Contents

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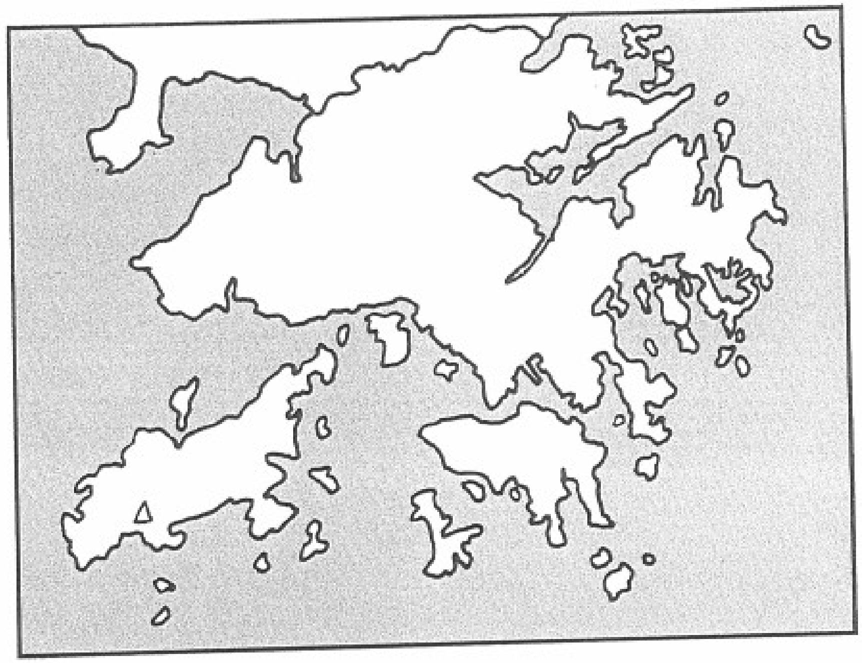

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Words from the Editor

The publication of this issue of the Hong Kong Geographer has experienced a great deal of delay. This is solely the fault of the editor and he would like to express his apology to the contributors of this issue and all members of the Hong Kong Geographical Association for this.

The theme of this issue is Computer Application in Geography. This is the second time the Hong Kong Geographer focuses on this theme. This reflects in the main the rapid development of computing technologies and the field of Geographical Information System (GIS) as a discipline of enquiry. The articles by Dr. Y L Siu and Mr Thomas Lee attempt to integrate the GIS approach with the more traditional topics of geographical concern. Siu's paper examines energy modelling, and the Lee paper studies the problem of location allocation. Miss Sunny Chang and Mr Jacky Pow's papers are of a slightly different nature. Chang discusses computer aided teaching from a psychological perspective and introduces the readers to three computer aided teaching packages in Geography, namely, PC Globe, SinEarth and SimCity. Pow points out the similarities between the Hypertext environment in computing and Geographer's concept of the region. Together, the four papers in this issue provide a more or less comprehensive outline of the major developments in the use of the computer in Geographical teaching and research.

Moreover, the publication of this issue is sponsored by the Manhattan Press (H.K.) Ltd. On behalf of the Board of Editors and the Hong Kong Geographical Association, I would like to extend our deep appreciation for this generous support.

Li Si Ming
Editor

Teaching Geography with Computer Games – A Psychological Perspective

by
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I. Introduction

The application of computers in education is expanding in importance. In 1926, Pressey produced the first recognisable teaching machine and in 1954, Skinner applied his findings from animal conditioning to the production of the first linear teaching programme. O'shea (1983) later developed the branching programmes to compensate for the limitation of the linear programmes. With the rapid development of software programmes in a comparatively short period of time, programmed learning techniques and teaching machinery have spread from the psychologist's laboratory through the business world into education.

The aim of this paper is to find out the feasibility of using some commercially available computer games in Geography teaching. The paper consists of three parts. The first part proposes some criteria for assessing educational software packages in psychological perspective. The second part applies these criteria in assessing some geographical computer games currently available in the market, and tries to find out whether these computer games could facilitate Geography teaching in the secondary school. The final part tries to find out the possibility of using ready-made computer games in the market to ease the work of the teachers and promote effective learning.

II. The Importance of Computer in Education

Due to the increasing importance of data collection, data analysis and interpretation in various science subjects and Geography, there is a general application of computers in education. However, the use of computers in teaching is rather restricted. Taking Geography teaching as an example, it is found that computers are mainly used for word processing, statistics, graphic and data processing (Yeung, 1989 & To, 1989). Actually computers are not merely computing when they are processing words or aiding instruction. They could solve our major problems in education. It is one of the solution for school repelling and to arouse subject interest. In short, computer is a reinforcer in education.

The successfulness of using computer in enhancing learning is also supported by the various studies done by Bates (1979), Kulik (1983), Condry & Keith (1983), Skinner & Allen Calvin (1984), Lepper (1985) and Child (1986). Their findings can be summed up into several points.

1. The provision of effective programmes can provide abundant reinforcement to motivate the students. [Skinner & Calvin (1984)]
2. Less capable students learn better when assisted by computer. [Kulik (1983)]
3. Computer game programmes could motivate and attract the attention of the students. [Bates (1979), Condry & Keith (1983) and Lepper(1985)]
4. Computer assisted learning provides immediate knowledge of results and allows students working at their own pace and by themselves. [Child (1986)]
5. Computer assisted learning avoids the embarrassment and humiliation of displaying ignorance in front of the class. [Child (1986)]
6. Computer assisted learning reduces the repetitive work of the teachers.

Although there is a number of advantages in using computer assisted learning, the technology is not yet mature. Some psychologists found that computer based instruction in the longrun might affect creative thinking. Moreover, it will affect performance due to the lost of motivation when the novelty wears off. Furthermore, when students work at their own pace, there is no guarantee that they are working to the best of their ability. The most important demerit of all is that the programmes may not be well designed. As a result, there is a need for educational software experts to evaluate the

effects and the effectiveness of the educational software in order to help teachers in facilitating effective learning.

III. The Attitude of Geography Teachers Towards The Use of Computers in Teaching

In a study on ' Teacher's attitude in the use of microcomputers in Geography teaching ', (To, 1989) it is shown Geography teachers in Hong Kong were quite supportive to the use of microcomputer. However the use of computers was mainly in handling routine work. Over 94% of the teachers strongly agreed with the effectiveness of the microcomputers in storing and handling geographical data but few actually used computers as a teaching aid in the classroom. The teachers showed a marked mixture of interest and skepticism in using computers as a teaching aid. They showed confidence in using computers in the classroom, but they are pragmatic and worried about the adaptability of this new teaching method to the existing curriculum as well as the time that is required.

Their skepticisms may be due to lack of training and compuphobia. This implies that teachers need to be equipped with the computer knowledge that permits them to teach much more effectively with this new technology thus reducing their anxiety. They could then demonstrate their faith in this teaching method by going out for a limb. This implies computer programmed instruction can be used as a reinforcer or an aid to facilitate learning as well as in routine calculation and word processing.

IV. Criteria for Evaluating Educational Software – A Psychological Perspective

After the needs of the students and teachers are realised, the next step is to assure the use of effective and efficient educational programmes in the classroom. There are two main constituents in a computer. The hardware and the software. The most important part of the whole process is the software. The programme containing the subject matter must be organised in a carefully arranged progression of information, questions and answers. Both the behavioural and gestalt psychologists have proposed several criteria for assessing the effectiveness of different educational software in schools.

A. The Behaviouristic view

Taking into consideration of all the basic concepts of behaviourism, such as conditioning and reinforcement, M. Alessi and Stanley R. Trollip (1985) had developed the following steps for the development of computer-based instructions.

1. Set the goals precisely. They should relate to the change of behaviours and arranged in hierarchy.
2. The resource materials should allow the students to identify the reinforcers presented by the computer.
3. To encourage brain-storm work and creativity.
4. To allow students to select the outcome of brainstorm.
5. To produce the drafting of the actual instructional message which fits into the display system.
6. To produce a flow-chart which describe in detail what operations a computer should perform and in what order.
7. To translate the draft into a series of instructions understandable to the computer.
8. The final step is to evaluate the programme by observing the results of the real students studying the lesson.

This is only a hypothetical plan for a lesson. It will serve as a framework for designing computer based instruction. Gagné (1975) and Skinner (Suhan, 1987) have added some concrete ideas on how should computer-based instruction be designed and how can behaviouristic aspects be applied on it.

Although Skinner did not invent any teaching computers or programmes, he had several comments on how the material should be designed. He had added to both the rationale and the technology of using computer as a teaching aid and programmed instructions. He stated several characteristics for planning the instructional material which illustrate operant conditioning or the shaping of behaviour.

1. The material should proceed in small steps, moving gradually and sequentially toward goals of knowledge and understanding.
2. Small steps will assure that the learner will make almost 100% correct responses which facilitates operant conditioning.
3. Immediate feedback should follow the response in the form of positive reinforcement.
4. To ensure the correct response, prompts should be used to help. However, the answer should be produced freely or emitted by the learner.
5. Negative reinforcement and punishment should not be used. Mistakes should be corrected immediately by providing hints when the student turns to the next frames.
6. Finally, teachers should bear in mind that learners will participate actively, making frequent responses only if he or she have successful experiences (positive reinforcement).

To Skinner, these illustrate the laws of operant conditioning and are called linear programmes.

B. Coginitive Theory

Inevitably, the linear programme proposed by behaviourists have several drawbacks. Kulhavy (1977) claimed that, 'Supplying feedback after an error is probably far more important than providing confirmation'. He thought that teaching actions were determined by student responses, two students would not in general receive the same material. The less capable student would receive more explanatory correction. This argument supports the viewpoint of cognitive theory of learning which contrast greatly with the behaviouralistic view. Cognitive psychologist, Crowder (Child, 1989) studied the information processing system of human thinking concluded that there are five components needed for an efficient mechanical teaching device.

1. The programme should allow active response on the part of the learner.

2. Immediate knowledge of the accuracy of the response should be given when the student makes a mistake.

3. It should be able to give information about the incorrect responses as well as new matters.

4. According to Cognitive psychology, one must see the whole context to make the parts more meaningful. Therefore the frames should contain more information than the linear programme proposed by behaviourist which contains small pieces of subject matter presented in sequence.

5. Allow students to work on their own pace.

The advantages of branching programme can redeem as the limitation of linear programme. It provides a large frame for the students to respond. Furthermore, it does not need to ensure that the students have to respond correctly and students can receive some comment upon their responses. There is a firmer grip on the elusive 'feedback' and 'individualisation', allowing students to learn by themselves. To some extent, the development from linear programming to branching programmes are inevitable, as computers can obviously do so much more with branching programmes. This is emphasized by the learner himself, his activities, his interests and his contributions to the conversation.

V. Critical Analysis of The Geographical Computer Games

The following analysis of the geographical software is based on the criteria drawn by the cognitive psychologist as their structures are mainly branching programmes.

Educationally sound software packages are rare and expensive. As a result, many software producers have begun to respond to the teachers' demand for better quality programmes that match with the curriculum requirement. Several educational software for Geography are currently available in the commercial market. The programmes that are related to the Geography syllabus in secondary schools are PC Globe, SimEarth and SimCity. The following is a critical analysis on these games by the cognitive approach. Table 1 below is a summary of the analysis.

Items for Evaluation	PC Globe	SimEarth	SimCity
1. Allow Learner's active response	YES	YES	YES
2. Immediate knowledge of accuracy provided	YES	YES	No Automatic Display*
3. Give information about incorrect response	NO	YES	No Automatic Display*
4. Frames contain enough information for users to see the whole context	YES	YES	YES
5. Allow students to work on their own pace	YES	YES	YES
6. Current list price	US$35	US$70	US$33

Table 1 : Summary table of the evaluation of the PC Globe, SimEarth and SimCity.

* *If students want to know the validity of their response, they can go to the data display windows. Each window shows one factor that affects the functioning of the city. For example, the budget for city development or the existing environmental pollution.*

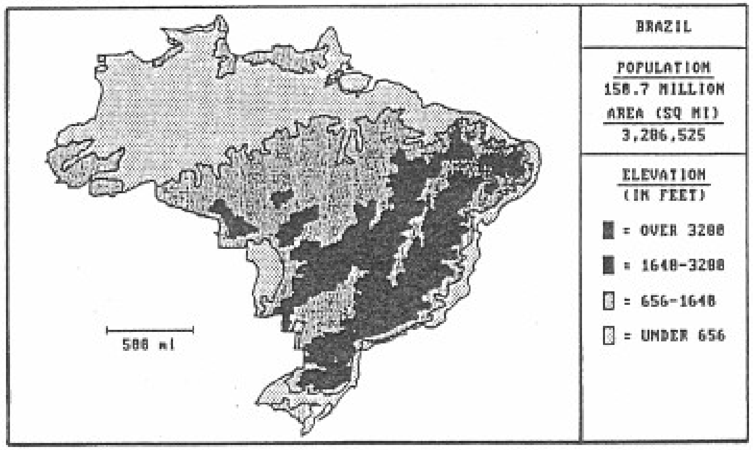
All the games are very useful in education and they satisfy the majority of the requirements of cognitive psychologist. They are interesting and can facilitate learning. In addition their prices are affordable, thus it is worthwhile for schools to experiment in using them in Geography teaching. The only drawback is that there is not enough information for correction when student makes mistakes.

A. PC Globe

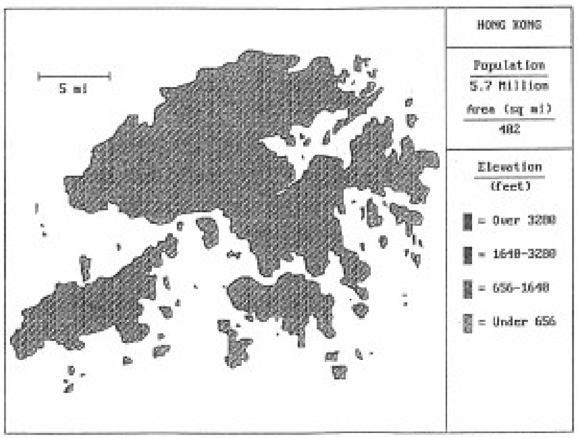
PC Globe was produced by the PC Globe, Inc. in 1988. It is an "electronic atlas" and an resource tool with detailed maps, graphics, facts and figures on 190 countries. It also includes climate charts of major cities, updated information, enhanced point-and-shoot capabilities, and additional special utilities such as country flags and their national anthem. Comparisons between countries can be made and are shown by colourful maps and bar charts. All the utilities are manipulated by the cursor keys or clicking the mouse.

PC Globe is quite user friendly since it is menu driven. It allows the students to find out the information by trial and error. Instructions are clear and easy to understand. The colourful maps and charts display, and the sound effect of the national anthems can serve as the reinforcer for the maintenance of learning behaviours (refer to Diagram 1). As

Diagram 1A Maps in PC Globe

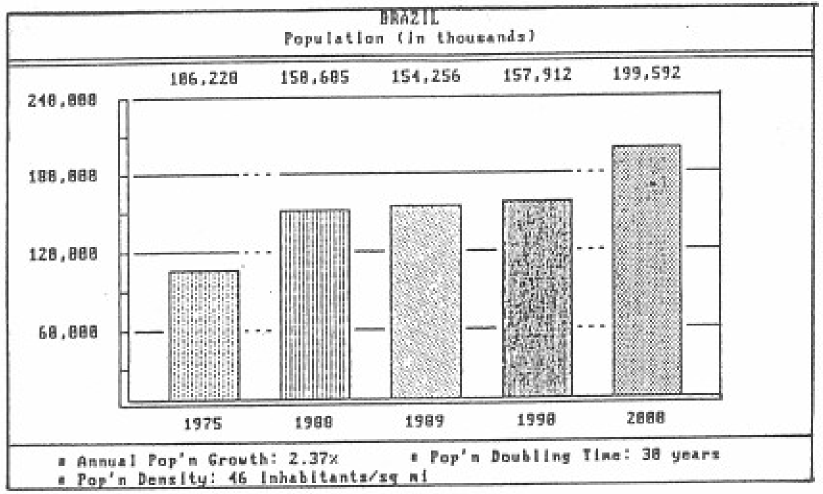


(a)



(b)

(a)



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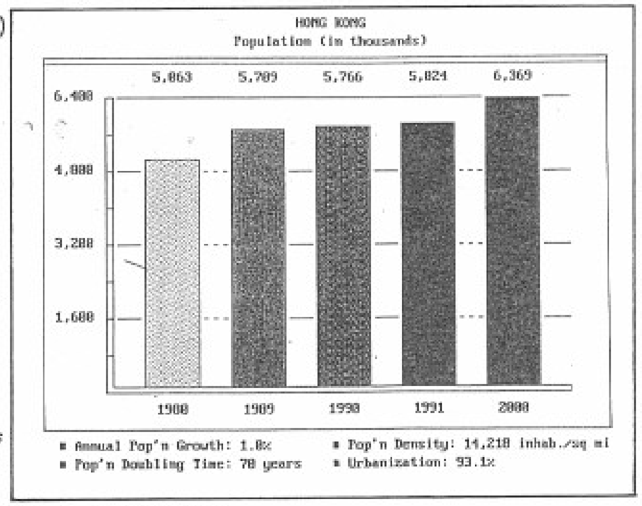


Diagram 1B Charts in PC Globe

it is an informative programme, no information is output if the students make a incorrect choice. Students know whether they have made a mistake by reading the information displayed. In another word, the programme requires active participation by the students. In addition, the programme allows students to see the whole context on one frame. Students can read all the information about a country simply by using a different menu selection and obtain the overall picture of the selected country on a single frame. Diagram 2 is an example showing how different information are displayed on the screen. Through the different arrangements of the information by the students, teachers are able to reveal the techniques acquired by the students, as well as their conceptions of the world.

In sum this programme is applicable in education as it allows students' to find out all the facts of certain countries by themselves. The colourful maps, charts, music and abundance of information may be a greater motivation than the voice of a teacher or Geography textbooks.

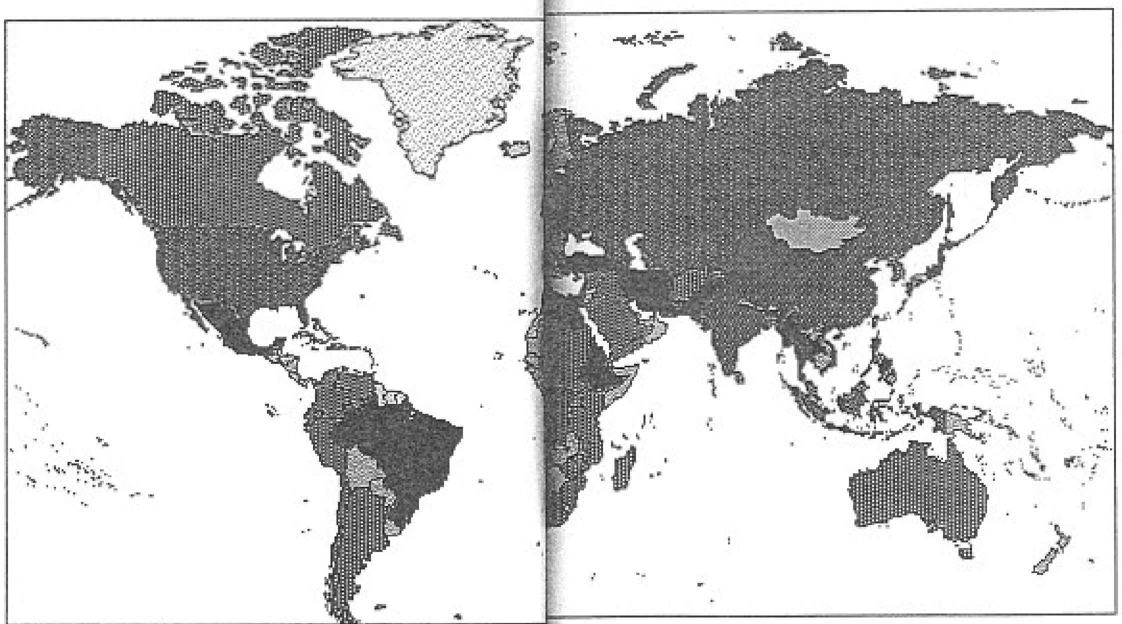


Diagram 2 Screen display in PC Globe

B. SimEarth

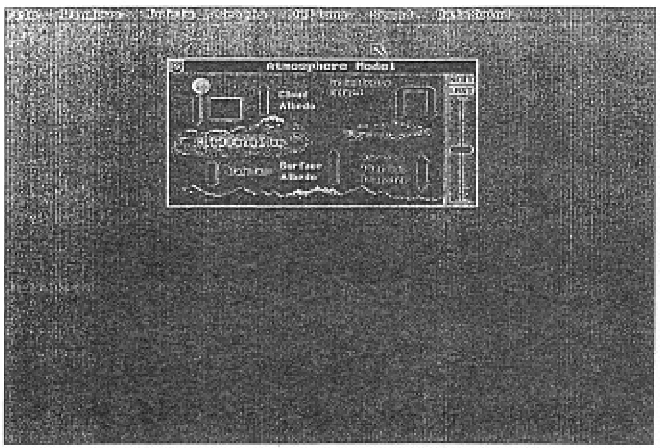
Unlike PC Globe, SimEarth is not an informative programme. It requires students to apply all their knowledge of the ecosystem on the planet that they selected. It is a game which requires the students to create their own ideal planet by putting abiotic and biotic components into it.

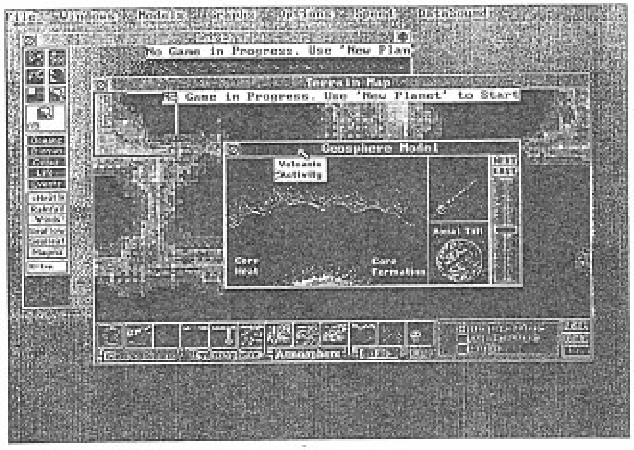
The programme starts with a question about the different planets in the Solar System. Students have to give a correct answer before they can get access into the programme. This can serve as a reinforcer for continuing the game. As the programme allows students to select and create their own planet, greater affective involvement by the students may result as it would be 'their' own planet.

The advantages of the SimEarth Programme is that immediate information of accurate and inaccurate response is shown on the Gaia window. There are four indicators in the Gaia window which shows the different conditions of the selected planet. If the students are upsetting the environment, a cross with a sentence 'no one can live' will appear. Then students have to save their planet by inserting other components which will bring the planet back into balance. Contrastly, if the students have created a balance planet, a smiling face will appear on the screen. This means they have won the game and they may be a potential town planner. In addition to these advantages, SimEarth also allows the students to see the whole context on one frame. There are twelve icons on the left of the screen. Each icon represents an area on the planet. Students can easily get the information of the geosphere, hydrosphere, atmosphere, biosphere and civilization of an area on the planet by moving the cursor to the icon and clicking the mouse. The existing of the 'model control panels' can also help the students to understand the interactions of the different components in the ecosystem (Diagram 3).

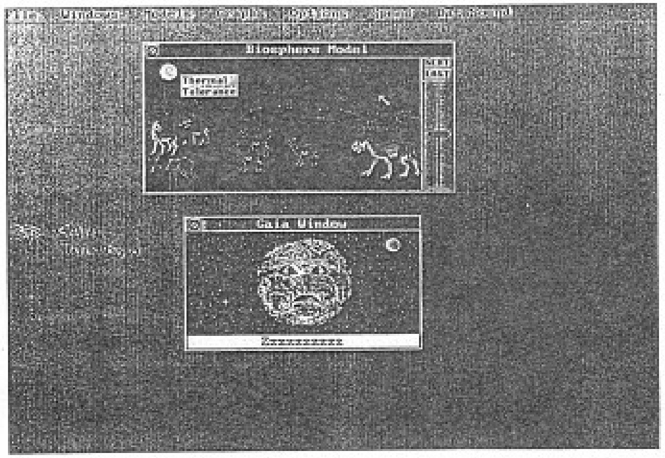
Diagram 3A 'Model Control' penals in SimEarth

(a) Atmosphere model





(b) Geosphere model



(c) Biosphere model

Students who are less capable can review the basic concepts before going into the game, while capable students can go straight into the game and give themselves a challenge.

Although this game consists the above merits, teachers should be reminded of the complexity of this programme. Due to the abundant information that it provides, intensive guidance for operation is needed before the lesson.

C. SimCity

Similar to SimEarth, SimCity is a programme which allows the students to create their own ideal city. It requires students to apply the knowledge of both physical and human Geography in designing the selected city. Correct or incorrect responses is not automatically shown on the screen. If students want to know the condition of their city, they can move the cursor to the icon which shows the different factors that are affecting city development and clicking the mouse. For example, they can read about the crime rate, budget, pollution or probability of having natural disaster (Diagram 4). Students have to judge whether the city is well-planned by using their knowledge and

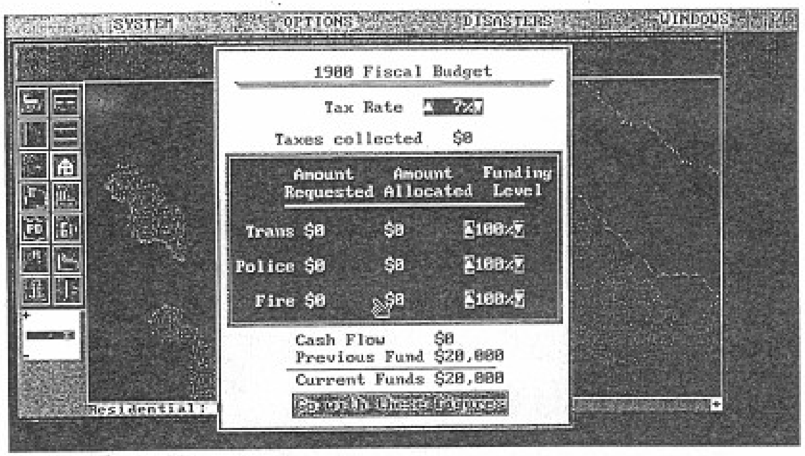


Diagram 4 'Budget Window' in SimCity

also by the public opinion shown by the evaluation window (Diagram 5). There is no right or wrong answer for the students. Their task is to create a city that can satisfy most people. This encourages the students to integrate all that they have learnt into a whole context and apply their knowledge into a simulated city. It is a very good exercise for the students to apply their knowledge and teachers can also reveal the ability of their students from these games.

The programme also allows the students to work at their own pace as it allows them to select the pace in which the city progresses. In addition, students can also increase the difficult level of the game by adding more constraints on the city. Less

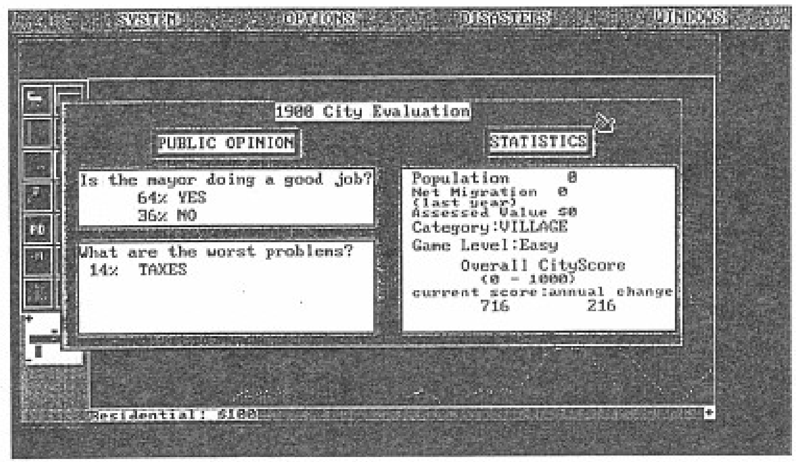


Diagram 5 'Evaluation Window' in SimCity capable students can choose a slower speed of progression and work on less difficult task while more capable students can choose a faster speed and a more difficult task. Students have a lot of freedom in their progress of learning and it could be fruitful to learning.

VI. CONCLUSION

Obviously, the application of computers in assisting learning is becoming more and more important. However, due to the lack of manpower in the development of educational software, the varied quality of the software and the query of applying computer games in teaching lead to skepticism. After reviewing some of the software packages available in the market, it is found that these computer games can be applied in education. To some extent, they can facilitate the cognitive development and learning of the students. It is possible for Geography teachers to use some of the computer software available in the commercial market in their classroom. It may reduce the workload of the teacher while promoting the interest in Geography. This paper only tries to propose a possible way of promoting Geography teaching. More detailed research should be carried out to find a breakthrough for Geography teaching in secondary schools in Hong Kong.

This analysis is based on cognitive psychology which is not a thorough one. More technical analysis into the software such as user satisfaction should also be carried out before one can conclude whether the programmes are well-designed. Moreover, teachers can also evaluate the feasibility of linear programmes by behavioural approach in order to find more usable programmes for Geography.

Furthermore, the facilities, budget and the manpower of the schools may also hinder the development of computer assisted learning in Hong Kong. The progress of computer assisted learning in Geography (or we may say in all subjects) will not be encouraging unless our government takes an active part in facilitating computer assisted learning. This can be achieved by establishing resource centres to develop educational software and improve computer facilities in secondary schools.

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Learning Geography in Hypertextual Environment

by Jacky Pow
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Abstract

This article introduces hypertext as a new ways to geography learning. After having analyzed the nature of subject contents of geography, it is found that geography is suitable in hypertextual learning environment. The disadvantages of hypertext learning are discussed, and recommendation on how to reduce the drawback of disorientation in hypertext is also made.

Introduction

Hypertext is not a new concept. This concept of relational approach to information retrieval was first put forward by Vannevar Bush early in 1945 (Bush, 1945) and became mature in the 60's when the first computerized hypertext system was developed by Ted Nelson (Nelson, 1967). Because its networking power enables storing and retrieving information like a human brain, it is believed that hypertextual environment can facilitate learning task (Kearsley, 1988). As a result, more and more studies research on the possibility of applying hypertext in education settings. This can be reflected by an increasing number of articles in journal and magazine, papers and presentations in educational conference.

Hypertext organizes information in a way that chunks of information are stored in small discrete units or nodes and joined together forming a "whole" by links. It opens up an environment which can support both hierarchic and non-hierarchic approach of information storage and retrieval. Because each node can be an unique unit of information (e.g. texts, pictures, sounds, animation, or video) collaborative and inter-disciplinary works are encouraged (Rada et al, 1989). In the other words, hypertext lets information stored in a node that can bring in more relevant information from another "related" nodes or reversely be referenced by another nodes, and thus forming a more holistic picture of the knowledge concerned. Geography which shares common boundaries with many other subjects seems playing an important role as "bridge" zone which is, according to Balchin (1970), "of utmost value in an age when the disruptive compartmentalization of too much specialization has led to an awareness of need to create inter-disciplinary cross-links".

This article aims at introducing hypertext as an environment for geography learning which can be facilitated by collaborative and inter-disciplinary efforts. The nature of subject contents of geography will be analyzed to see whether it is a good candidate in hypertextual mode of learning. The advantages of hypertext will be discussed and recommendation in reducing disorientation in hypertext is made.

Hypertext

Linear Text

No matter in what languages, people read and present their ideas, information or knowledge sequentially for the ease to communicate with others. Different civilizations have their own style of reading and writing. English is read in row from left to right, from top to bottom; but Chinese is read in column from top to bottom and from right to left. However, language is basically uni-directional. People stick to sequential and linear way of reading and writing because they think it could avoid unnecessary confusion as well as eliminate ambiguity in idea presentation. Thus if one wants to get the idea of somebody else, he has to follow the "rule" so that he can grasp the meaning of the writer without difficulties. The same applies when he tries to set forth his idea to others. This sequential and linear way of idea presentation has mastered the way of knowledge acquisition and learning habit ever since the beginning of human civilization.

Due to the physical limitations of paper, printed, linear-text is inflexible in reading. Readers have to read through texts line by line, page by page in order to understand in context the materials. When a reader comes across an unfamiliar idea

or technical jargon, he may expect some explanatory notes before he continues. Although cross references, references or notes at the end of the text may satisfy the reader provided that he has the patience to turn to the page indicated or find that describe references, if not handy, by himself in library or what ever sources available, these seem rather discouraging.

Sometimes, the reader may trigger new ideas or insights when he goes through an article or paper. He may jot down some notes or comments right next to the point from he generates the idea (but often running out of space in the margin), or he may like to link them to another books or works that contain the related view, concept, opinion, etc.

However the links are made mentally, physically they are not. It is often the case that the linked documents are on the shelves of library when a reader is reading on his desk at home. So, if he wants to consult the 'linked' references at times, frustration follows.

Non-linear Text

Fostered in 1960's, the concept of non-sequential information access is crystallized and applications based on this principle are made possible with the breakthroughs in computer technology (Ellis, 1991). This new way of information access and presentation offers great flexibility that printed, linear-text cannot give. Being a three dimensional medium, non-linear text which only exits in electronic forms offers opportunities for readers to monitor what they prefer to read and how to read . It, on the other hand, allows writers to create linkages among discrete information units to form an information pool in which readers can navigate at will to browse through or search for materials specifically of interest to them. Such non-linear texts are termed hypertexts — originally coined by Ted Nelson to mean non-sequential writing in the Sixties. However, hypertext, as being used today, means more than just a non-linear document. Janet Fiderio (1988) stated:-

Hypertext, at its most basic level, is a DBMS that lets you connect screens of information using associated links. At its most sophisticated level, hypertext is a software environment for collaborative work, communication, and knowledge acquisition. Hypertext products mimic the brain's ability to store and retrieve information by referential links for quick and intuitive access.

How Hypertext works?

Instead of using typical field-record-file structure, hypertext programs handle data/information in an innovative approach. All the data/information in hypertextual environment are stored and retrieved in screen-size workspaces called Nodes. Links are then created to join nodes together in various styles to form hyperdocumnet by Points or Buttons.

Nodes

Nodes are non-decomposable information units consist a single concept or idea and are the most basic unit in processing. The data/information in each node can be in any form (text, graphics, digitized photographs, animation, audio signals or video images) depending on what purposes they serve.

There are two kinds of Nodes; namely, typed and untyped. An untyped node is an un-labeled blank space for information. Users can fill in anything they want to suit their needs. A typed node is labeled, and with descriptor that helps to determine what sorts of information should contain in it. Therefore, typed nodes facilitate classification which is helpful in selecting particular areas of interest in databases.

Nodes, though cannot be disintegrated into smaller units, can be combined to form a composite node which is treated as a single object. Usually, only those nodes that have close inter-relationships are composed to form composite nodes. However, the content of each sub-node should be clearly indicated for easy access and these sub-nodes can be rearranged without serious constraints if necessary.

Links

Links are the only means of transportation in a hypertext network. A link is an electronic path which carries readers from one point of information (node) to another. In other words,

links form the basic structure in framing a hypertext system. Without links, nodes are only discrete information units without any organization.

Links, therefore, are used to connect the nodes. Linkages can either be hierarchical or non-hierarchical. Nevertheless current hypertext programs usually support both so that readers can move about between varies nodes more freely. Under most circumstances, links between nodes are created in the user's preferences. Yet as links are easy to build only in small databases, some products can create links automatically, it is definitely useful for systems which need to cross-reference large text databases.

Besides typing up nodes, link can also bring up annotations to documents; connect elucidations to particular concepts or join definitions to technical terms. Thus, by embedded inks into the text, difficult ideas or concepts can be either further explained by importing detailed explanations from other nodes through links or skipped, making the document more dynamic to read.

Links in any hypertext system should have two properties: First, they must be able to transport a reader from one node to another quickly. The total time needed for the whole transaction must not exceed two seconds. An average of one second or less is regarded as reasonable. Second, the procedures required to transport a reader from one to the next must be as simple as possible. On the whole, only one or two keystrokes or a click on a mouse should be able to activate the linkage.

While the source of link or link reference, is usually a word or a phrase, the destination, called a link referent, could be another word, a sentence, a region of text, a chunk or even a node with graphic and sound. Information point can also be a link reference as well as a link referent. In this case, it acted as an information interchange, just like a road junction that diverts traffic to different directions.

Points and Buttons

A point is a distinguishable area that signifies a link in a document. It can be a single character / number, word, or icon. To make them more indicative, users usually name them with what they will bring to. A point named 'hotels' is not likely to bring in information about 'hospitals'.

Some programs, like HyperCard (for Macintosh) and ToolBook (for IBM and compatible under Microsoft Windows 3.0 or above) refer to point as buttons. A button is a 'live' area which can be created on screen. It can bring forth additional information, ship readers to another node or link referent, or activate a program. Since buttons are powerful tools, if use and name them appropriately, they can be directive and instructive; otherwise, they will lead readers to no where.

The Nature of Geography

The subject contents of geography are extremely diverse and inexhaustible because it concerns nearly every topic that is related to the human habitat — the Earth's surface. Since geography is a science to study and understand the physical environment and its inter-relationships with the human beings, it involves the study of (1) the earth sciences which study the land, the biosphere, the oceans, and the atmosphere; (2) the man-environment relationships; (3) area studies; and (4) the spatial situations that concentrate on mapping places according to their "actual" and relative position on the "space" of the earth's surface (Cole, 1982). These four divisions of subjects are organized into two major aspects, namely the systematic geography and regional geography (Balchin, 1970a). Division (1), (2), and (4) are grouped into systematic geography which employs a thematic or topic approach to study, (3) is the area of regional geography.

Systematic geography studies both the natural phenomena which constitute Physical Geography and cultural phenomena which constitute Human Geography. Systematic geography fuels regional geography by feeding in new knowledge and applies the findings with selective relevance to the regions concerned. Thus building up a relationship just like putting pieces of jigsaw puzzle together to form the whole picture. For instance, climatology which is one of the subdivisions in systematic geography provides a general description and explanation of the atmosphere in a global scale, and Cultural

Geography gives general accounts on the spatial relationships of cultural demarcation of human civilizations. They may not have close relationships with each other, but they (including all the other subdivisions of systematic geography) are indispensable if one wants to comprehend the regions or the world as a whole. In this sense, systematic geography organize materials into streams of study that provides fundamental knowledge for studying regional geography while regional geography provides a common ground to integrate the efforts and findings of systematic geography in order to give a coherent view of places. As a result, an extensive network of information cross-links is built not only within geography but has extended to other subject areas as well (Balchin, 1970a). This web of ready made cross-links in geography has a direct correspondence with the concept of hypertextual information retrieval.

Learning Geography in Hypertextual Environment

Just because the holistic approach of geography matches the philosophy of hypertextual information presentation, learning geography in hypertextual environment will have three major advantageous characteristics

1. Facilitating learning in an interactive mode which complementary languages of geography (maps, photographs, signs, charts, and diagrams) are available whenever needed. Balchin said "without spatial records such as maps, photographs and diagrams, geography would not be geography. Therefore, in explaining the formation of landforms, serious of annotated diagrams are used in order to make it easier to understand. But now these information channels used in most geography books and lessons are replaced by animation in hypertext. Referring to spatial distribution, maps at different scales can be consulted at any time by simply a keystroke or a mouse click. This lets the learner concentrate on the learning tasks rather than devote to finding out the appropriate maps. The complementary tools (maps, charts, serious of diagram, etc.) to facilitate geography learning are now available in a single deliverable system, making geography learning more interesting.

2. Hypertext is an ideal medium for collaborative work in geography. Since geography is a varied and versatile subject, it is impossible for every geographer to master all the branches in systematic geography. Collaborative and inter-disciplinary authorships in regional geography to integrate related in-depth materials will be made possible in hypertext format which can link associated topics from different authors through its unique information retrieval method. As a result, the hypertext database may benefit from collaborative information inputs from various sources and therefore increases the importance of the database for education. The learners may then benefit from the rich information they can get.

3. Hypertext lets learners understand spatial concept in a self-paced learning environment.

For example, an hypertext database about regional geography of Europe may contain detailed information for the learners. He may start with a map on screen telling the relative location of each country of Europe. He may browse through some information about each countries first before he starts. If Switzerland has attracted his attention, he can get more about Switzerland by simply moving the mouse pointer to Switzerland and clicking on it. He may then come to a screen with some descriptions about the physical landscape, political, economic and social condition. If he is interested, he may continue to delve in the topic to get further details by clicking the mouse or to click on the "music button" to listen to "Trittst im Morrgenrot Daher" — the national anthem of Switzerland. He can also bring in a topographic map of Switzerland showing the contour of the pyramidal Mount Titlis and glacial landscape with some pictures. Or he may like to get back to the map by clicking the backtrack icon (small button that appears at the upper left-handed corner of the windows) that bring him to the neighbouring countries for comparison. Since maps at different scales are handy, chances to consult map are higher. Consequently learners' spatial concept are enhanced in the course of this amazing journey of learning. Therefore hypertext allows learning through a spatial concept at one's own pace and will. (The above is part of the databases in BookShelf: a commercially available CD-ROM hypertext reading system under Microsoft Multimedia.)

The Problems with Hypertext

Despite much improvement has been made by hypertext programs, there are still several problems for this immature technology to be overcome (Fiderio, 1988). One if the major problems of hypertext or non-linear document is, according to Conklin (1987), disorientation or 'getting lost' in a three-dimensional information network. Users may easily be frustrated and not knowing what to do next if they do not have a clear idea about their location, either absolutely or relatively. Elm and Woods (1985) describe an embarrassing situation: the user not having a clear conception of the relationships within the system, or knowing his present location in the system relative to the display structure, and finding it difficult to decide where to look next within the system.

This situation is not uncommon even though many hypertext products have made great efforts to relief this problem by incorporating graphical browsers in the system.

Besides disorientation, the difficulty in breaking down a thought or segment of information into a self-contained and meaningful chunks of information generates another problem. A particular theme in a document may be tightly interconnected in itself, the breaking of these ideas into discrete nodes may spoil the original meaning. Therefore, ways that can transform text into hypertext without changing the original meanings or ideas are needed.

Last, but not least, the lack of a sound underlying model in building a hypertext system may eventually make the system end up with a set up meaningless linkages. Also, it will cause troubles in maintaining the database.

The above problems related to hypertext systems implementation, design and maintenance need to be resolved before hypertext can be fully developed and beneficial to us.

Recommendation

To tackle disorientation in hypertext, Foss (1989) has suggested four types of browsers, namely graphic history lists, the history tree, the summary boxes, and summary tree. They all serve to trace back the routes that the readers has gone through. They cannot give an idea of "where" the readers are in a hypertextual environment. In view of this, a complementary browser map showing the relative location of the reader with (1) the shape of the region / country, and (2) colour to show the level of information hierarchy is recommended in a geographical hypertext database. A small colourful browser map at the screen corner will help readers to figure out "where" and "how deep" they are in the database. For example, the browser map showing China in blue may mean the reader is reading materials about China in a certain level of details represented by blue.

There are still no good means to eliminate disorientation in hypertext reading and writing. Browsers which can reduce part of the effect of disorientation are only one kind of solutions. New solutions to minimize the drawback of disorientation such as Artificial Intelligence Interface are being developed in order to make hypertext a good environment for learning and information storage.

Conclusion

Hypertext as a learning environment for geography is introduced. The interrelationships of systematic geography and regional geography form a network of instant cross-links which is corresponding to the hypertext concept. Three advantages of learning geography in hypertext are (1) facilitating learning in interactive mode with complementary geographic languages, (2) providing rich information source for geography learners through collaborative works, and (3) understand spatial concept in a self-paced environment. But the problem of disorientation, segmentation of information, and lacking of a sound model in development and maintenance are still needed to be resolved and on-going researches are encouraged.

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An Expert Spatial Decision Support System Approach in Solving Location - Allocation Problem

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ABSTRACT

This paper addresses the problem of providing an integrated systems approach to solve location/allocation problems. This approach is called the Expert Spatial Decision Support System (XSDSS). The system aims to assist the user to find the best method in solving a particular location/allocation problem using an Expert System approach. Three different commonly used L/A methods are combined in the system. These are classical location/allocation (L/A) modelling, Geographic Information System (GIS) cartographic modelling and Interactive Computer Graphic (ICG) analysis approach.

The system was implemented for the half-year M.Sc. dissertation (M.Sc in GIS 1990) in Department of Geography, University of Edinburgh, Scotland on ESRI's ARC/INFO GIS software, ORCALE Relational Database Management System, and a L/A software package. A case study of hospital location/ allocation problem, in Lothian Region, Scotland, was carried out.

I. INTRODUCTION

The problem of choosing the locations of a set of supply points usually for some kind of service, and allocating demand points to them is called the Location/Allocation (L/A) problem. However, individuals coming from different backgrounds have diverse interpretations of a particular problem and use differing methods to solve the same problem. The problem might be treated as a transportation problem or as a classical L/A problem by an L/A expert. The same problem, however, may be classified as a site location problem in land-use suitability

analysis by a Geographic Information System (GIS) expert. In other cases, others may use Interactive Computer Graphics (ICG) method associated with heuristic approaches and rules of thumb to solve a similar problem. The aim of this methodology is to investigate and integrate these three approaches in one system in order to find out the best solution for a particular problem with assistance of the expert system and computer technology.

Conventionally, L/A problems are usually represented by mathematical models based on equations and inequalities. The aim is to optimize an objective function which is a mathematical equation in terms of some parameters. However, the complexity of these classical L/A model has made them difficult for the user to understand and use, and has led to their unpopularity.

At present, modelling within GIS is largely based on polygon overlay and proximity analysis. Therefore, using GIS is inflexible when optimizing a particular objective functions of classical L/A modelling. This is because of the inability of the descriptive and prescriptive cartographic models (Johnston, 1988) to carry out the mathematical optimization operations using the boolean logic of polygon overlay. The main use of cartographic modelling in solving these problems is by narrowing down the feasible sites using the set of site and situation criteria.

ICG technique, which is based on a trial and error, provides another alternative in solving L/A problems. It uses computer sensitivity analysis to solve problems. Hence, the user employs heuristical methods to evaluate the results. It can only be workable if the decision maker is an expert in the particular L/ A problem or they are familiar with the study area. Otherwise, ICG together with a report generator will be a kind of blind searching.

All the above three methods have been used to solve L/A problems. This study attempts to integrate and combine these three approaches in a single system. It is hoped that this may produce a more comprehensive method to solve L/A problems.

Since the aim of this kind of system is to support decision making by providing suitable spatial information, it can be called a Spatial Decision Support System (SDSS) (Dobson, 1986; Armstrong et al., 1986 and 1989).

However, the users may have problems in using the integrated system as most are familiar with only one technique. They may find it difficult to select the best method for a particular problem, or indeed a combination of methods. An expert system for the decision maker and the SDSS is suggested for this purpose. The expert system will help the system user to define a poorly structured problem and find the appropriate methods for the problem after a computer diagnosis. When the problem class is found by the system, corresponding solution models and methods are searched in a model base. The solution is then carried out by employing appropriate tools or software in the tools base. The final result is displayed to the decision maker by report generator in a form of textual report, listing or computer graphics and digital maps on a screen or paper. The advantage of the expert system is that it can isolate users from technical, humdrum details of computer operations. Emphasis is on the maintenance of knowledge of the domain that can solve various forms of problems and carry out different applications in the same domain in different situations. Hence, an expert system embedded in a SDSS will be called Expert Spatial Decision Support System (XSDSS). The scenario of the XSDSS is shown in Figure 1.

In order to test the feasibility of the proposed system, a case study of L/A analysis of hospital in the Lothian Region, Scotland, was carried out. The Lothian Region consists of four districts namely Edinburgh, Midlothian, West Lothian and East Lothian. The area covers 1,723 km. sq. and has a population of 723,108. It is derived up into 2553 enumeration districts. In May 1989, Lothian Health Board decided to build a new teaching hospital. It has identified three potential sites. This project uses the XSDSS to assess the siting of this new hospital. The empirical objective is to evaluate the existing hospital pattern and three proposed new sites and find out the

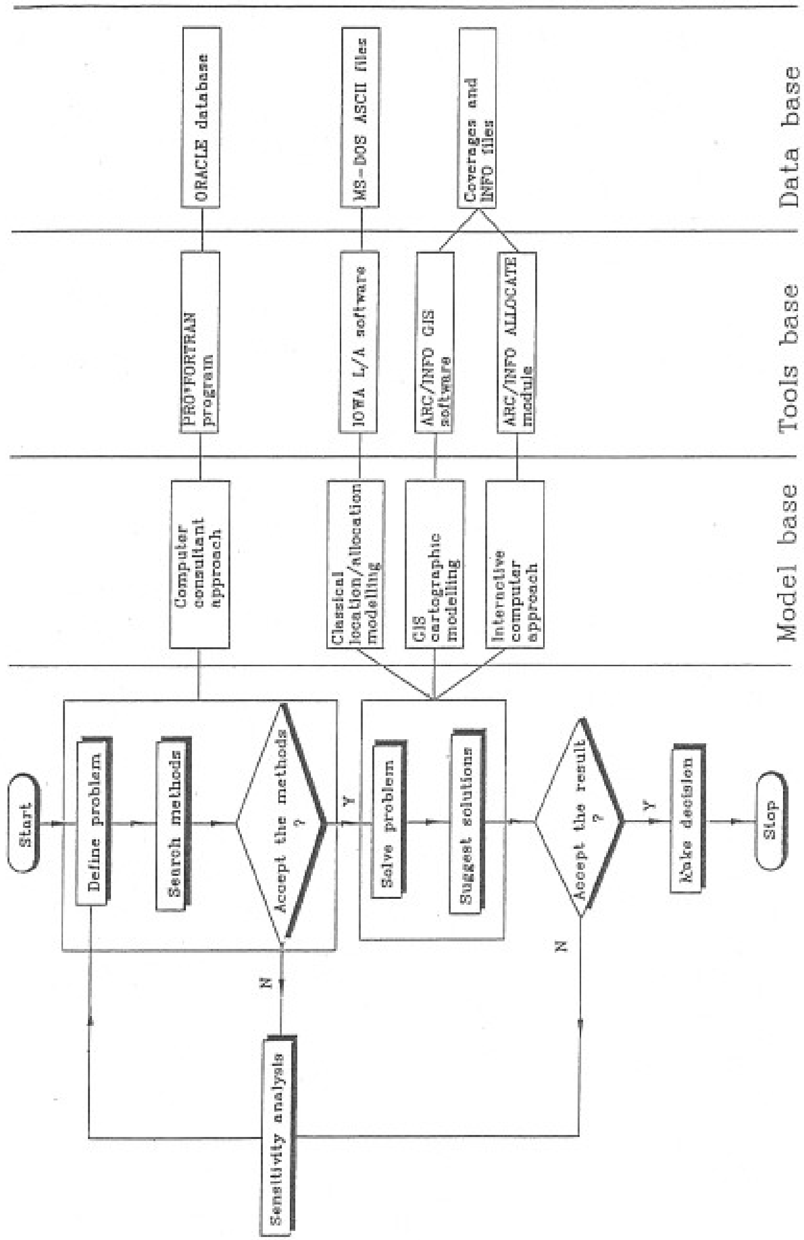


Figure 1

optimal site for a new hospital based on the existing hospital locations. The system was implemented on a DEC VAX 6340, using ESRI's ARC/INFO GIS software, ORCALE Relational Database Management System, and a L/A software package developed by Paul Densham and other authors at the Department of Geography in University of Iowa (hereafter called IOWA L/A software) running on a PC.

II. OVERVIEW OF THE METHODOLOGY

In the system, an expert system interface was written in PRO*FORTRAN language of ORACLE, which was used to simulate an expert in diagnosing L/A problems of users. Under different combinations of answers to a set of questions that are asked by the program, the expert system provides suggestions as regards the classification of problem, or problem domain, and the corresponding methods for solving it. The user could then start the analysis by choosing appropriate modelling methods or re-defining the problem by changing the answers in the system. In addition, backward deduction processing of a problem was also facilitated. This was done by selecting a hypothetical problem and answering a series of questions in reverse sequence to yield a deduced problem domain. If the deduced problem domain was the same as the hypothetical one, the test of hypothesis is right. Otherwise, the problem domain was the deduced one. The expert system will then suggest the suitable method for the solution of the problem. This may be a combination of the IOWA L/A software suitable for P-median problem solving, ARC/INFO core module to locate feasible sites using GIS cartographic modelling and ARC/INFO ALLOCATE module which provides ICG funtion.

III. ASSUMPTIONS IN MODELLING

Before starting any system design and data acquisition, the following assumptions were defined. These were used throughout the expert system, classical L/A modelling, GIS cartigraphic modelling and ICG approach.

1. All members of the population had an equal probability of using the hospital service, i.e. the health condition of all people were taken to be the same.

2. The number of patients in one area or district is therefore assumed to be directly proportional to the area's or district's population.

3. The trips of patients to a hospital was assumed not to be multi-purpose.

4. It was also assumed that people would go to the nearest hospital. This is the standard assumption of a p-median model.

5. It was assumed that people would not go farther than 10km to a hospital in using the IOWA L/A software to find optimal site locations.

6. The numbers of staff, lecturers and students in the new Southern General Hospital, Royal Infirmary hospital (a central hospital) and King's Buildings (a part of the University of Edinburgh) were assumed to be the same and their combination of trips among these three places would have the same probability.

7. Overlapping catchment areas were not used in this analysis as the IOWA L/A software and the ALLOCATE module in ARC/INFO could not handle this situation.

8. It was also assumed that the best route choice from any node to another one would not be significantly different from that given when turntable data (no available in the analysis), such as the delay in turning at a road junction, was used.

9. Lastly, it was assumed that there was no spatial interaction by the hospitals nearby the Lothian Region. That is, the population in the region will only go to the hospital inside the region.

IV. THE MODELS AND TOOLS

A. Expert System (ORACLE)

The concept of using a decision table (Blanning, Karagiannis and Schneider, 1988) to represent the decision tree (Keral, 1988; Ng 1990) for choosing suitable methods for solving a poorly structured L/A problem was used in the implementation of the expert system. The expert system was developed by using ORACLE Relational Database Management System (RDBMS) and a PRO*FORTRAN program. A PRO*FORTRAN program is a special language embedded within Structure Query Language (SQL) designed to directly assess the ORACLE database. The program provides a mechanism for asking a series of questions and leading the user to define the problem domain and the potential solution. It also provides a function to explain the purpose of asking a particular question. This functionality has been called question reasoning in expert system terms.

After reviewing the three different knowledge domains of classical L/A model, GIS models and the ICG approach, it was concluded that with three questions, the problem definition task could be easily narrowed down. Of course, more questions could be asked if desired in relation to a particular problem. However, there is a lot of uncertainty in defining the L/A problem and this small expert system was only an illustration to simulate an expert with knowledge of choosing classical L/A modelling, GIS cartographic modelling and ICG for solving a L/A problem in a simplest way.

Expert knowledge to help to define a poorly defined problem was firstly constructed in the form of a decision tree (see Figure 2). The decision tree consisted of question nodes, answer links and problem nodes. Here, both the program control and the diagnostic strategy were explicitly represented. A question node represents a question asked by the expert to the user. The answer links leaving the question node provides various choices available to the user when answering a

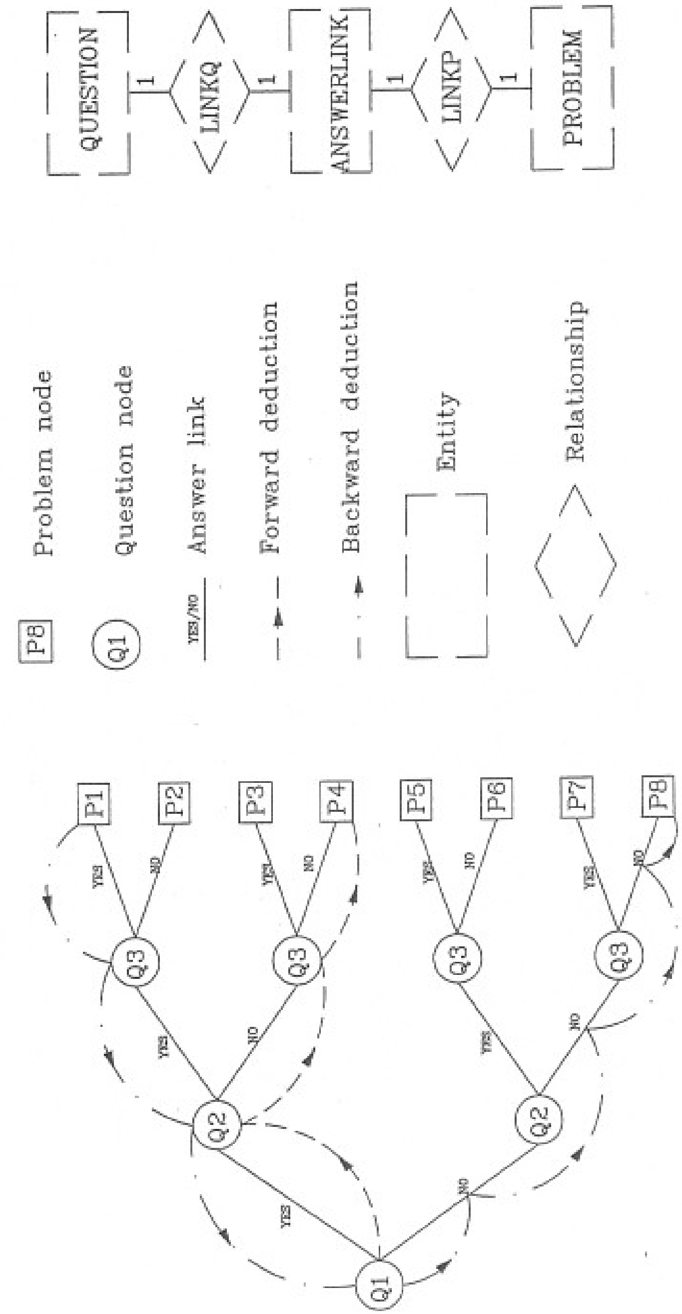


Figure 2 The decision tree of L/A problem classification and data model of the ORACLE tables

question. A problem node represented a classification of the user problem associated with likely methods to produce the optimal solution.

The decision tree was then transformed to five decision tables stored in ORACLE. The relationship between answers of questions and problem nodes was a kind of "If-then" relationship. For example, refering to the decision tree, if the answer in question one is "YES", the deduction will start from node 1 and then followed the "YES" answer link to node 3. The deduction process will be continue until it reaches the problem node. Hence, problem domain and methods of solution will be found. The PRO*FORTRAN program was written to interpret the rules from the ORACLE tables. Rules of deduction, problem domain classification, methods of solution and connectivity between questions, answers and problems could be added or modified by direct operation on the decision table in a user-friendly windowing environment.

The main questions in the decision tree or the diagnosis are:

Question 1 (Q1)	=	Do you know the number of facilities ?
Question 2 (Q2)	=	Do you know the location of the facilities ?
Question 3 (Q3)	=	Do you know the capacity of the facilities ?

The tree thus had a total of 8 problem nodes. Some examples of question flow and derived solution description are shown in Table 1.

Q1	Q2	Q3	Solution node description
Y P1	Y	Y	The problem may be existing facilities evaluation with capacity constraint ora test of a set of proposed facilities with defined locations. The suggested solution method is, ARC/INFO ALLOCATE.
Y P2	Y	N	The problem may be existing facilities evaluation without capacity constraint or a test of a set of proposed facilities with defined locations. The suggested solution methods are, IOWA L/A software, ARC/INFO ALLOCATE, ARC/INFO cartographic modelling with backward deduction.

Table 1 Problem domain and suggested solutions description

The user can also carry out backward deduction. If a user select backward deduction, a problem domain suggestion from the problem nodes should be selected and a series of questions would be asked in a backward sequence from the problem node to the root (top) of the tree. The system would trace down to the problem nodes level again based on the user's answers. If the deduced problem domain was the same as the proposed one, the hypothetical problem domain was true. Otherwise, the deduced one was the problem of the user (see also Figure 2).

As stated before, the expert system could explain the question asked during processing. An explanation would be provided when the users answered 'why' in a question rather than "Yes" or "No" (see Table 2).

Table 2 QUESTION DESCRIPTION

Question	Question explanation

1	If your answer is yes, then
	- it may be a p-median problem and you can use IOWA L/A software.
	- it may be an evaluation problem and you may use IOWA L/A software or ARC/INFO ALLOCATE.
	If your answer is no, then
	- it may be a total or partial coverage problem and you may use ARC/INFO ALLOCATE.
	- it may be a problem of feasible sites searching and you may use ARC/INFO cartographic modelling.

2	If your answer is yes, then
	- it may be an evaluation problem and you may use IOWA L/A software or ARC/INFO ALLOCATE.
	If your answer is no, then
	- it may be a p-median problem and you may use IOWA L/A software.
	- it may be a total or partial coverage problem and you may use ARC/INFO ALLOCATE or IOWA L/A software.

3	If your answer is yes, then
	- it may be an evaluation problem and youmay use ARC/INFO ALLOCATE.
	If your answer is no, then
	- it may be a total or partial coverage problem and you may use ARC/INFO ALLOCATE or the IOWA L/A software.

It should be pointed out that the sequence of questions was implicitly predefined by the tree structure or the connection between nodes. This functionality was used to speed up chronological order of questioning when the same pattern of questions would be asked after a question. It was especially significant when the expert system expands, and lengthly repeation of sub-trees in the whole decision tree can be avoided. Another reason was that this approach would simulate the sequence of questioning by an expert in L/A problem classification (Karel and Kenner, 1988; Ng 1990).

B. Classical L/A Model (IOWA L/A Software)

The IOWA L/A software only provides p-median model solution based on a node swapping algorithms, the Tezti and Bart or Goodchild methods. It does not allow capacity constraints but it does have distance constraints through using the 'Hillsman editing' routine. Therefore the software could only solve p-median problems with unlimited capacity but with a limited number of nodes. The population should be aggregated into road junction in this problem and there was no graphic display routine available in this study. These problems was solved by the ARC/INFO core module. All the above aggregation and data transfer between IOWA L/A software and ARC/INFO core module were carried out smoothly by an user-friendly interface program developed in the study. The software has constraint in number of feasible nodes and number of nodes connected to a node. Hence, only a relative small amount of data or an area with limited road nodes chosen can be processed at a time. As the XSDSS had assumed users had no knowledge in the L/A domain, a batch file was constructed so that users did not need to use the default interactive menu to submit the more than 40 parameters in 5 different routines needed for the whole processing. The user only needed to type on command to start a batch job. This analysis was based on the population distribution being aggregated onto both theoretical and the real road network.

C. GIS Cartographic Model (ARC/INFO Core Module)

The descriptive cartographic modelling describes the suitability for the location of each land use by site and situation criteria. Site criteria are concerned with relationships between a proposed land use and the characteristics of the existing study area. Situation criteria define the relationships between one proposed land use and the other land uses. The prescriptive cartographic model then transforms the site suitability maps (maps showing the suitable sites for proposed facilities) and situation rules (conditions in choosing a proposed site) into a scoring form (Tomlin and Johnston, 1988). This modelling and scoring approach was carried out by the GIS polygon overlay and proximity analysis. Landuse capability, contour lines, the Green Belt boundary, thirty-one existing hospitals' locations, three proposed sites for the new hospital and the Lothian road network data had to be digitized in ARC/INFO core module.

The criteria for siting the new hospital established by the Lothian Health Board were

1. on a greenfield site south of the city,
2. mainly for the south of the city, Midlothian and much of East Lothian,
3. on a site greater than 20 acres (about 80937 m sq. or 280m X 280m),
4. on a soil type that was feasible for building construction,
5. on relatively flat land
6. the main teaching hospital for Edinburgh University Medical School which should be near the Royal Infirmary hospital and Kings building,
7. near Western General hospital,
8. close to the city by-pass,
9. close to main roads (Lothian Health Board, 1989a and 1989b), and
10. of least landscape impact

The above criteria were the site and situation criteria for a descriptive cartographic model. The next step was to convert the descriptive criteria into prescriptive form for the GIS polygon overlay and proximity analysis using ARC/INFO core module. The criteria became:

1. inside the Green Belt polygon,
2. inside designated catchment area polygon of the new hospital,
3. a polygon with area bigger than 80937 sq. m,
4. inside landuse polygon with score as high as possible,
5. inside polygon with a slope angle as small as possible in terms of score assigned,
6. inside ellipse buffer zones with the Royal Infirmary and King's Buildings as foci (higher score being assigned to areas nearer to these two places, see Figure 3).
7. inside circular buffer zone with Western General hospital as the centre. The area nearer the Western General Hospital, would be assigned a higher score.
8. inside by-pass buffer zones (the area nearer the by-pass receiving a higher score).
9. inside motorway and A roads buffer zone, and
10. having the least area visible from the proposed site in a visibility analysis.

In criterion 6, staff, lecturers and students would be assumed to start from the Royal Infirmary Hospital, Kings Building or the new hospital to go to one of the other two sites to do practicals, give lessons or attend lectures. The trip might be one way, return or multiple. As it had been assumed that all types of trips were equally probable, the maximum distance travelled in a trip was the distance to go around these three places once. The aim was therefore to minimize the maximum travelled distance. Since the loci of a moveable point with a fixed distance from one fixed point through itself to the next fixed point is a ellipse, ellipse buffer was invented in this special criterion.

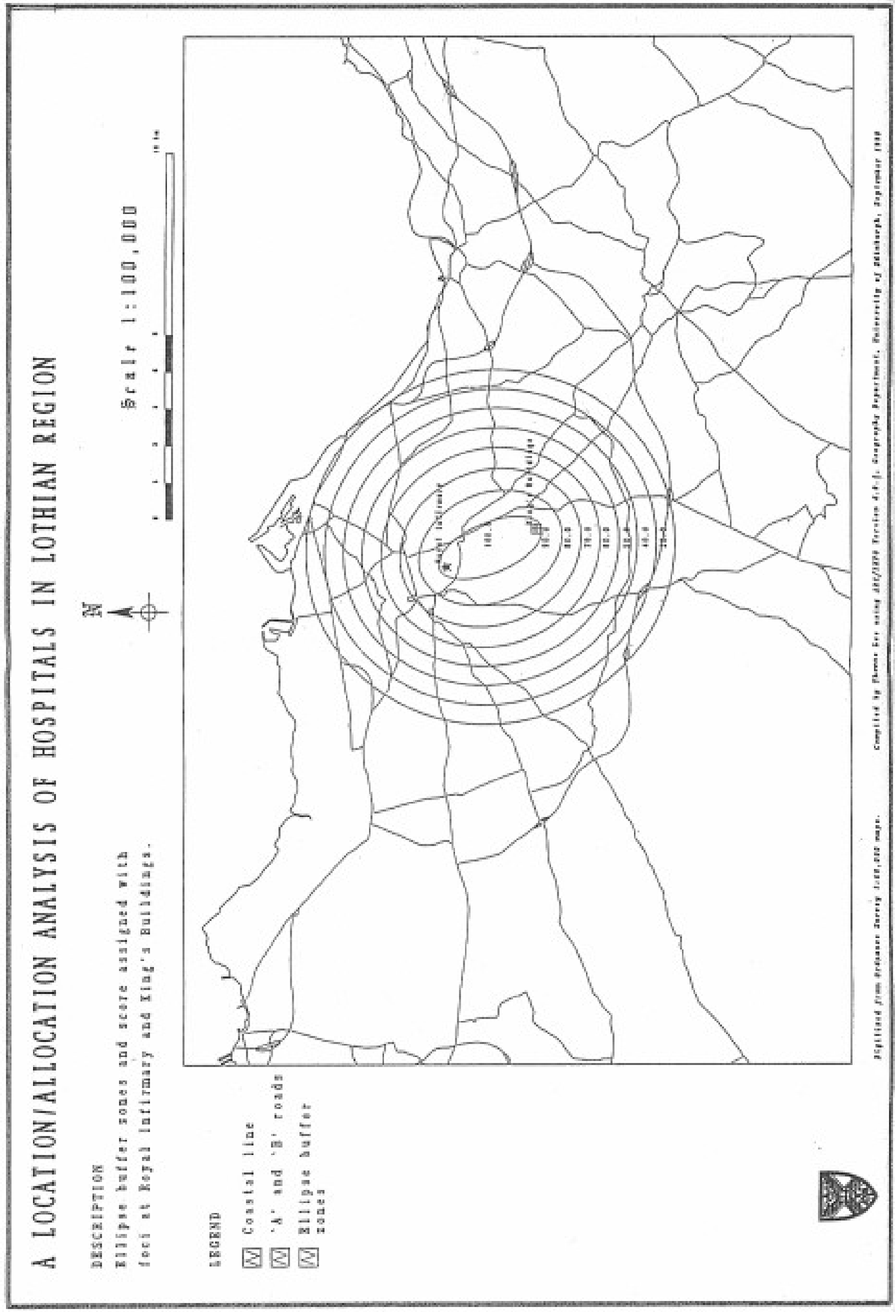


Figure 3

The modelling not only aimed at finding the feasible sites for the new hospital under the scoring system but also provided score for each final polygons after polygon overlay analysis so that any proposed site could be tested to see if it was inside the highest scoring polygon or not. The latter method was similar to a backward deduction theory in the expert system program. In addition, some data like road network and hospitals' locations is now avaliable for the ICG analysis.

D. Interactive Computer Graphics (ARC/INFO ALLOCATE Module)

The ICG method uses computer sensitivity analysis to solve L/A problems. Sensitivity analysis is an evaluation of model performance and robustness subject to the different values being put in the model. Hence, the user employs heuristical methods to evaluate the results. The analysis was based on the population distribution aggregated onto the real road network rather than road junction in classical L/A models. This ICG system has a user-friendly menu providing the following options and functionalities:

1. choose the level of detail needed for analysis of the road network for analysis (e.g. All roads in the region or only those in the catchment area),
2. choose one or more centre(s) having different capacity and impedance limitation for analysis,
3. add or delete a centre interactively,
4. report allocation statistics in terms of centres,
5. list the demand data along the road network,
6. save allocation result.

By means of this menu, the user locates hospitals in a set of proposed sites. Then, the user can ask for the allocation or accessibility of the population to the hospitals. The answer will be displayed on the screen or shown in a report form. Moreover, the locations of testing sites can be used in GIS cartographic modelling to implement the backward deduction analysis.

V. ANALYSIS IN THE CASE STUDY

Three different studies were carried out in the project to test the feasibility of the integrated system.

A. Study 1 - Evaluation of Existing Hospitals Location by Different Population Aggregations and Road Patterns

Tools recommended by the expert system were IOWA L/A software and ARC/INFO ALLOCATE module.

The following evaluation were done:

1. Thirty one optimal sites analysis using 2 km grid and Manhattan road pattern with IOWA L/A software (see Figure 4)
2. Thirty one optimal sites analysis using 1.5 km grid and Manhattan road pattern with IOWA L/A software
3. Thirty one optimal sites analysis using 1.5 km grid and star road pattern with IOWA L/A software (see Figure 5)
4. Thirty one optimal sites using real road network with IOWA L/A software (see Figure 6)
5. Assessment of 31 existing sites using IOWA L/A software
6. Assessment of 31 existing sites using ARC/INFO ALLOCATE module

In 'Manhattan' road pattern, a node or road junction in a grid pattern road network connects directly to four other nodes in four different directions, namely, N, E, S and W. In 'Star' road pattern, a node or road junction in a grid pattern road network connects to eight other nodes in different directions namely, N, NE, E, SE, S, SW, W and NW.

In searching for the optimal sites using the different aggregation levels and road networks from (a) to (e), it was found that the level of aggregation and road network pattern would greatly affect the siting of the hospital in areas of low population density. It was interesting to know that the density

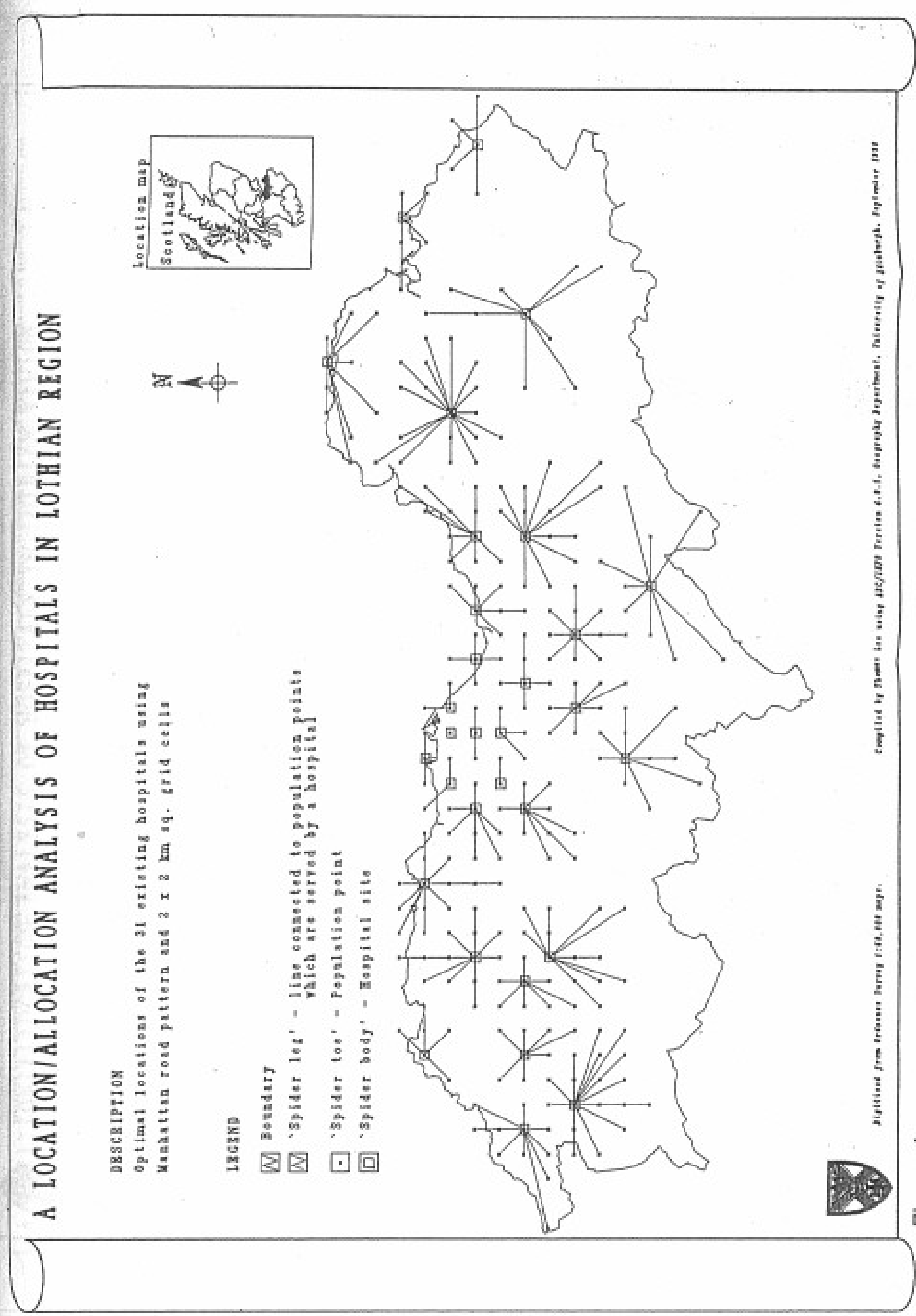
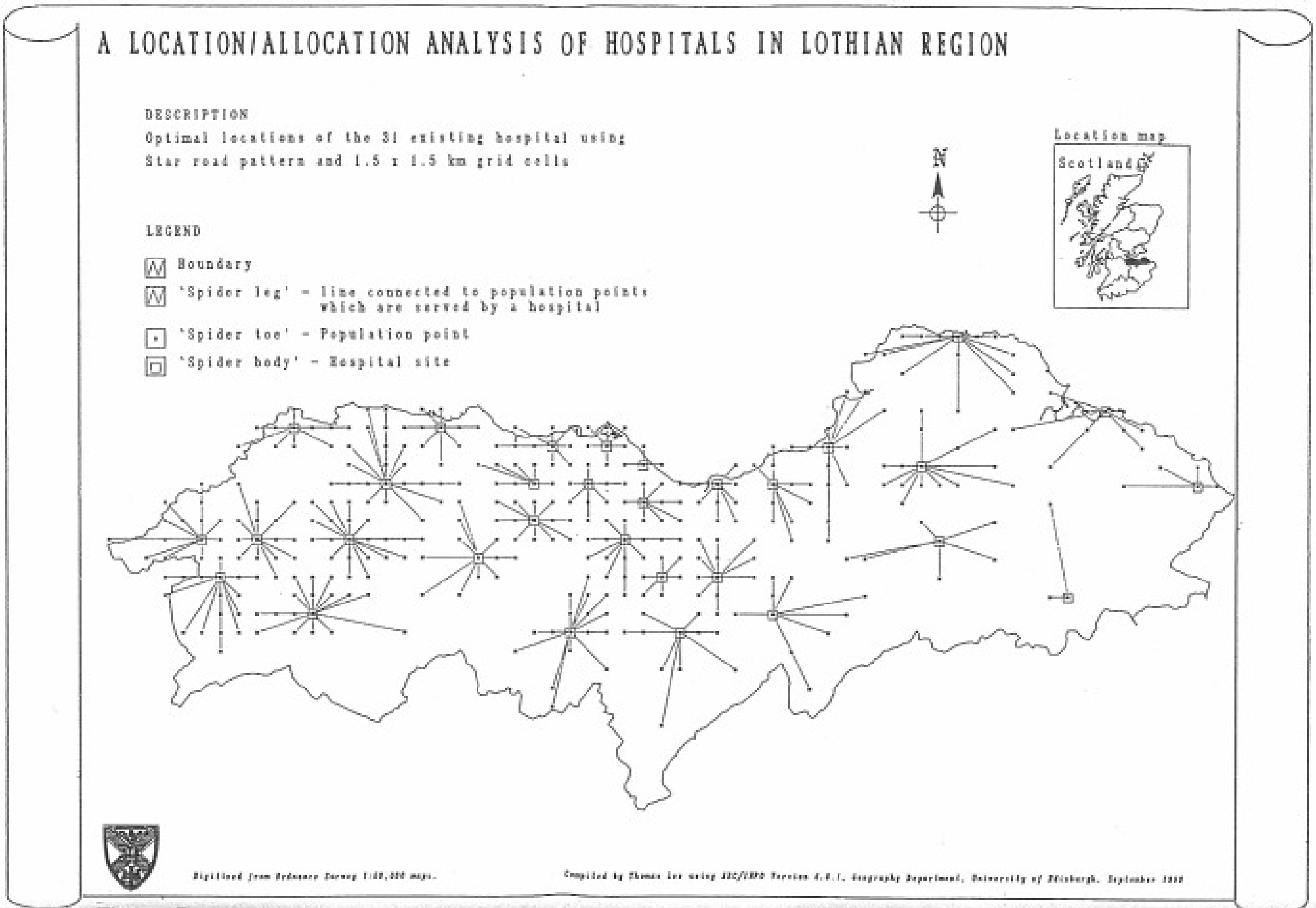


Figure 4


A LOCATION/ALLOCATION ANALYSIS OF HOSPITALS IN LOTHIAN REGION
DESCRIPTION
Optimal locations of the 31 existing hospital using
Star road pattern and 1.5 x 1.5 km grid cells
LEGEND
Boundary
'Spider leg' - line connected to population points which are served by a hospital
'Spider toe' - Population point
'Spider body' - Hospital site
N
Location map
Scotland

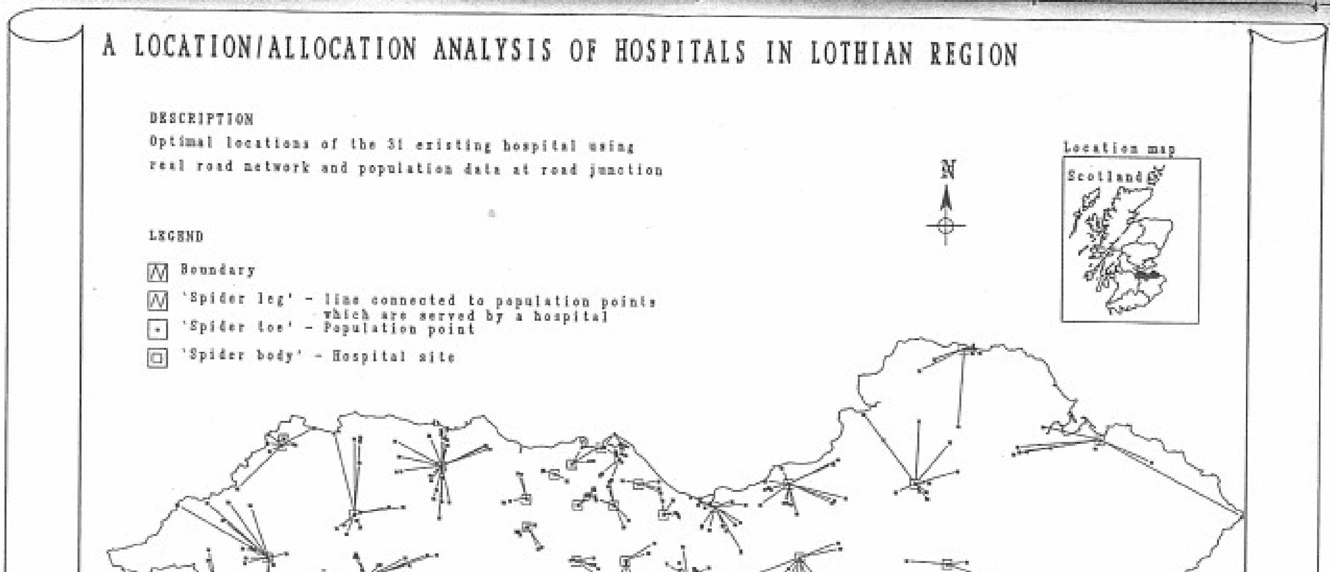

A LOCATION/ALLOCATION ANALYSIS OF HOSPITALS IN LOTHIAN REGION
DESCRIPTION
Optimal locations of the 31 existing hospital using
real road network and population data at road junction
LEGEND
Boundary
'Spider leg' - line connected to population points which are served by a hospital
'Spider toe' - Population point
'Spider body' - Hospital site
N
Location map
Scotland

Figure 6

of the real road network was similar to a Manhattan road network with 6 X 6 km grid cells or a Star road network with 14 X 14 km grid cells. Hence, this may be critical in using the imaginary road network with abitrary grid size or pattern to simulate the real road network before knowing the actual density of the real road network.

In assessing the existing hospital pattern (f and g), both methods gained similar result. Typically, it was found that as many as three hospitals had no population allocated and only 20 hospitals had more than 90% utilization of their capacities i.e. about 1499 beds were not used. There was 57.60% of total population serviced by the existing hospital pattern and this used up 72.76% of the total number of roads.

B. Study 2 - Finding the Possible Location for the New Southern General Hospital

Tools recommended by the expert system were IOWA L/A software and ARC/INFO core module.

Using the IOWA L/A module, the hospital was located in the middle of the northern coast line of the region. This was about 6 to 10 km away from the three sites proposed by the Lothian Health Board. This highlighted the problems of L/A analysis based purely on population distribution. It could not included the criteria specified by the Lothian Health Board in the site location. Unless the candidate or feasible sites can be determined beforehand by heuritstic method or GIS cartographic modelling.

In the second method, polygon overlay of 6 different coverages, namely land use, slope, circular buffer zones, ellipse buffer zone, by-pass buffer zones and 'A' road buffer zones was carried out. A score at a polygons in the final coverage was the sum of the above 6 coverages' scores at that polygon. The result is shown in Figure 7 with different classes of scores.

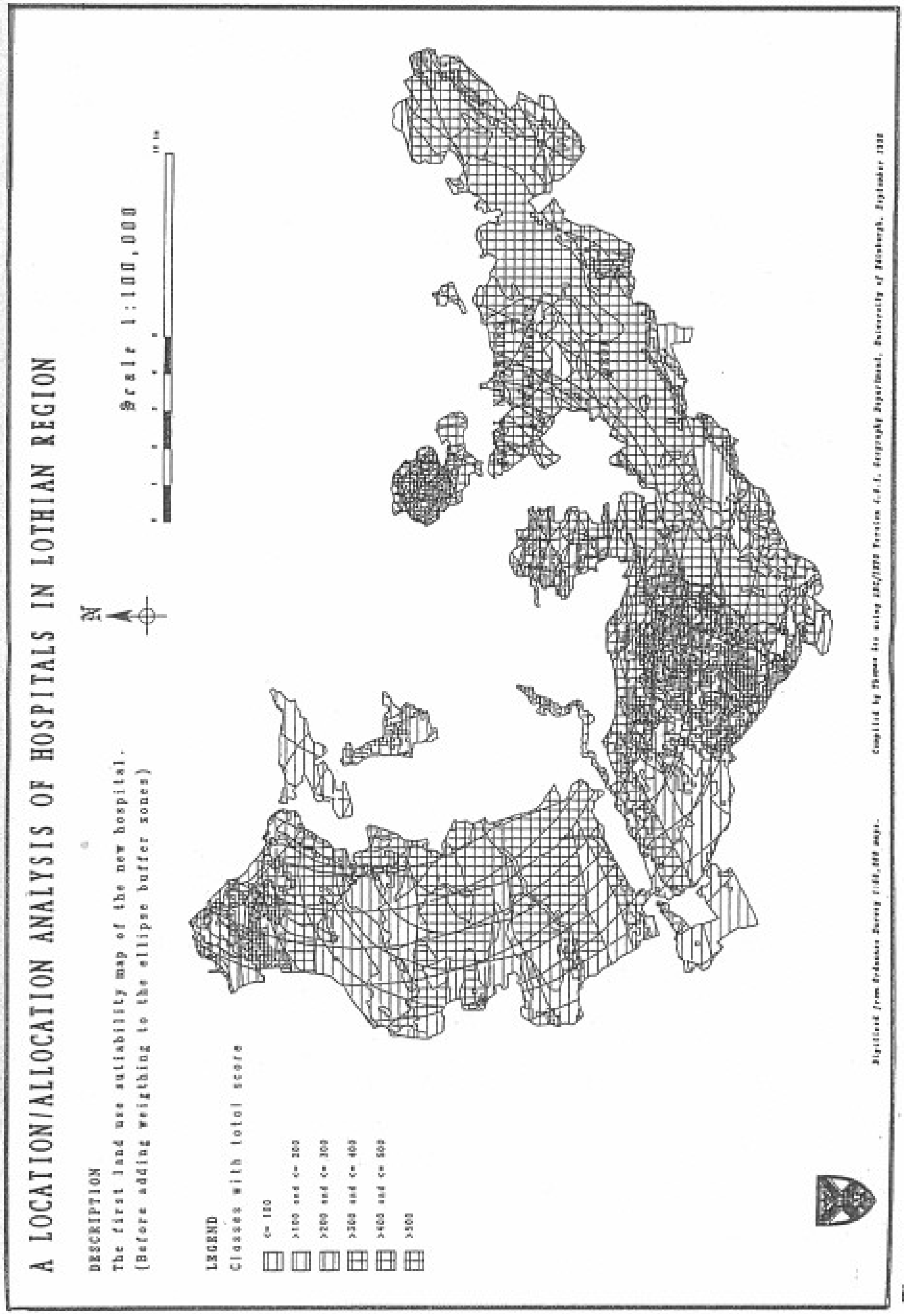


Figure 7

The areas with highest score category showed no spatial clustering. This had assumed that the weighting given to the criteria of nearness Royal Infirmary Hospital and King's Buildings had not been large enough under the importance of teaching role criteria. Hence, a sensitivity analysis was implemented by changing the weighting or scores for ellipse buffer zone of Royal Infirmary Hospital and King's Buildings. It was found that top score class was clustered in nearer position. The sensitivity analysis by changing a parameter in the model yielded a successful prove in the hypothesis.

In addition, a comparison to the proposed sites designated by the Lothian Health Board was carried out. Two out of the three proposed sites fell into a score class higher than 400 in the second analysis rather than only one site in the former analysis. This result illustrates that the criteria in the ellipse buffer zones was highly related to the decision of the proposed sites from the Lothian Health Board. This backward deduction concluded that the decision maker had pay more weighting in this criteria. Hence, the XSDSS showed that it helped to understand and give some insight into the values of the behaviour of decision makers and the emphasis they put on some factors by backward deduction techniques and sensitivity analysis in GIS cartographic modelling.

C. Evaluation of Three Proposed Sites for a the New Southern General Hospital

Tools recommended by the expert system were ARC/INFO ALLOCATE module and ARC/INFO Core module.

The three proposed sites were tested. The sites were Royal Nurseries, Little France and Drum. The evaluation was based on a combination of their accessibility and landscape impact analysis. In this first evaluation, a comparison was made using ARC/INFO ALLOCATE module and the real road network as the basis of accessibility, with the evaluation produced by the Regional Research Laboratory for Scotland and the Department of Community Medicine, University of Edinburgh using straight line distance (Hodgart et al. 1990).

The relative ranking in the population covered within a distance band was similar using the real road network and straight distance in two out of the three locations. However, in the third location, the percentage of population covered by distance 0-6.44 km was as much as two times greater when using the real road network. Hence, it was better to use real road network for L/A analysis.

The second analysis among the sites was visibility analysis for evaluating their landscape impact. It was found that the site at Little France had the least visible area and hence had the least landscape impact to the surrounding area (see Figure 8). As a whole, Little France was more suitable than the other two to build the new hospital based on the analysis result.

VI. FINDINGS AND DISCUSSION

A. Expert System

It was found that the connection between conditions, or primitive in expert system terms, and the conclusion of a question did not need to be explicitly declared nor did the sequence of questioning to be pre-defined. The decision tree structure implicitly defined the sequence. This gave a very-efficient diagnostic process which closely paralleled real expert diagnosis and also facilitated forward and backward deduction in the diagnosis.

However, although the ORACLE database provided several advantages in maintaining the expert knowledge in diagnosis, it could not provide a graphics editing function to manipulate the decision tree. This function is called a goal browser in the Expert System terms. The browser interface is very useful in updating and manipulating the knowledge base graphically. This functionality though, could be implemented by using the ARC/INFO software package. It should be noted that this study did not include null node and unknown node, when there is no solution and no knowledge stored for solving a question (Karel, 1988), which are required in a complete decision tree.

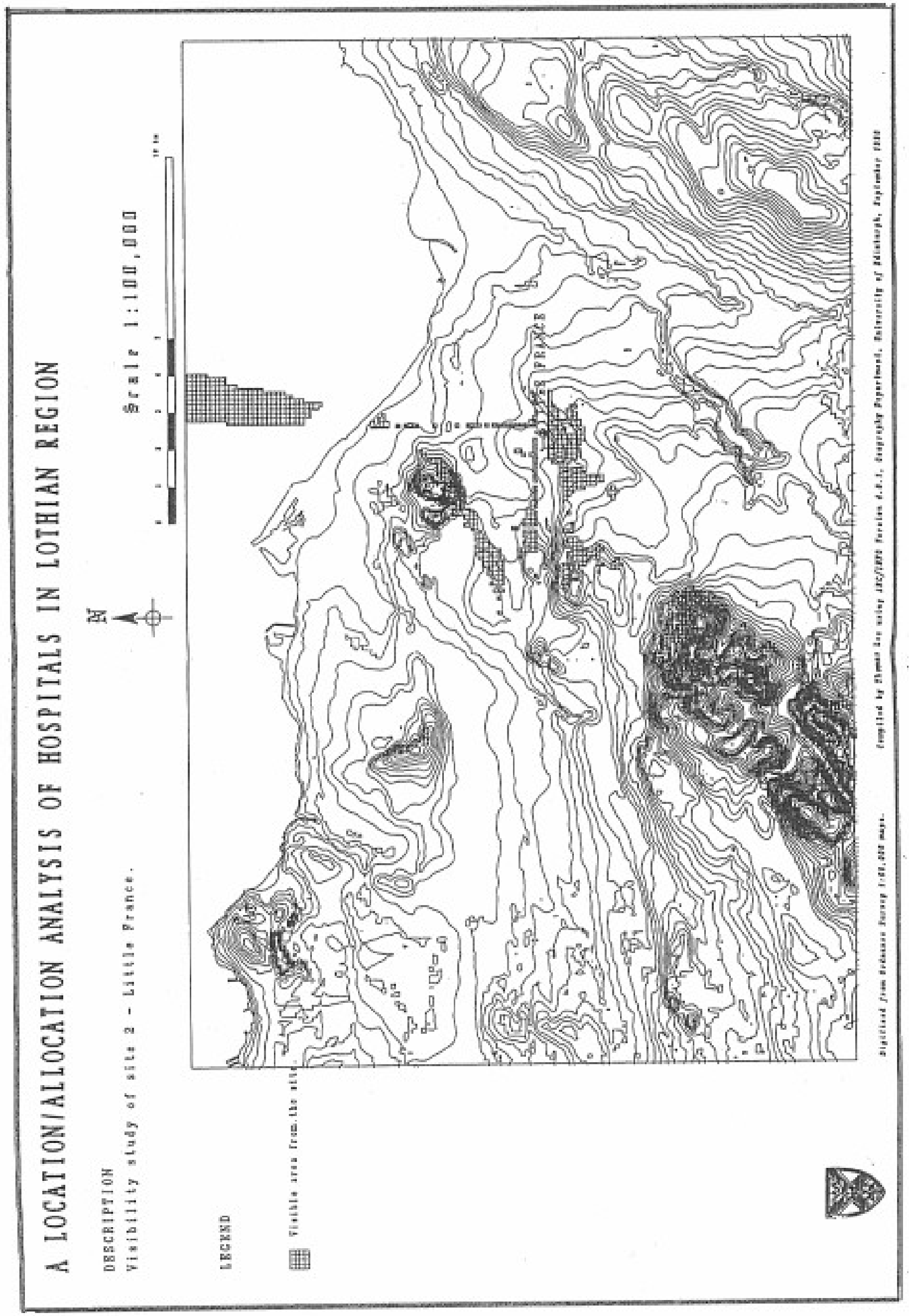


Figure 8

B. Classical L/A Modelling

Since the classical models are usually based only on the population and road network data to carry out their analysis, they neglected consideration of land use suitability for facility construction. For example, these models may result in locations which are within a build-up residential area, on a road junction or another geographical features where a facility cannot be built (e.g. in the sea).

They are mainly concerned with the economic impact, for instance time or cost of travel over the whole region but not the feasibility of site location. To a certain extent, the definition of candidate sites could take account of the possibility of facility building at the points concerned. Finding the candidate sites requires pre-processing which was usually not part of the location theory involved. Moreover, finding in the selection of a candidate site is likely to be related to economic, political and physical factors.

Another problem of locating facilities using this model, is that it could not specify the exact location to build the facilities as the possible locations are all based on theoretical or existing road junctions. Hence, additional post-processing is needed. The models could not provide final solutions in facility location but only assisted in or narrowed down the choice of locations. Of course, it may be possible to increase the number of nodes in the region and pre-select those nodes which are feasible for facility building. However, it must be remembered that increasing the number of nodes would increase the processing time and computer memory needed. The author suggests that the pre-selection can be solved by GIS cartographic modelling.

Furthermore, most of the algorithms for solving classical L/A problems required an initial solution. The choice of initial solution may be very critical in terms of processing time and the possibility of yielding a local optimum solution. As Cooper and Steinberg (1970) stated, the first step in the transportation algorithm was to determine an initial basic feasible solution by any method. Also, Armstrong, Densham and Rushton (1986) pointed out that these locations could be identified either *a-*

priori or in some arbitrary fashion. Most of the L/A theories did not mention how to find feasible solutions. A vital question was : 'do we need to find them by common sense or will it be better to choose then under a set of rules-of-thumb?'. One systematic way may be to use a GIS approach to narrow down the feasible locations in terms of land use suitability through using a scoring system as stated before. We could therefore take the highest scoring locations as the initial solution in the L/A processing.

Another critical problem hightlighted by this study was that the locations derived from the model were dependent on the grid sizes and the road pattern used. Besides, using a grid system, some grid centres may be located in some unrealistic positions, e.g. in the sea or in lochs. However, one might argue that as the sites' positions could be moved inside individual grid cell, it would still be possible to choose a nearby location within that area without losing the integrity of the grid framework. But strictly speaking the optimal value of the objective function would probably no longer be retained. The main advantage in using a grid system is convenience in programming and operation. However, it can only be used with confidence where the population is fairly evenly distributed. Another point which should be remember is that in aggregating population into the roads from enumeration district, it was found that error may be introduced when there was no road in an enurmeration district. Moreover, rounding up processing would lose some people in some districts !

C. GIS Cartographic Modelling

In the L/A domain, GIS cartographic modelling could not provide optimization of an objective function like classical mathematical modelling. It could only provide land use suitability and proximity analysis related to a physical object, but is not concerned with the spatial impact and interaction of total population in the study area. Unless ICG approach was used in the GIS software, relationship between population and

distance could not be taken into account and interactive p-median solution could also not be stimulated. This kind of modelling not only facilitated the sensitivity analysis as in the ICG but also provides a backward deduction technique as in expert system. Moreover, this provides solution in searching feasible sites and initial solution for classical L/A modelling and ICG analysis.

D. Integration of ARC/INFO and IOWA L/A software

The advantage in using GIS for L/A was that the road network data for IOWA L/A software could be easily generated from the GIS spatial database without any error in connectivity of the network as discussed in the previous section. It could therefore avoid human error in typing the random or ordered link file for IOWA L/A software. Besides, the node file contained candidate sites and population data could also be created from the same database without much difficulty. Hence, this approach was more efficient and secure. In addition, ARC/INFO provided not only a handy graphics display for the analytical result of IOWA L/A software but also a special database for the sensitivity analysis in both GIS cartographic modelling and ICG approach or for further GIS analysis.

E. Location/allocation Model in ALLOCATE Module

Unlikely IOWA L/A software, it was found that the ALLOCATE module in ARC/INFO could simulate a coverage model with unlimited capacity and distance constraint. Even the total and partial coverage problem can also be solved in this model. This was because each centre had capacity parameters and an impedance limit (distance constraint). The former parameter could be assigned to be greater than the total population in the study area. This will simulate a partial or total coverage problem. In addition, the aggregation method allows the assignment of population along road lengths rather than road junctions as in classical L/A modelling e.g IOWA L/A software.

Indeed, if the impedance limit (distance constraint) was set to a specified value and changed the facility locations interactively to yield minimum total population travel distance, this situation could replicate a p-median problem with distance constraint.

If the capacity constraint was set to be less than and equal to the total population, a typical coverage problem would be identified. This would differ from the classical coverage problem having unlimited capacity constraint.

In the allocation operation, a center with smaller identification number will start the processing earlier to others. Hence, those hospitals near the end of a list may not have any population to serve if there are some hospitals nearby and with smaller identification number. A similar finding had been found in the Buffalo Shuffle test done by Ezra Zubrow (1988). This supports the idea of using parallel data or program processing to solve this problem in the future as recommended by Zubrow.

F. Data accuracy

In 31 existing hospitals allocation analysis using ARC/INFO ALLOCATE or IOWA L/A software based on the real road network, the displacement of hospitals position had a range from 50m to 2 km. It proved that the accuracy of finding the hospital position from maps was very critical in this of operation. A way to minimize the displacement was to split a road and create a road junction near a hospital manually or densify the road network by dividing each road with defined distance automatically. However, this brings a disadvantage that we add virtual road junctions that do not exist in reality and for any future analysis using total road junctions, the result of analysis will be wrong. A possible solution is to digitize the lower category roads near each hospitals so that the displacement of the hospital during data processing will be minimized. The reader must also pay attention to the consistency of detailed level of road data when this problem is addressed in the future analysis so that lower category roads must be digitized for the whole study area.

Hence, the uncertainty and inconsistency within different data sets must be evaluated in an XSDSS. The uncertainty can be associated with positional, classification or transient data and has many possible sources. A model of the various types and levels of uncertainty must be established in order to maximize the informational value of a system. Statistical inference, fuzzy set theory and information theory can be used to monitor the uncertainty and consistency of the spatial data. A technique called consistency preserving transactions can be utilized which checks data during transaction from one consistent state to another. The aim in data accuracy maintenance is to understand the quality of the data and to have knowledge to handle the discrimination of data in order to use the apply different set of data in different application, without losing confidence in the integrity of the data.

G. A Consideration of Land Information System (LIS) in L/A Problem

L/A problems are mostly concerned with the relationship between population distribution and the proposed siting of facilities, for example, to minimize the total population travelling cost. Thus, accurately locating population distribution at household level is very decisive in this analysis. However, a GIS usually stores population in at lower level of detail, that is population is aggregated into a polygon representing an enumeration district or postcode area. However, the accuracy of the centres of these polygons are commonly not known. This kind of data aggregation cannot support analyses where distance between population and proposed facility locations are the critical parameters as most of the L/A mathematical models are based on these parameters.

In contrast, LIS usually stores population data in terms of land parcels which are the smallest polygons in representing population or land ownership acquired through field surveying by Chartered Land Surveyors. Therefore from LIS, the accuracy of the population point can be upgraded leading to a better analytical result. However, population data from the census is normally collected with the legal precondition, such as 1926 Census Act in UK, that no individual or household can be identified from the published data. Therefore, it may be difficult to use the ideal data resolution level under this data publication constrain constraint.

VII. CONCLUSION

The L/A analysis can be made more realistic if more attention is paid to data representation, where a GIS or LIS can provide a very sound tool for this application. The classical L/A modelling supports objective functions related to total population travelling that a GIS cannot as yet accommodate. The scoring formulation in GIS cartographic modelling is analogous to the multi-objective situation of classical L/A modelling and sensitivity analysis in ICG approach. In addition, GIS can be used to test of the hypothetical location of a proposed facility which simulates the backward deduction procedure in an expert system. As the result, the system users can understand more about the relationship between their locational criteria and their goals. The ICG provides real-time heuristic solutions and introduces a new aggregating method which distributes demand data along the arcs in a network rather than at nodes as in IOWA L/A software. It also gives users an alternative way to solve the problem if the classical L/A modelling and GIS cartographic modelling cannot take account of their special and unpredicted criteria. This XSDSS successfully integrate three commonly used L/A tools and models to faciliate comprehensive solution for L/A problems.

One should remeber that this system only provides suggested solutions to decision makers in tackling L/A problems but not the final solution. It is simply the nature of the multiple objectives involved in the decision making process that there are many uncertainties which cannot be incorporated in the XSDSS.

Futhermore, it should be stated that all the results from the analysis were dependent on the assumptions in modelling, available data, modelling theories and software algorithms. Hence, it is difficult to state with confidence whether the result are 'correct'. However, it can provide an alternative view of point from which to approach the techniques and theories of solving and understanding a particular L/A problem. To a

certain extent, the confidence level of the results are better than non-computerized methods due to the large amounts of data involved and the complexity of the analysis.

Finally, the author would like to emphasise that data quality maintenance in spatial decision support system is critical for multi-purposed spatial analysis.

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"Application of GIS in Energy-environment Modelling"

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(I) INTRODUCTION

Geographical Information Systems (GIS) have been used in the fields of ecology, earth sciences, geo-science and remote sensing for many years. Recently, social scientists have had their attention drawn to the fast-growing developments in GIS applications. Although there have been many discussions and evaluations of GIS applications in sciences and social sciences, there is little by way of review of the state-of-the-art of GIS, particularly in relation to energy-environment modelling and decision making.

The reason for this may be the absence of a unique definition of GIS within the field. The problem is further complicated by the existence of a great variety of GIS applications in the literature. Any computer software designed to handle spatial data for mapping or analytical purposes can literally be called a GIS application. In such circumstances, a comprehensive review would not be possible, or necessarily desirable. Thus, the review of this paper is mainly confined to the state-of-the-art "first generation" GIS applications [1] which are basically oriented to maps. The recent development of analysis-based (or "second-generation") GIS applications to cope with specific requirements in particular fields (e.g. housing, health care, regional and town planning) is not included [2]. For convenience, the "first-generation" GIS is abbreviated as existing GIS applications below.

The primary objective of this paper is to examine the usefulness of existing GIS software for the field of energy studies. Discussion is based on two aspects: the theoretical-conceptual (e.g. issues of interests, methodologies) and the technical (e.g. program structure and system design). Strengths and weaknesses of existing GIS applications are explored with particular reference to the existing energy computer-aided models. Important insights and suggestions for further development are then portrayed.

(II) AN OVERVIEW OF "FIRST-GENERATION" GIS APPLICATIONS

(1) Theoretical-conceptual aspects

There are various definitions of Geographical Information Systems (GIS). Broadly speaking, as manifest in the existing available software (e.g. ARC/TNFO [3], GRASS [4], CARP [5]), a GIS is a computerised database system for inputting, editing, coding, storing and retrieving information with reference to a geographical coordinate system or a set of places (i.e. spatial data). Conventionally, the initial concern of GIS was the combination and evaluation of different map overlays in order to provide additional (if not new) information to end-users about issues of interests. Later on, additional functions were added to GIS including the digital storage of map data, the production of maps and graphic displays, and the reporting of statistical summaries.

(2) Technical aspects

Application of GIS depends on two major components: computer hardware and computer software modules. Some applications work on a variety of hardware platforms [6], others on only a specific computer system [7]. However, there must be one or more input devices (e.g. digitiser, mouse, keyboard), one or more output devices (e.g. visual displays, printers, plotters), and some form of data storage (e.g. disk drive). A wide range of devices is required by each particular GIS software, though these are not taken as the major concern of this paper.

Turning to the application software, GIS is largely composed of five components:

(1) data input and edit
(2) data coding, storage and retrieval
(3) data output and presentation
(4) data transformations
(5) user-interfaces

The first component is usually presented to the end-users as an "editing environment" provided by the specific GIS application. This is done either by inputting from keyboard or digitiser. The second component is often handled by a "database management system" [8], the detailed operation of which is of little concern to the users. The third component projects a visually impressive representation of the input data to end-users via mappings and/or graphic displays. In some cases, statistical summaries are also given in conjunction with these visual representations by particular applications. The fourth component involves a huge array of programming algorithms that can be applied to transforming the input data in order to 'answer' the queries asked of GIS. In particular, stress is placed on converting a set of digitised map coordinates to machine readable formats which can be displayed on screen or drawn on paper. These data transformations include the storage of data for use in changing mapping scales, calculations of specific regional areas or perimeters, and imports and exports of the required data from and to third party software, for example. Finally, the interactive environment provided by GIS to the end-users to activate various functions of the application software is the in-built "menu system" - an intertace between users and the program components discussed above. Attached to the user-interfaces, there are a set of system warning, error detecting and data range checking sub- components.

In brief , GIS is a system (or set of programmed modules) integrating the technologies of relational database and graphical displays/packages.

(III) STATE-OF-THE-ART EXISTING COMPUTER-AIDED ENERGY MODELS

(1) Theoretical-conceptual aspects

There is a great variety of energy-economic-environment models found in the field of energy studies, including input-output, econometric, systems dynamics, and linear programming energy models [9]. At present, there is no unique classification to categorise these energy models: each existing energy computer-aided model has been built by energy researchers to investigate their own specific energy issue(s). For instance, an energy model is specifically designed to examine changes of energy demand through a change in income or population patterns. Energy researchers formulate one (or more) energy problems and then build or find the similar tool(s) (e.g. energy models) to achieve their goals. This can be regarded as adopting the concept of a purposive-instrumental style of energy modelling approach [10].

Furthermore, each energy computer program is unique within the field in the sense that each model requires specific sets of data input to make it run. The 'composition' of the required datasets is entirely governed by the equations in chosen energy models. Energy modellers are interested in building, computing, testing and simulating a set of either pre-specified or user-defined energy equations. Results generated by the model run are used for analysis. In this case, energy models are mostly data-oriented and analytical-based applications.

(2) Technical aspects

Techniques adopted to tackle the specific energy issues vary from a purely conceptual (theory-building) to a highly technical (computerised) skill. Despite the differences in the energy problems addressed, only the applied and technical, aspects of energy models formulated in the form of energy computer programs are considered in this paper.

Various applied computer-aided energy models can be found within the field, for example, IIASA's Energy System Program [11], U.N.'s ENERPLAN [12], and London Imperial College's ETB [13]. There is no uniform 'representation' of the programs for these energy computer models (i.e. the appearance and context of the software package). This is largely due to different specific needs and levels of programming techniques of the energy researchers.

In terms of programming structure, there is little difference between computer-aided energy models and GIS applications except that energy modelling packages are geared to model

calculation and scenario simulation. Reports from the computer-aided energy programs are mainly in the form of tabular (e.g. spreadsheet) or graphical (e.g. line graph, bar chart) formats. In some cases, results can also be superimposed onto pre-digitised mapping areas in more sophisticated applications. Unlike GIS applications, digitising and mapping facilities are not the primary concern of the computer-aided energy models.

(IV) INTENDED USES OF GIS IN ENERGY STUDIES

Despite the distinction between the mapping- and analytical-orientation, great similarities are found in both GIS and energy computer applications in terms of the composition of essential programming components. Learning from existing GIS applications, various aspects of energy-economic-environment modelling and planning decision making can be improved at different levels

(1) Improved data structure and record formats

All first-generation GIS applications are mapping-oriented. Due to this, the main concern of the software is to digitise and record the details of the physical landscape including the discrete features (e.g. bridges, roads, buildings) found on it. In this case, the recorded data can be massive. Yet, the input data is usually recorded in a specific way so that each dataset has a reference to another dataset. In so doing, it is easy and very efficient to find out the related datasets when a particular dataset is called for analysis. The kind of data records can be relational or hierarchical in structure for which many commercial database systems have been developed.

In the field of energy studies, energy and energy-related data are generally available from many international organisations (e.g. U.N., O.E.C.D) and the relevant national departments of specific interested countries. Despite the differences in level of detail, there is no uniform format and structure to record the data. It is commonly found that one dataset is incompatible with another from different source. Much time has to be spent by researchers in converting and compiling different sources of datasets to suit their needs.

If the original energy data could be put into a similar structure as used by GIS applications, the task of extracting and converting the data would be easier. Internal inconsistency and statistical differences due to the compilations of different sets of data from different sources are then minimised. Work in this area would build up an efficient databank. If these data structures were adhered to, and new data incorporated through time, then a useful set of data would always be available to energy modellers.

Furthermore, within this kind of data recording structure, simple statistical analyses and mathematical calculations can be pre-programmed and embedded within the database system. Simple energy questions such as changes in energy supplies and demands by type or percentage can be answered instantly without the need to run a separate model program. In fact, this helps energy researchers a lot as time-series analyses are frequently needed

At present, facilities for importing and exporting recorded data in ready usable formats from one computer model to an another are often inadequate or completely absent. It is not uncommon for users to re-enter the required data, which can be very time-consuming. With the proposed data structure and record formats, the problem of data imports and exports is minimised.

(2) Adding spatial dimension to energy data

Energy-economic-environment modelling embodies a combination of social sciences and sciences. To a large extent, the available energy and energy- related data is quantified and recorded in relation to time with reference to particular countries. Within a country, more disaggregated energy data at provincial or county level is limited in supply. This is particularly true in the developing countries as most official statistical records are kept at national level. Without individual (private or commercial) efforts, disaggregated energy data cannot be found. Unfortunately, these energy records are not normally accessible by the public, which further restricts the comprehensiveness of energy studies.

GIS was, originally developed from mapping techniques and cartography. With advances in digitising techniques and accuracy of map-scaling, tremendous mappings of, say, housing, commercial and industrial locations, and administrative territories are available via GIS applications for planning and decision-making purposes. For a long time, geologists have been applying GIS software to generate digitised maps, showing the structures and shapes of landscapes with reference to the available natural resources of an area. Besides relying on building and calculating energy models, awareness of energy problems or solution findings can be illuminated by mapping the changes of energy systems in relation to changes in the socio-economic-political environment of a society. In this case, GIS helps energy researchers to construct and record the spatial dimension of energy and energy-related data for further study.

(3) Helping site-specific energy resources analysis

With the outbreak of oil crises in 1970s and the gulf war in the early 1990s, greater attention has been paid to the studies of renewable resources as alternatives to the conventional fossil fuels.

The potential yield of renewable energy, such as water, wind power and biogas, is very site-specific and variable in time. For example, in case of water power [14], if a convenient site is not available on the stream itself, the usual practice is to divert some of upstream water, transport it along a channel or elevated conduit to another site, and then let it fall through a water wheel or stream. The amount of power obtained from a stream is proportional to the rate at which the water flows and the vertical distance which the water falls. Since stream flow varies by month and season, the pattern of availability of water power is space and time specific in the physical landscape of the studied region. For a long time, GIS applications have been used for landscape analysis (e.g. river and road diversions). With the availability of such site-specific GIS datasets, studies of the location and cost-effectiveness analysis of a particular renewable energy resource in aspecific region would be helped.

(4) Increasing lobbying in energy policy and decision making

Energy strategic planning and decision making should not be restricted to the technicalities of building and testing energy models, but more importantly, to reviewing what the past was and what is really wanted for the future. Past data which can be found in statistical data books. Development of a better energy and energy-related database information system definitely contributes to the achievements of energy experts in tackling energy problems more efficiently in the future. At the same time, with the transformations of quantitative energy data and model results in the form of maps and graphs, the dissemination of information can be made more effective. The ability to display information in an easily understandable form (e.g. colour or pattern shading) means that even people without specific energy knowledge are enable to enquire about the present and future energy policies just by looking at the reports generated on screen. Owing to this, there is an increase in public enquiries and lobbying about energy policies, in particular the environmental issues (e.g. construct a nuclear power station).

(V) DRAWBACKS OF GIS APPLICATIONS

Although the development of GIS applications provides a range of insights for the energy field, there are several limitations which to date hinder its full utilisation in energy computer-aid modelling approaches.

(1) Hunger for data

As mentioned previously, in order to develop a comprehensive, well-organised databank for use in energy models, a massive amount of energy and energy-related data input is required, in particular spatial data. Procedures and processes for collecting, compiling, converting and inputting relevant data from various sources prove to be extremely costly in terms of money, time and labour. It is far beyond the effort of an individual energy researcher. In addition, there is a relative lack of spatial data for energy analytical uses. The data hunger of existing GIS

applications is the major drawback for use in energy studies. A purpose built energy computer-aided package would be comparatively less-demanding in data requirements, fulfilling the current needs of energy researchers.

(2) Difficulties in handling qualitative energy data

Given the present concern with environmental issues, strategic energy planning almost invariably involves consideration of a wide range of environmental factors in conjunction with monetary evaluations. For instance, qualitative data used in the studies of energy environmental risk perception and assessment are representations of personal attitudes, feelings or even cultural constraints. Although energy economists and environmentalists have recently been developing robust and practical methods for internalising environmental and other externalities into the energy planning and decision making processes, no consensus has yet been achieved as to how this should be done. Disputes in choosing appropriate methodologies and tools of analysis are inevitable within the field. More importantly, contents of the texts reviewed by the viewers are not normally recorded in the existing data record. They are usually generalised and quantified by energy researchers by means of a straightforward yes or no answer or a degree of percentile measurement (e.g. 20%, 40%, 60%, 80%, 100% dislike). In many cases, qualitative statements and text is available (e.g. from questionnaires) but is not entered into the system. It would be an easy step to include such information, in the form of a free text field in the data structure. This extra qualitative information could be made available to the researcher on demand, enabling further decisions to be made.

GIS applications are heavily based on processing quantitative data. Recorded data are mostly in the form of relational or hierarchical structures. Pure text or flat format data input is rare in GIS applications, but would seem to be the best representation of the qualitative energy data. in this respect, these required data record structures must be included in the future developments of GIS in order to be of great value to energy environmental analyses.

(3) Lack of modelling oriented modules

Mapping and graphical techniques are substantial in GIS applications, but the essential elements of analytical and modelling facilities found in computer-aided energy models are lacking. Routines such as inputting, evaluating and calculating energy model equations and expressions are normally unavailable. This limits the utilisation of GIS applications within the field of energy modelling.

(4) Absence of sophisticated analytical tools

Apart from providing simple statistical summaries, more sophisticated analytical tools such as time-series multivariate regression analysis, factor analysis, multi-criteria analysis are missing in most existing GIS applications. These analytical tools are essential to energy researchers for building and testing different types of energy models. Software like SPSS [15] and SAS [16] have been used by energy researchers for many years to achieve these goals. The absence of sophisticated statistical and mathematical analytical modules severely diminishes the degree of usefulness of existing GIS application in energy analysis.

(5) Missing decision support or expert systems

Recent energy computer-aided models rely on developing an intelligent, sophisticated decision support or expert system, to help strategic energy policy planning and making. In many cases there is a need to ask "what if" types of question. Most GIS are able to produce results whether or not the input is reasonable. The user gains no guidance from the GIS in attempting to come to an optimal result. Techniques in decision support and expert systems have been improved over the past few years, but as yet there is a shortage of these required functions in existing GIS applications.

(6) Incompatibility of one GIS applications to an another

Although most GIS applications possess rather sophisticated in-built data transformation routines, problems of incompatibility of data imports and exports are encountered. Rather than

helping to solve the problem of inconsistency of internal energy data, GIS applications create a further type of spatial data problem.

(7) Elicitation of knowledge and energy theory seeking

Despite advances in GIS development, each software package is restricted to its own pre-defined functions. Apparently, there is no error-free or foolproof program. improvements of future GIS applications rely entirely on advances in computer and programming-technology rather than conceptual-theory building. The creation of menus, database, drawing, plotting, calculation, reporting and decision supporting modules is geared towards knowledge of science. An intimate relationship between GIS and computer science can be seen. Yet, it is worth asking whether future energy researchers should have to acquire these computer skills as a priority. If so, the process of theory or knowledge seeking would seem to be overwhelmed by the technical aspect of any proposed energy computer-aided model in the future.

(8) Requirements of intensive training and expert support

GIS applications are not easy to use without any proper training or expert advice. The processes of data input, compilation, transformations and generating reports requires a high level of technical training and institutional organisation if it is to be done efficiently. In this respect, costs of labour, equipment and time involved are substantially high, making GIS an expensive planning tool.

On the other hand, most available stand-alone energy computer-aided models are comparatively cheap to buy-and to run. Most of them run on personal computers. At the same time, energy computer programs are rather simple and easy to use. They enjoy a high degree of user-friendliness. Furthermore, the existing energy programs are specifically built to fulfil certain purposes, say, to evaluate changes in energy systems for a certain period of time. A good energy computer program often provides sufficient guidance and information to the end-users. With a prior knowledge of energy, users can manage to use the program on their own and in a short period of time, productive model results can be generated.

(9) Problems of bureaucratic or institutional constraints

As numerous energy models are found within the field, there is no shortage of computer-aided energy models and skills to aid energy-economicenvironmental planning and decision planning. Problems encountered are not purely technical but are largely imposed by the structure of bureaucracy and the institutional context of an organisation, and its political ideology. Advances in GIS might offer valuable contributions to strategic energy planning or theory building, but at the same time, there is a risk that it would be used intentionally as a superficial means to assure the public credibility of prechosen policies, through a process of mystification.

(10) Inappropriate technology for the developing countries

GIS cannot be regarded as an appropriate technology applied for developing countries for energy policy making or assessment. Research findings from authors such as Dickinson and Calkins (1988) and Yapa (1991) also suggest that GIS applications are costly in terms of hardware and software requirements. Strict legal restrictions are normally imposed to the use of those GIS applications to protect copyright. Furthermore, there is a severe lack of 'local' expertise to support the software in developing countries. A long training session for staff is needed before the software can be used efficiently. Thus, a hasty acceptance of existing GIS applications for use in energy environment-economic planning and decision making means a reduction of the level of self-dependency of the third world countries. It is preferable to import knowledge than to sell 'technical' products from the West to the East.

(VI)CONCLUSION

The current development of GIS applications offer significant insightsand technical aspects to improve the present state-of-the-art of existing energy computer-aided modelling programs

(such as data structure and records, mapping and graphic displays). Despite inherent limitations of the software design, present GIS technology cannot be fully adopted for use in energy modelling, strategic energy decision making and planning. Considerations to be taken into account are the massive hunger for fully integrated spatial and economic energy and energy-related data, the absence of sophisticated analytical (mathematical and statistical) computer modules, deficiencies in intelligent, expert support and information systems, and so forth. In addition, economic evaluation of the implementation of a GIS also proves extreme costly in terms of time, labour and capital (e.g. computer equipment and costs in Research & Development). Furthermore, lack of local expertise and practical skills severely hinder the effectiveness of utilising the existing GIS applications in the Third World for use in energy studies.

Finally, it is realised that advances in GIS largely rely on improvements in (computer) technicalities rather than theory- or knowledge-seeking. According to Siu (1989), the problem of fragmentation in theory and model building is found within the field. The diversifications of adopted methodologies and (computer) tools for use in energy strategic planning and decision making is deemed to be unavoidable. The greatest concern of energy-environment-economic studies is the need for a strong, conceptually sound theory with technical and pragmatic strengths to solve the problems of diversification and fragmentation. Without further refinement and modification of first generation GIS, great contributions towards energy studies will not be achievable.

Footnotes

[1] Since there is no unique definition or classification, the categories "first-" and "Second-generation" are adopted by the author to distinguish between the map-oriented and analysis-based GIS applications. Early GIS applications were initially developed to handle and process spatial data for mapping purposes. Current GIS applications often built with statistical and mathematical analysis in conjunction with mapping facilities. They are geared to analysis-based applications.

[2] A paper discussing the potential and intended uses of the "second- generation" GIS applications in energy studies will be presented in due course.

[3] ARC/INFO is copyright of Environmental Systems Research Institute (ESRI). Basically, ARC/INFO consists of two sub-systems:

(a) ARC - a set of programs for the management of locational coordinates or geographical features (e.g. points, polygons and lines) which are stored and processed in vector format.

(b) INFO - a set of programs to handle the thematic data processing. It is a relationaldatabase systemwhichisa commercialsoftware that has been linked to themapeditor ARC.

[4] GRASS (Geographical Resources Analysis Support System) is a public domain GIS software developed by SCS.

[5] CARP (Computer Assisted Regional Planning) was developed at the Pennsylvania State University as a low-cost computer mapping and planning tools. It has the capability for use in the regional planning offices of the Third World by linking locally-available popular software.

[6] Variants of ARC/INFO are available to run on a Sun Workstations, DEC VAX systems, and on IBM PC or compatible systems.

[7] For instance, GAIA (Geographic Access Information and Analysis) is a software program for the colour Macintosh platform designed to display, manipulate, and analyse digital earth imagery (e.g. satellite images). Further queries should put forward to Richard Podolsky, GAIA Project Leader, 300 w. 23rd St. 10D, NY, NY 10011.

[8] Basically, there are four types of database systems: flat form, relational, hierarchical and free text. The commonly used database systems are more often the relational type (e.g. dbase, Paradox, FoxPro and DataEase).

[9] A substantial literature is found on the energy modelling approaches mentioned. For illustrative purpose, only a few are cited below:

(1) Input-Output energy model:

The demand driven 1-0 energy model developed by Common and McPherson (1982).

The supply driven I-0 energy model introduced by Giarratani (1976).

The dynamic I-0 energy model discussed by Hoffman and Jarass (1982).

(2) Econometric energy model:

Single-equation econometric energy models were discussed by Smil & Kuz (1976), and Pearce & Westoby (1984).

(3) Systems dynamics energy model:

Systems dynamics energy-demand model developed by Allen et.al. (1984).

(4) Linear programming energy model:

Linear programming energy model developed by Muller (1979).

[10] Discussion of the theory of purposive-instrumental rationalisation can be found in Siu (1989:3-5,233-271).

[11] The International Institute for Applied Systems Analysis's Energy System Program (IIASA's ESP) was an international energy study, under the leadership of W. Hafele, concentrated on global aspects of the long-term (from 1980 to 2030) transition from the present energy system based on cheap fossil fuels to one which may be more sustainable. The whole computer program comprises of three major interconnected modules:

(a) The MEDEE-2 (Module d'Evolution de la Demand d'Energie) - for energy demand forecasting

(b) The MESSAGE - for energy supply prediction

(c) The IMPACT - for the overall economic assessment

[12] ENERPLAN is a micro-computer program designed to be used by energy planners in developing countries. It was developed by the Tokyo Energy Analysis Group in 1985, under the auspices of the Department of Technical Cooperation for Development of the United Nations.

[13] Energy Tool Box (ETB) is an energy modelling package developed at Imperial College, London, in late 1990.

[14] The use of water power is restricted by the availability of a stream water. In addition, the capability of a specific stream water to generate usable energy depends on two factors: the velocity of water (i.e. the kinetic energy) and the difference in elevations between two sites (i.e. the potential energy).

[15] SPSS (Statistical Package for Social Scientists) is a registered trademark of SPSS Inc. Various SPSS software run in different computers have been used by energy researchers such as SPSSX on mainframe, SPSS/PC on personal computers.

[16] SAS (Small Area Statistics) is a registered trademark of SAS Corporation.

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