type of approach and which type of software really does allow the landuse planner to effectively address the choice problems in this area.

Concluding comments

The beauty of the federated system is that the user can evolve from one variation of an SDSS to another -- i.e. that an SDSS could be either a 'full system' with a full complement of the elements of IT, or only a 'partial system' just consisting of one or two of these elements if that is the limit of the support required. How close can it come to the ideal system proposed by Densham and Goodchild (1989). Given the time and incentive, probably pretty close. 'User-friendly' shells could be set up in systems like Hypercard® to tailor systems to guide special users to only those tasks they need. Facilities for knowledge elicitation could be set up, and expert systems could be created for a particular task. However, many users of spatial decision support may never actually reach the point of needing the most effort-intensive features. For example, only particular tasks that are not too complicated, not too trivial and frequently required are suitable for automation by an ES (one example for landuse planning is the application of zoning regulations).

Driving this whole project is the idea that the most effective information system of any kind is one that is used. Effectiveness is substantially enhanced if the system is driven by the people who need it.

> An information system (GIS, SDSS or whatever) "can be used off in one corner of the organization with its own team of specialized analysts and

> programmers, or it can be a tool fully integrated into the human workings of the organization. The choice is between the existing knowledge and experience in the organization and the systems available." (Hershey and Whitehead 1991)

A federated SDSS makes this possible.

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Appendix I

Glossary

accessible: an accessible system is one that is reachable by the target group. This is similar to its use in transport except that instead of being measured in terms of time, cost and distance, an accessible system is measured in terms of cost, ease-of-use, availability etc. For landuse planners, this means a system that is easy to use, non-trivial, non-limiting, inexpensive and flexible (see chapters 1 and 4 for further discussion).

ad-hoc linkage: a description of the structure of a computer system (e.g. GIS, SDSS) in which each software component incorporated into the final system is developed separately and integrated together later (see chapter 4).

attribute data: It represents properties or attributes of real world entities, and is usually used to refer to non-spatial characteristics. These attributes may be actual, hypothetical or normative (has also been called empirical knowledge).

computer system: this term is used when the system being referred to is based entirely on computer hardware and software. Where it could be made up of either computer or computer-human parts, the term 'system' is used alone.

coupled:[41] a measure of the degree to which functions in one package can be directly controlled from another. Modifiers usually used with it are rough descriptions such as:

loosely coupled: a degree of coupling in which each software package remains entirely separate, but data can be transferred between packages with only a small degree of external manipulation if at all.

moderately coupled: a degree of coupling that is somewhere in between loosely coupled and intimately coupled.

intimately coupled: a degree of coupling in which whole series of commands and functions from one package can be driven from within another.

data: a representation of facts or concepts in a formalized manner suitable for communication, interpretation or processing.[42]

database management systems (DBMS): computer-based technology which provides the function for the capture, storage, retrieval, transformation, manipulation, analysis and display of attribute data. It is used here as a single element of IT.

decision support systems (DSS): computer systems, often commercially available, which incorporate some form of preference technology together with any variety of other elements of IT. Is usually aimed at supporting decision-making in the choice phase.

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[41] See NOTE at the end of the glossary.

[42] Modified from the "GIS Dictionary" published by the Association for Geographic Information (1991).

decision-making process: an iterative process consisting of 3-4 phases including: intelligence, design, choice and implementation (see chapter 2).

element of information technology (element of IT): used to refer to those individual elements of computer software which can be combined to create a computer system.

expert system (ES): contains a knowledge base and an inference engine. It is used here as a single element of IT.

federated system: a cooperation of existing commercially available applications. The linkage between the applications would vary from ad-hoc (they exist alongside one another and share data only) to partial linkage (packages can be controlled from one another--e.g. via macros).

full linkage: a description of the structure of a computer system (e.g. GIS, SDSS) in which each software component has been developed in close interaction with the other components. The data provided by one component is well-tailored to that required by the other component (see chapter 4).

geographic information systems (GIS): computer systems which usually combine a SDBMS and a DBMS to create a powerful tool.

information: intelligence resulting from the assembly, analysis or summary of data info a meaningful form.[43]

information technology (IT): a general term used to refer to those computer-based applications, primarily software, which have been developed to assist man in dealing with information--e.g. by providing computerized techniques and methods for information exploration, analysis, presentation etc. As the term is used here it also includes that technology developed to help man incorporate judgemental information or preferences (i.e. preference technology) (see chapter 3).

knowledge base (KB): where information is stored in a particular structure reflecting relationships of reason. In comparison, a DBMS stores data according to their taxonomic relationships. It is used here as a single element of IT.

landuse planning process: an iterative process very similar to the decision-making process in format (perhaps even a specific form of the d-m process), in which the 4 phases refer to the development of plans affecting the management of land and landuse (see chapter 2).

landuse planning: a general category referring to those areas of planning dealing primarily with land. This would be roughly equivalent to Town and Country planning, Urban and Regional planning, and Natural Resource planning.

linkage:[44] using Badji and Mallants definition, this is a measure of the degree to which each software package has been designed around another package. Evidence of this is the way the data is structured and handled in each package, and whether each package will output data in a format that can be directly used by the other package. In the Macintosh environment, many packages output data in common formats because they have been designed around a standard rather than designed around another specific package. This is not considered a form of linkage here, although it could be (i.e. it could be argued that most software package for the Macintosh are already partially linked according to Badji and Mallants definition). Instead, only

[43]Taken from the "GIS Dictionary" published by the Association for Geographic Information (1991).

[44]See NOTE at the end of the glossary.

packages that are known to have been developed with reference to each other are considered to have linkage beyond 'ad-hoc linkage'.

module: represents a particular function (e.g. a mapping module) or range of functions (e.g. an analysis module). Rarely has a stand alone capability (see chapter 4).

package: an individual element of software, often providing a specific function or capability (from 'software package'). The integration or linkage of several applications creates a federated system. Frequently has a stand alone capability (see chapter 4).

partial linkage: a description of the structure of a computer system (e.g. GIS, SDSS) in which additional software components (e.g. models) are developed around one of the other components. In this case the additional component is specifically designed to import and output data in the form specific to the first software component (see chapter 4).

preference technology: computer-based technology which provides a mechanism to help people form preferences, make judgements and take decisions (e.g. incorporating decision analysis techniques). It is used here as a single element of IT (Phillips 1988).

software component: a generic term referring to the elements making up a computer system. Intended to include both 'module' and 'package.'

spatial database management system (SDBMS): computer-based technology which provides the function for the capture, storage, retrieval, transformation, manipulation, analysis and display of spatial data. It is used here as a single element of IT.

spatial data: data inherently described by its position in space--typically described by X and Y coordinates. E.g. where spatial features are represented by their boundaries.

spatial decision support system (SDSS): an integrated set of flexible capabilities implemented as a set of linked software modules or applications, that are designed to provide support to the complexities of decision-making in a spatial context. It will generally include an SDBMS, DBMS and preference technology in addition to communication and presentation facilities (i.e. GIS and DSS), but it should be flexible enough in design to incorporate whatever elements of IT are most suitable to the planning problem and the approach of the management team involved.

support: a system provides support when it assists the user in the It can do this by providing information, or analysis for, or output for.

system (or computer-based system): refers to a coordinated or integrated combination of more than one elements of IT. It can be used to include the entire complex of interacting parts, both human and computer (e.g. as in DSS and SDSS), or to refer to those parts based primarily on the computer components of the system (i.e. the hardware and the software) (e.g. GIS) (see chapter 3).

user interface: that part of the software which is dedicated to communication with the user.

NOTE: There is a difference implied between 'coupling' and 'linkage.' Linkage refers to a package's development history, which will affect how it defines and handles features and objects. Coupling refers to the physical and logical connection between the software packages in the implemented system. In other words, coupling can be added during SDSS development and implementation, linkage cannot.

Appendix II

List of Software and Hardware Referred to

Software package	Developer	Supplier	Price
4th Dimension™	ACI 5 Rue Geaujon 75008 Paris France tel: (33) 1 42 27 37 25	ACI (UK) Ltd. St. Ann's House Parsonage Green, Wilmslow Cheshire SK9 1HT (0625) 536178	£ 620
Double Helix™	Odesta 4084 Commercial Avenue Northbrook, IL USA 60062 1 (708) 498-5615	Computer Capability	£ 445
Empower®	Magna 2540 N. First Street Suite 302 San, Jose, CA USA 95131 tel: 1 (408) 456-2500	Amtech International Limited Mulberry Court Stour Road Christchurch Dorset BH23 1PS tel: (0202) 476877	(I) £ 129 (II) £ 239
FileMaker Pro™	Claris Corporation 5201 Patrick Henry Drive Box 58168 Santa Clara, CA USA 95052-8168	Claris International Inc. Richmond House Bath Road Speen, Newbury Berkshire RG13 1QY (0256) 463344	£ 225
FileVision IV®	Admiral Computing 193-199 London Road Camberley Surrey GU15 3TJ tel: (0276) 692269	Admiral Computing 193-199 London Road Camberley Surrey GU15 3TJ tel: (0276) 692269	£ 495
FoxBASE+/Mac™	Fox Software, Inc. 118 W. South Boundary Perrysburg, OH USA 43551 tel: 1 (419) 874-0162	Fox Software International Intech House 34-35 Wilbury Way, Hitchen Hertfordshire SG4 0AP tel: (0462) 421999	£ 395
HiView	Dr. L. Phillips (Decision Analysis Unit) Enterprise LSE tel: (071) 955-7101	Dr. L. Phillips (Decision Analysis Unit) Enterprise LSE tel: (071) 955-7101	£ 600
Hypercard®	Apple Computer, Inc. 20525 Mariani Avenue Cupertino, CA USA 95014-6299 tel: 1 (408) 996-1010	Apple UK Ltd. 6 Roundwood Avenue Stockley Park, Uxbridge Middlesex UB11 1BB tel: (081) 569-1199	free with the purchase of any Macintosh
MapCon	Aquaterra n.v. Ijzerweglaan 48 9050 Gent Belgium tel: (32)91/305515	Admiral Computing 193-199 London Road Camberley Surrey GU15 3TJ tel: (0276) 692269	£ 1470
MapGrafix™	ComGrafix, Inc 620 E Street Clearwater, FL USA 34616 tel: 1 (813) 443-6807	Admiral Computing 193-199 London Road Camberley Surrey GU15 3TJ tel: (0276) 692269	£ 4995
MapLink™	same as above	same as above	£ 295

MapView™	same as above	same as above	£ 295
Microsoft® Word 4.0	Microsoft Corporation 16011 NE 36th Way Box 97017 Redmond, WA USA 98073-9717	Microsoft Ltd. Excel House 49 de Montfort Road Reading RG1 8LP tel: (0734) 391123	£ 275
Nexpert	Neuron Data Corp. 444 High Street Palo Alto, CA USA 94301 tel: 1 (415) 321-4488		£2780
StatView™	Abacus Concepts tel: 1 (415) 540-1949		£ 495
STELLA® (with STELLA®Stack)	High Performance Systems, Inc. Lyme, NH USA	Gomark Ltd. 10 Hurlingham Business Park Sulivan Road London SW6 3DU tel: (081) 731-7930	£ 194 (£ 379)
SPSS®	SPSS Inc. 444 North Michigan Avenue Chicago, IL USA 60611 tel: 1 (312) 329-3500	SPSS UK Ltd. SPSS House 5 London Street Chertsey Surrey KT16 8AP tel: (0932) 566262	£ 545
Systat®	SYSTAT, Inc. 1800 Sherman Avenue Evanson, IL USA 60201-3793		£ 595
WhizSurf	WTC Scientific 152 Buxton Road Macclesfield Cheshire SK10 1NG tel: (0625) 420210	WTC Scientific 152 Buxton Road Macclesfield Cheshire SK10 1NG tel: (0625) 420210	£ 210
Wingz™	Informix Software, Inc. 16011 College Boulevard Lenexa, KS USA 66219	Informix Software Ltd. Informix House Littleton Road, Ashford Middlesex TW15 1TZ tel: (0784) 240444	£ 295

Appendix III

Those issues perceived as most important in national forest management in the United States

Forest policy and forest management and planning has been a recent issue in the United States, instigating a major discussion of the role of forestry and forest management. This discussion has led to a critical assessment of forest management and the emerging issues that are affecting the application and effectiveness of current management strategies. One survey was conducted in 1988 in the United States among National forest supervisors and district rangers, those responsible for the management of the more than 180 million acres of national forests. The seven most often identified as of top priority are: (Jakes et al. 1990)

- There are an increasing number of challenges to decisions and forest plans, as resource professionals lack credibility with the public and professionals question the public's ability to make informed decisions.
- There are increasing conflicts among forest users.
- There are increasing conflicts between local and national interests and priorities.
- There are increasing constraints being imposed on management and planning activities due to environmental/conservation concerns expressed in laws or regulations.
- There are inconsistencies between priorities established in the planning process and those established in the budgeting/appropriations process
- There is concern about the effectiveness and the cost of the forest planning process
- There are declining resources to manage the national forests.

Most of these emerging issues in forest management and use in the US are concerned with difficulties in the planning and management decision-making process. Most noticeable is the recurring theme that planning is becoming more complicated and more important all the time, and that it sometimes lacks effectiveness.

Although there may be differences in the scale of the situation or of the relative importance of the problems, the above list applies very closely to the present situation in the United Kingdom as well.

Appendix IV

Outline of the actual chain of events during system development

Date/Place	method of contact	job	w/who*	result
Jan 10, 1989 Alice Holt Lodge	meeting	informal chat	BH AB	gained an understanding of forestry in the UK
spring 1990	letters	suggested the possibilities of computer-based systems for supporting forest management and planning	AB	FC interested
Nov 19 1990	meeting	described my interests in SDSS, and presented a few related demos on the Mac	AB BR	interested and willing to cooperate
period Nov 1990 to March 1991	letters		AB	suggested Thetford Forest District (TFD) as an appropriate subject area for the example
March 19, 1991 Thetford	meeting		AB AH SM BRb	TFD want to cooperate and proceed with the project. High Lodge Warren is chosen as the area of interest, and it includes in it the Red Squirrel Conservation area and the site of the new visitor centre. They keep my sheets describing their management needs for further study and comment.
period March 1991 to September 1991	letters	Found suitable software. Set up SDBMS and DBMS for Thetford. Identified the other software elements that would be appropriate. Further defined their present management system.	SM	Maps received from TFD. Data received from Alice Holt Lodge. Discrepancies sorted out. Some difficulties finding an appropriate DBMS. They further defined their present difficulties and identified the task of forest restructuring as a major problem.
Sept 20, 1991	meeting	Showed them (via hardcopy output) the results so far and discussed again how the system as its being set up fit their current management problems, where it falls short, and how they would like to expand it from there.	SM JL	Further defined their present management system, and their needs for information, analysis, communication, output etc.
period Sept-Nov 1991	phone calls	Confirmed various queries I had during system development	SM JL	
Nov 22, 1991	meeting	run a working demonstration of the partially developed SDSS , and bits and pieces of other elements to demonstrate their capabilities		

*

Forest Research Station, Alice Holt Lodge, Wrecclesham, Surrey
AB = Alan J.A. Betts, Survey Officer, Forest Surveys Branch
BR = Bruce Rothnie, Database Manager, Forest Surveys Branch
BH = Brian Hibberd, Communications Officer

Thetford District Office, Santon Downham
BRb = Brian Roebuck, Forest District Manager
SM = Simon E. Malone, District Forester: forest management
JL = John Lyons, District Forester

East England Conservancy, Cambridge
AH = Alisdair I.D. Horne, Operations Support Officer

Appendix V

The Functional Requirements of the DBMS as Defined for Thetford Forest District

FIELDS

Between 100 and 130 fields in all

- some with value lists
- some with restrictions on format
- one with the current date (and one with year only)
- some with auto calculations using other fields (including 'if/then' clauses as well it possible)
- some for free text (and can search free text)
- some with look-up tables (e.g. if field A has code *X*, then field B will reflect the corresponding text, or vice versa)

Need to be able to query all fields

Need to be able to browse through records via user- designed views (i.e. not limited to browsing through data in a spreadsheet format)

May need several databases

Will need several user-defined views of the same database (e.g. one displaying the fields relevant to conservation, another displaying the fields relevant to stand management and history, etc.)

Ideally when in one view, the user is only faced with those fields for export and analysis (130 can be a daunting list to find the field you

SEARCHING

Need to be able to search for missing entries, duplicate entries.

Search for records that have changed since *X* date*

IMPORTING

Need to be able to import intelligently--i.e. the database will match the ID's and change only those fields with a new value (e.g. similar to the way FileVision does it)

can preset up some standard import formats

EXPORTING

capability to export tab-delimited text (for import into spreadsheet models)

capability to export fixed character fields (for import into the national Subcompartment Database)

can preset up some standard export formats (i.e. which fields and in which order)

OUTPUT

Need to have user-defined reports and forms (e.g. forms for forest operators, some standard monthly or annual reports)

CAPACITY

somewhere around 8,000-10,000 records

AUTOMATE

Some standard searches or searches and reports (probably only about 5 to begin with)
Ideally: connect the subcompartment in database and in map so that if its DBMS record is deleted while it still exists on the map, the area concerned is highlighted (or brought to attention some other way)

The users themselves need to be able to:

- add and adjust fields (and delete)
- add and adjust reports
- design their own additional views, and modify those already set up
- set up user-defined import/export of data to and from other packages and systems